Biological Evaluation

the Approval of Virginia's Water Quality Standards Title 9 VACS 25-260 Water Quality Standards Regulations Adoption of Ammonia and Cadmium

by U.S. Environmental Protection Agency for the U.S. National Marine Fisheries Service

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Executive Summary

This biological evaluation (BE) assesses the potential effects which may occur to federally listed threatened and endangered marine species and anadromous fish under the jurisdiction of the U.S. National Marine Fisheries Service (NMFS). The specific focus of this evaluation is the U.S. Environmental Protection Agency (EPA), Clean Water Act (CWA) approval of Virginia's proposed updates to its aquatic life criteria to be consistent with the EPA's recommended criteria for ammonia and cadmium. These criteria consider the best available science, including local and regional information, as well as applicable EPA policies, guidance, and legal requirements, to protect aquatic life including listed species. EPA finds that our proposed approval of Virginia's acute and chronic ammonia and cadmium criteria are Not Likely to Adversely Affect (NLAA) aquatic listed species through direct and indirect effects and will not adversely modify Atlantic sturgeon critical habitat.

EPA views the ammonia and cadmium criteria revisions as insignificant and/or discountable to the conservation and protection of aquatic life, including listed species and their food sources in Virginia. The revisions are expected to aid in the conservation role of critical habitat. The listed sturgeon, turtles, and whales occurring in Virginia freshwaters and/or estuarine/marine waters are not sensitive to acute and chronic freshwater ammonia and cadmium exposures at the respective criteria magnitudes under conservative exposure conditions.

Introduction

Description of the Proposed Action

Endangered Species Act (ESA)

Federally protected species are listed as endangered or threatened under the Endangered Species Act of 1973, as amended, 16 U.S.C. Section 1536, and its implementing regulations, 50 C.F.R. Part 402. Section 7(a) of the ESA grants authority to, and imposes requirements upon, federal agencies regarding endangered or threatened species of fish, wildlife, or plants ("listed species") and habitat of such species that have been designated as critical ("critical habitat"). The ESA requires every federal agency, in consultation with the Secretary of Interior, to ensure that any action it authorizes, funds, or carries out, in the United States or upon the high seas, is not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat. The United States Fish and Wildlife Service (USFWS) administers Section 7 consultations for freshwater species, while the United States National Marine Fisheries Service (NMFS) administers Section 7 consultations for marine species and anadromous fish. This BE representing an effort by the EPA to informally consult with NMFS regarding the EPA approval action of Virginia WQS, which may affect listed species sand their critical habitat.

EPA 's WQS Program

A WQS defines the water quality goals for a waterbody by designating the use or uses of the water, by setting criteria necessary to protect the uses, and by preventing or limiting degradation of water quality through anti-degradation provisions. Under Section 303(c) of the CWA and 40 CFR Part 131, states and authorized tribes (state) have the primary responsibility to develop and adopt WQS to protect their waters. Also under the CWA Section 303(c) and 40 CFR Part 131, the EPA is required to review and either approve or disapprove new and revised state WQS.

New and revised state WQS are not considered effective for CWA purposes until approved by the EPA under CWA Section 303(c).

Unlike other EPA actions that may introduce a pollutant into the environment, approval of a WQS limits the allowable level of a pollutant that, in the absence of the standard, would be unlimited. As an analytical simplification, this BE protocol considers whether the criterion at issue is sufficiently stringent so that listed species would be protected. This federal action neither authorizes the introduction of a pollutant into the environment nor represents a plan to authorize any such introduction so long as the criterion is not exceeded.

Virginia's Ammonia and Cadmium Aquatic Life Criteria Revisions

On September 18, 2017, the Virginia Department of Environmental Quality (VADEQ) announced for public review and comment its proposed amendments to its cadmium and ammonia aquatic life water quality criteria. The comment period ended December 8, 2017. Virginia is expected to respond to public comments and publish revised cadmium and ammonia aquatic life water quality criteria within the coming year. Pursuant to the EPA's authority outlined in CWA Section 303(c) and 40 CFR Part 131, the EPA must review and approve the final new or revised cadmium and ammonia aquatic life water quality criteria. If the revisions to the aquatic life criteria are consistent with the revisions submitted to the EPA during the public comment period and evaluated below, the EPA requests concurrence from the Services to confirm that the revisions are not likely to adversely affect listed species or their critical habitat. If revisions to the aquatic life criteria significantly differ from what was published during the public comment period and evaluated below, the EPA will resubmit another BE for informal consultation.

Virginia's amendment to its cadmium criteria for the protection of fresh and saltwater aquatic life is based on the EPA's national recommended water quality criteria issued in 2016. The EPA updated national recommended cadmium criteria account for many new laboratory toxicity tests for cadmium. In addition, the effect of total hardness on cadmium toxicity was also revised using the newly acquired data, including toxicity data for 75 new species and 49 new genera.

Virginia has proposed to amend its freshwater ammonia aquatic life criteria to be consistent with the EPA's 2013 nationally recommended freshwater ammonia aquatic life criteria, issued by the EPA 2013. Like Virginia's current criteria, the proposed criteria are calculated as a function of temperature and pH and account for the presence or absence of trout and early life stages of fish. The recalculated ammonia criteria now incorporate toxicity data for freshwater mussels in the family unionidae, which are the most sensitive organisms in the recalculation data base. The new criteria are about twice as stringent as the existing criteria primarily because more recent toxicity data show that mussels and snails (including endangered species) are very sensitive to ammonia and the current ammonia criteria do not provide sufficient protection for these species. Site specific options to calculate criteria omitting mussel toxicity data are proposed to be used in waters where a demonstration has been made that mussels are absent; however, Virginia's consultation with FWS and the Virginia Department of Game and Inland Fisheries indicate freshwater mussels should be considered ubiquitous in Virginia and likely to be present in any perennial waterbody.

The federal action being evaluated under ESA, Section 7 is the approval by the EPA of the new and revised provisions regarding Virginia's proposed updates to its cadmium and ammonia aquatic life water quality criteria. These criteria are adopted and implemented to maintain and protect the waters of Virginia, and they provide for the propagation and protection of aquatically-dependent listed species. The WQS revisions discussed here consider the best available science, including local and regional information, as well as the applicable EPA policies, guidance, and legal requirements, to protect aquatic life.

EPA 's 304(a) Nationally Recommended Criteria

Section 304(a) of the CWA authorizes the EPA to develop and revise recommended criteria for specific pollutants reflecting the latest scientific knowledge. These criteria documents provide justification for water quality criteria, including comprehensive literature reviews and toxicological analyses. In 2013, EPA published revised recommended criteria for ammonia and in 2016, EPA published revised recommended criteria for cadmium, both of which are for the protection of aquatic life. The updated criteria are reflective of new toxicity data, which were unavailable during past updates. The criteria are intended to be protective of aquatic life, including federally-listed endangered and threatened species. VA proposed to adopt EPA's recommended criteria for ammonia and cadmium; therefore, EPA's criteria documents are used throughout this BE to evaluate the potential effects of VA's WQS revisions on listed species

The Ammonia Criteria

Ammonia is one of several forms of nitrogen that exist in aquatic environments and is considered one of the most important pollutants not only because of its highly toxic nature, but also its ubiquity in surface water systems (Russo 1985). The agricultural industry uses approximately 90% of the U.S. annual domestic ammonia production for fertilizer (USGS 2004). Ammonia also has numerous industrial applications, including use in metal finishing and treating applications (e.g., nitriding; Appl 1999), in the chemical industry for the production of pharmaceuticals (Karolyi 1968) and dyes (Appl 1999), in the petroleum industry for processing of crude oil and in corrosion protection, and in the mining industry for metals extraction (U.S. EPA 2004). Natural sources of ammonia include the decomposition or breakdown of organic waste matter, gas exchange with the atmosphere, forest fires, animal waste, the discharge of ammonia by aquatic biota, and nitrogen fixation processes (Environment Canada 1997; Geadah 1985).

Ammonia can enter the aquatic environment via anthropogenic sources, such as municipal effluent discharges and agricultural runoff, and natural sources, such as nitrogen fixation and the excretion of nitrogenous wastes from animals. In 2011, there were approximately 4.7 million pounds (lbs.) of ammonia documented as discharged from all reporting industries to surface waters (U.S. EPA 2011).

Ammonia is unique among regulated pollutants because it is a toxicant that organisms have developed various strategies to excrete. When ammonia is present in water at high enough levels, it is difficult for aquatic organisms to sufficiently excrete the toxicant, leading to toxic buildup in internal tissues and blood, and potentially death. The toxic action of ammonia on aquatic animals, particularly in sensitive fish, may be due to one or more of the following causes: (1) proliferation in gill tissues, increased ventilation rates and damage to the gill epithelium (Lang et al. 1987); (2) reduction in blood oxygen-carrying capacity due to progressive acidosis

(Russo 1985); (3) uncoupling oxidative phosphorylation causing inhibition of production and depletion of adenosine triphosphate in the brain (Camargo and Alonso 2006); (4) and the disruption of osmoregulatory and circulatory activity disrupting normal metabolic functioning of the liver and kidneys (Arillo et. al.1981; Tomasso et al. 1980).

Among invertebrates, studies testing ammonia toxicity to bivalves, and particularly studies with freshwater mussels in the family Unionidae, have demonstrated their sensitivity to ammonia (Augspurger et al. 2003; Wang et al. 2007a, b; Wang et al. 2008). Toxic effects of unionized ammonia to both freshwater and marine bivalves include reduced opening of valves for respiration and feeding (Epifanio and Srna 1975); impaired secretion of the byssus, or anchoring threads in bivalves (Reddy and Menon 1979); reduced ciliary action in bivalves (U.S. EPA 1985); depletion of lipid and carbohydrate stores leading to metabolic alteration (Chetty and Indira 1995) as well as mortality (Goudreau et al. 1993). These negative physiological effects may lead to reductions in feeding, fecundity, and survivorship, resulting in decreased bivalve populations (Alonso and Camargo 2004; Constable et al. 2003).

In 2013, EPA revised and published recommended aquatic life criteria for ammonia in freshwaters based on EPA's latest scientific studies and toxicity data from over 69 aquatic genera including fish, invertebrate, and amphibian species, of which 12 are federally-listed as endangered, threatened, or a species of concern (U.S.EPA 2013). The 2013 document, which represents a revision of the 1999 recommended aquatic life criteria for ammonia, incorporates additional toxicity data for several sensitive freshwater mussel species. EPA's research suggests that freshwater mussels and gill-breathing snails are generally more sensitive to ammonia as compared to other aquatic life, such as fish and other invertebrates. The acute ammonia criterion is pH and temperature dependent, with invertebrates being more sensitive at higher temperatures (e.g., > 16 ^{o}c) and fishes in the genus Oncorhynchus being the most sensitive organisms at lower temperatures. The chronic ammonia criterion is also pH and temperature dependent, but does not differ based on the presence of fishes in the genus Oncorhynchus. VA revised it criteria to be consistent with EPA's recommended criteria, which represent the latest scientific knowledge regarding ammonia toxicity on aquatic life.

The ammonia criteria are defined by a magnitude, duration, and frequency. The magnitude is the maximum pollutant concentration allowable, the duration is the time period in which the magnitude is averaged, and the frequency is the allowable number of times the pollutant concentrations can exceed the magnitude during a recurrence interval. It is important to note that analysis of the criteria magnitude has been the primary focus of previous BEs. Critical aspects of the criteria, including the duration and frequency, provide a high level of additional conservatism and protectiveness to the criteria overall. The magnitude of the ammonia criteria is represented as acute and chronic concentrations and are expressed as functions of temperature and pH of the receiving waterbody. The criteria document describes the relationship between ammonia and these water quality factors. For example, at a pH of 7 and temperature of 20^{0}C, the 2013 acute criterion is 17 mg TAN/L and the chronic criterion is 1.9 mg TAN/L. In addition, the proposed criteria include a duration requirement that the highest four-day average within the same 30-day period used to determine compliance with the chronic criterion shall not exceed 2.5 times the chronic criterion and a one-hour average may not exceed the acute criterion. A frequency requirement states that the criteria are not to be exceeded more than once every three years.

Acute measures of effect used for aquatic organisms to develop the ammonia criteria are the lethal concentration (LC) 50 and effective concentration (EC) 50. LC is the concentration of a chemical that is estimated to kill the noted percentage of the test organisms. EC is the concentration of a chemical that is estimated to affect growth, survival, and/or reproduction in the noted percentage of the test organisms. These concentrations are then normalized to a pH of 7.0 (for all organisms) and temperature of 20^0C (for invertebrates). The pH and temperature conditions to which these data are normalized were deemed to be generally representative of ambient surface water. These normalized values were then used to rank genus mean acute values (GMAV) calculated from combined species mean acute values (SMAVs) within each genus. A final acute value (FAV) is then determined by regression analysis using a log-triangular fit based on the four most sensitive GMAVs in the data set to interpolate or extrapolate (as appropriate) to the 5th percentile of the distribution represented by the tested genera. If there are 59 or more GMAVs, as is the case with ammonia, the four GMAVs closest to the 5th percentile of the distribution are used to calculate the FAV. Finally, the FAV is divided by two to calculate the acute criterion as per the 1985 guidelines (Stephan et al. 1985). The FAV divided by two approach was developed to estimate minimal effect levels, those which approximate control mortality limits, and is based on the analysis of 219 acute toxicity tests for a range of chemicals, as described in the Federal Register on May 18, 1978 (43 FR 21506-18). Ammonia acute toxicity data were available for 44 species of fish, 52 invertebrates, and four amphibians, including 12 species federally-listed as endangered, threatened, or species of concern.

Chronic measures of effect used for aquatic organisms to develop the ammonia criteria are EC20, no-observed-effect-concentrations (NOEC), lowest-observed-effect-concentrations (LOEC), and maximum acceptable toxicant concentration (MATC). EC20 values were used to estimate a low level of effect observed in chronic datasets that are available for ammonia (see U.S. EPA 1999). The NOEC is the highest test concentration at which none of the observed effects are statistically different from the control. The LOEC is the lowest test concentration at which observed effects are found to be statistically different from the control. The MATC is the calculated geometric mean of the NOEC and LOEC. All chronic data in individual studies were analyzed using regression analysis to demonstrate the presence of a concentration-effect relationship within the test. For those studies that demonstrated a concentration-effect relationship, EPA used regression analysis to estimate the EC20. These values were then used to rank genus mean chronic values (GMCV) calculated from combined species mean chronic values (SMCVs) within each genus. EPA calculated the chronic criterion as the final chronic value (FCV) based on the fifth percentile of the GMCVs. The four lowest values were used to calculate the FCV because values for fewer than 59 genera exist. Ammonia chronic toxicity data are available for 21 species of freshwater organisms: ten invertebrate species (mussels, clam, snail, cladocerans, daphnid, and insect) and 1 1 fish species, including three Federally-listed salmonids.

The acute and chronic ammonia toxicity data used to develop the acute and chronic criteria for ammonia in freshwater were collected via literature searches of EPA' s ECOTOX database, EPA's Ambient Aquatic Life Water Quality Criteria for Ammonia (U.S. EPA 1985, 1998, 1999), data provided by the U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (collectively known as the Services),

and EPA regional and field offices. All available, reliable acute and chronic toxicity values published since 1985 were incorporated into the appropriate ammonia tables and used to recalculate the acute and the chronic criterion, as outlined in detail in the 1985 Guidelines. The most recent literature search covered the period from 1985 through October 2012.

The Cadmium Criteria

Cadmium is a relatively rare, naturally occurring metal found in mineral deposits and distributed widely at low concentrations in the environment. Cadmium is used by industry to manufacture batteries, pigments, plastic stabilizers, metal coatings, alloys, electronics, and nanoparticles for use in solar cells and color displays. These anthropogenic sources are responsible for over 90 percent of the cadmium found in surface waters. Upon entering aquatic environments, majority of cadmium becomes strongly adsorbed to sediments, removed from the water column, and often not bioavailable to organisms.

Cadmium is a non-essential metal with no biological function in aquatic animals (Eisler 1985; Lee et al. 1995; McGeer et al. 2012; Price and Morel 1990; Shanker 2008). In one study comparing the acute toxicity of all 63 atomically stable heavy metals in the periodic table, cadmium was found to be the most acutely toxic metal to the amphipod, Hyalella azteca, based on the results of seven-day acute aquatic toxicity tests (Borgmann et al. 2005). In addition to acute toxicity, cadmium is a known teratogen and carcinogen, is a probable mutagen and is known to induce a variety of other short- and long-term adverse physiological effects in fish and wildlife at both the cellular and whole-animal level (Eisler 1985; Okocha and Adedeji 2011). Chronic exposure leads to adverse effects on growth, reproduction, immune and endocrine systems, development, and behavior in aquatic organisms (McGeer et al. 2012). Other toxic effects include histopathologies of the gill, liver and kidney in fish, renal tubular damage, alterations of free radical production and the antioxidant defense system, immunosuppression, and structural effects on invertebrate gills (Giari et al. 2007; Jarup et al. 1998; McGeer et al. 2011; Okocha and Adedeji 2011; Shanker 2008). Cadmium can bioaccumulate in aquatic organisms, with total uptake depending on the environmental cadmium concentration, exposure route and the duration of exposure (Annabi et al. 2013; Francis et al. 2004; McGeer et al. 2000; Roméo et al. 1999).

Toxic effects are thought to result from the free ionic form of cadmium (Goyer et al. 1989), which causes acute and chronic toxicity in aquatic organisms primarily by disrupting calcium homeostasis and causing oxidative damage. In freshwater fish, cadmium competes with calcium at high affinity binding sites in the gill membrane and blocks the uptake of calcium from water by interfering with ion uptake in specialized calcium channels that are located in the mitochondria-rich chloride cells (Carroll et al. 1979; Evans 1987; McGeer et al. 2012; Morel and Hering 1993; Pagenkopf 1983; Tan and Wang 2009). The combined effect of competition for the binding sites and blockage of calcium uptake on the gill membrane results in acute hypocalcaemia in freshwater fish, which is characterized by cadmium accumulation in tissues as well as decreased calcium concentrations in plasma (McGeer et al. 2011; Roch and Maly 1979; Wood et al. 1997).

In 2016, EPA revised and published recommended aquatic life criteria for cadmium (U.S. EPA, 2016). The revised criteria represent an update to EPA's 2001 cadmium criteria and

include additional aquatic life toxicity tests on 75 new species, nine of which are federally-listed as endangered or threatened, and 49 new genera published since 2001. DC adopted EPA's recommended criteria, which represent the latest scientific knowledge regarding cadmium toxicity on aquatic life.

Like ammonia, the cadmium criteria are defined by a magnitude, duration, and frequency. The magnitude of the cadmium criteria is represented as acute and chronic concentrations and are expressed as a function of hardness of the receiving waterbody. The criteria document describes the relationship between cadmium and hardness. For example, at a total hardness of 100 mg/L as CaC03, the acute criterion is 1.8 gg/L and the chronic criterion is 0.72 gg/L. In addition, the proposed criteria include a duration requirement that the acute criterion not be exceeded over a one-hour average and a chronic criterion not be exceeded over a four-day average. A frequency requirement states that the criteria are not to be exceeded more than once every three years.
The acute measures of effect used for aquatic organisms to develop the cadmium criteria are the LC50, EC50, and Inhibitory concentration (IC) 50. IC is the concentration of a chemical that is estimated to inhibit some biological process (e.g., growth) in the noted percentage of the test organisms. These concentrations are then normalized with a hardness of 100 mg/L CaC03. The hardness conditions to which these data are normalized were deemed to be generally representative of ambient surface water. These normalized values were then used to rank genus mean acute values (GMAV) calculated from combined species mean acute values (SMAVs) within each genus. A final acute value (FAV) is then determined by regression analysis using a log-triangular fit based on the four most sensitive GMAVs in the data set to interpolate or extrapolate (as appropriate) to the 5th percentile of the distribution represented by the tested genera. As per the 1985 guidelines and because the SMAV for the commercially and recreationally important rainbow trout was lower than the calculated FAV, the final FAV was lowered to protect the species. Finally, the FAV is divided by two to calculate the acute criterion. Cadmium acute toxicity data are available for 101 species and 75 genera of invertebrates, fish, and amphibians, of which nine species are federally-listed as endangered, threatened, or a species of concern.

The chronic measures of effect used for aquatic organisms to develop the cadmium criteria are the EC20, NOEC, and LOEC. EPA selected an EC20 to estimate a low level of effect that would be statistically different from control effects, but not severe enough to cause chronic effects at the population level (see U.S. EPA 1999a). Reported NOECs and LOECs were only used for the derivation of chronic criterion when an EC20 could not be calculated for the genus. When LOECs and NOECs are used, a MATC is calculated. These concentrations were normalized to a hardness of 100 mg/L CaC03. The values were then used to rank GMCVs calculated from combined SMCVs within each genus. EPA calculated the chronic criterion as the FCV based on the fifth percentile of the GMCVs. The four lowest values were used to calculate the FCV because values for fewer than 59 genera exist. Cadmium chronic toxicity data are available for 27 species representing 20 genera, of which four species are federally-listed as endangered, threatened, or a species of concern.

During CWA Section 304(a) criteria development, EPA reviews and considers all relevant toxicity test data. Information available for all relevant species and genera are reviewed to identify: 1) data from acceptable tests that meet data quality standards; and 2) whether the acceptable data meet the minimum data requirements (MDRs) as outlined in EPA's 1985

Guidelines (Stephan et al. 1985; U.S. EPA 1986). The taxa represented by the different MDR groups represent taxa with different ecological, trophic, taxonomic and functional characteristics in aquatic ecosystems, and are intended to be a representative subset of the diversity with a typical aquatic community.

Action Area

The EPA's proposed approval of the Virginia revised ammonia and cadmium criteria applies to all waters of the United States (within the Commonwealth of Virginia) under federal jurisdiction. Jurisdiction over non-navigable, isolated, and intrastate waters would likely have to be determined on a case-by-case basis. The area evaluated for action is the surface waters of the Commonwealth. Waters of the Commonwealth are defined in section Title 62.1 of the Waters of the State, Ports and Harbors Law as "water includes all waters, on the surface and under the ground, wholly or partially within or bordering the Commonwealth or within its jurisdiction and which affect the public welfare."

According to ESA. the action area is defined as "all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action" (50 CFR Part 402.02). This includes the project's footprint as well as the area beyond it that may experience direct or indirect effects that would not occur but for the action. For NMFS listed species, applicable waters include coastal waters of the Atlantic Ocean, the Chesapeake Bay, and the Potomac, Rappahannock, York, and James Rivers, inclusive of all tributaries. These water bodies represent the extent of where effects of the action on listed species may occur.

Listed Species and Critical Habitat within the Action Area

Species that have more than a limited exposure to water are considered either aquatic or aquatic-dependent and, as such, are subject to consultation. The EPA obtained a current list of species believed to or known to occur in Virginia from the NOAA Fisheries, Greater Atlantic Region website to determine if any listed, proposed or candidate species may be present in the action area. This list is included as an attachment to this BE. EPA has determined that based on the overlapping action area with species ranges, the following species and associated critical habitat may be affected by EPA's approval of VA's WQS revisions.

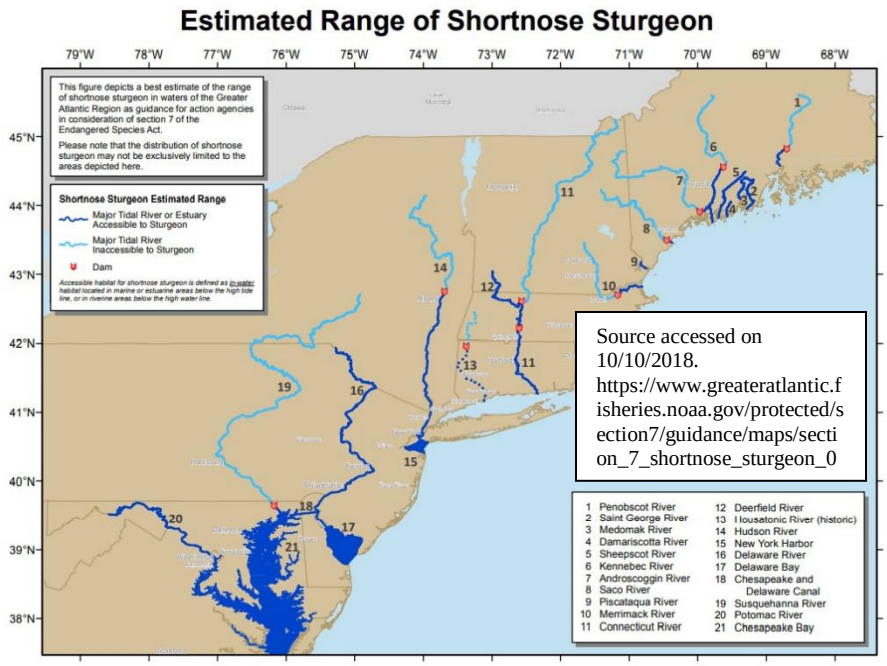
TABLE: VA Species of Interest for ESA Consultation w/ NMFS

Jurisdiction	Category	Class	Species	Applicable Aquatic Life Criteria for this action
NMF	Aquatic	Fish	Atlantic sturgeon Acipenser oxyrinchus	Freshwater & Estuarine/Marine
NMF	Aquatic	Fish	Sturgeon, shortnose Acipenser revirostrum	Freshwater & Estuarine/Marine
NMF	Aquatic	Sea Turtle	Green Sea Turtle Chelonia mydas	Estuarine/Marine
NMF	Aquatic	Sea Turtle	Kemp's Ridley Sea Turtle Lepidochelys kempii	Estuarine/Marine
NMF	Aquatic	Sea Turtle	Leatherback Sea Turtle Dermochelys coriacea	Estuarine/Marine
NMF	Aquatic	Sea Turtle	Loggerhead Sea Turtle Caretta caretta	Estuarine/Marine

TABLE: VA Species of Interest for ESA Consultation w/ NMFS				
Jurisdiction	**Category**	**Class**	**Species**	**Applicable Aquatic Life Criteria for this action**
NMF	Aquatic	Whales Mammals	North Atlantic right whale Eubalaena glacialis	Estuarine/Marine
NMF	Aquatic	Whales Mammals	Fin whale Balaenoptera physalus	Estuarine/Marine

Shortnose Sturgeon

Year listed: 1967 Status: Endangered. Shortnose sturgeon are a large long lived benthic species. They are anadromous, living mainly in slower moving riveriene waters or nearshore marine waters, and migrating periodically into faster moving fresh waters areas to spawn, Shortnose sturgeon mainly occupy the deep channel sections of large rivers, but will forage where food is accessible. They feed on a verity of benthic and epibenthic invertebrates including mollusks, crustations (amphipods, chironomids, isopods), and oligochate worms in soft-sediment habit. Shortnose sturgeon are opportunitc foragers, and will forage where appropriate prey items are located.



Source accessed on 10/10/2018. https://www.greateratlantic.fisheries.noaa.gov/protected/section7/guidance/maps/section_7_shortnose_sturgeon_0

General distribution: (Source Shortnose Sturgeon GARFO Master ESA Species Table dated 9/17/18, found at https://www.greateratlantic.fisheries.noaa.gov/protected/section7/listing/garfo_master_esa_species_table_-_shortnose_sturgeon_09172018.pdf. accessed on 10/10/2018)

Atlantic Ocean waters and associated bays, estuaries, and coastal river systems from Minas Basin, Nova Scotia, Canada, to the St. Johns River, Florida; only adults occur in marine waters, with some adults making coastal migrations between river systems (e.g., Penobscot River to Merrimack River via the Gulf of Maine; Merrimack River to Connecticut River via the Gulf of Maine and Long Island Sound; Connecticut River to Hudson River via Long Island Sound and the East River); typically, distribution in rivers and inshore bays occurs from the estuary or river mouth up to the first impassible barrier (e.g., a dam or falls); comprehensive information on species biology and distribution is available in the Shortnose Sturgeon Status Review Team's Biological Assessment (SSSRT 2010; available at: http://www.nmfs.noaa.gov/pr/pdfs/species/shortnosesturgeon_biological_assessment2010.pdf) Critical habitat in GAR: None

Waterbodies within the Action Areas: The shortnose sturgeon (Acipenser brevirostrum), which has been federally listed as endangered since March 1 1, 1967, is one of the species under NMFS's jurisdiction that may occur within the action area in Virginia. Shortnose sturgeon have been rarely documented south of the Maryland-Virginia border and into areas of southern Chesapeake Bay. Spells (1998), Skjeveland et al. (2000), and Welsh et al. (2002) all reported only one capture each of adult shortnose sturgeon in the Rappahannock River. In the James River, one adult shortnose sturgeon was captured at river kilometer (RKM) 48 in March 2016 (Balazik 2017), and one gravid female shortnose sturgeon was captured in the James River just downstream of the Hog Island discharge (near RKM 48) in February 2018 (Balazik, pers. comm.). These captures of adults are the only records of shortnose sturgeon in the southwestern portion of Chesapeake Bay, at this time.

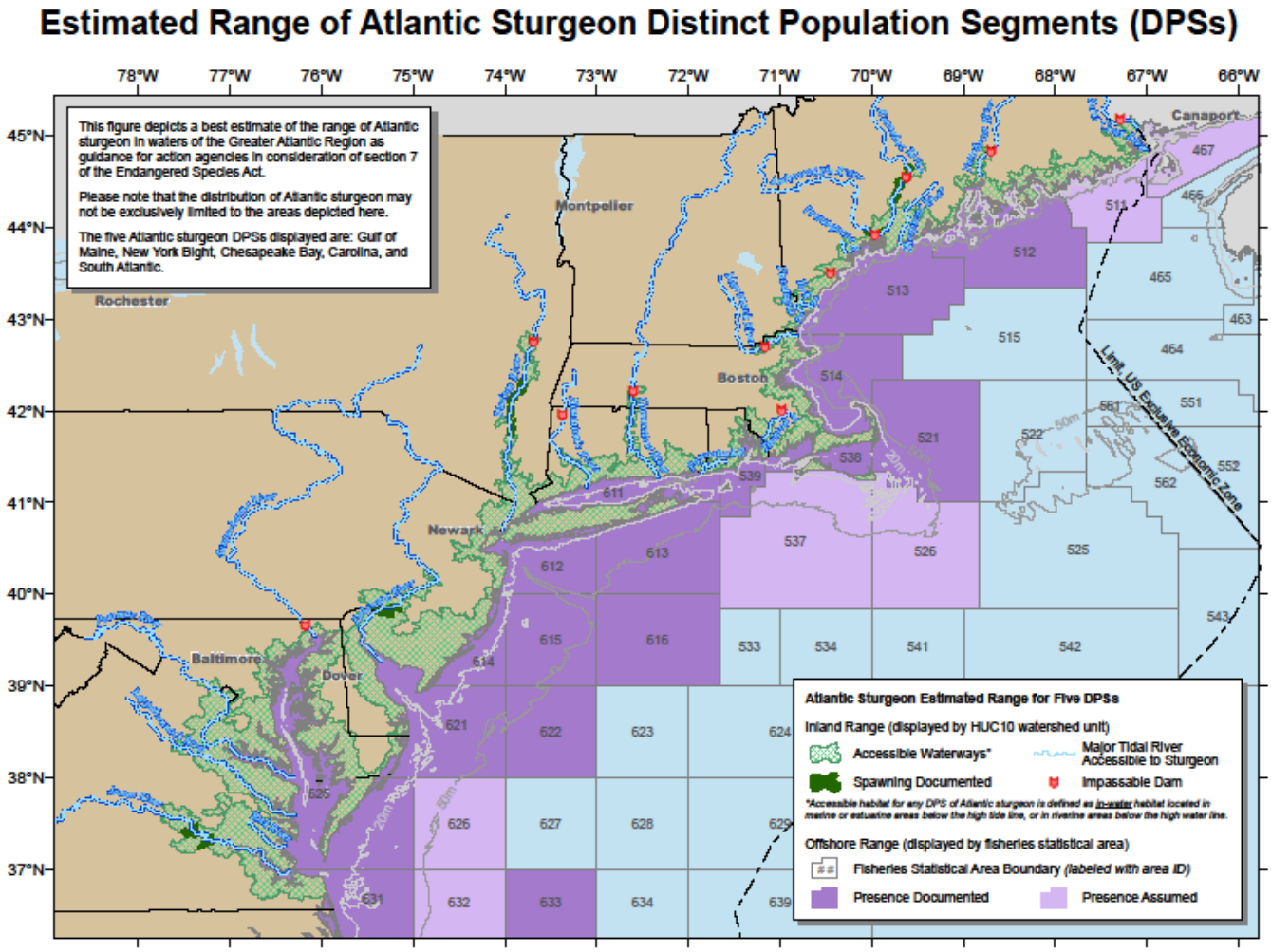
Body of Water (State)	**Distribution/Range in Watershed**	**Life Stages Present**	**Use of the Watershed**	**References**
Chesapeake Bay (MD/VA)	Maryland and Virginia waters of mainstem bay and tidal tributaries including those specifically listed below.	adults documented; other life stage presence unknown	**Foraging, Resting, and Overwintering** -Assumed to occur in areas with suitable forage [1][2]	[1] SSSRT 2010; [2] Balazik 2017
Potomac River (MD/VA)	Up to Little Falls Dam (RKM 189)	adults documented; other life stages assumed but unknown	**Spawning** - Historically occurred; current spawning not documented but assumed based on presence of pre-spawning females and suitable habitat at RKM 185-187[1] **Rearing** - Eggs expected at RKM 185-187, larvae would be present downstream in freshwater [1] **Foraging** - Mainly in the deepwater channel from RKM 63-141[1][2] **Overwintering** - Near Mattawoman Creek; saltwater/freshwater reach near Craney Island [1][2] (RKM 63-141)	[1] Kynard et al. 2007; [2] Kynard et al. 2009
Rappahannock River (VA)	Range not confirmed, but they have been documented in this river (likely throughout the entire river)	adults	**Foraging** - Potentially occurs where suitable forage is present; one was captured in May 1998[1]	[1] Spells 1998
York River (VA)	Range unknown (potentially throughout the river and tributaries)	adults	**Foraging** -Potentially occurs where suitable forage is present [1]	[1] Balazik, pers. comm., June 7, 2018
James River (VA)	Range not confirmed, but likely up to Boshers Dam (RKM 182.3)	adults	**Foraging/Spawning** - Foraging potentially occurs where suitable forage is present; a sturgeon, possibly from the Potomac or Delaware River, was captured on March 13, 2016, at RKM 48[1]; on February 2018, a second sturgeon (a confirmed gravid female) was captured near RKM 48[2] (genetics results not yet available); spawning area unknown; the salinity at RKM 48 is usually low (brackish).	[1] Balazik 2017; [2] Balazik, pers. comm., February 10, 2018

In summary, NMFS expect adult shortnose sturgeon to utilize all waters of the action area in VA. These fish would be migrating, foraging, resting, and potentially spawning only in the upper portions of the Potomac River, where early life stages (ELS) (eggs and larvaes) as well as juveniles may also be present within this portion of the action area.

Atlantic Sturgeon

Year listed: 2012 Status: Endangered. Atlantic sturgeon live in rivers and coastal waters from Canada to Florida. Hatched in the freshwater of rivers, Atlantic sturgeon head out to sea as juveniles, and return to their birthplace to spawn, or lay eggs, when they reach adulthood. Atlantic sturgeon are slow-growing and late-maturing, and have been recorded to reach up to 16 feet in length and up to 60 years of age. Atlantic sturgeon were once found in great abundance, but their populations have declined greatly due to overfishing and habitat loss. Atlantic sturgeon were prized for their eggs, which were valued as high-quality caviar. During the late 1800s, people flocked to the Eastern United States in search of caviar riches from the sturgeon fishery, known as the "Black Gold Rush." By the beginning of the 1900s, sturgeon populations had declined drastically. Close to 7 million pounds of sturgeon were reportedly caught in 1887, but by 1905 the catch declined to only 20,000 pounds, and by 1989 only 400 pounds of sturgeon were recorded. The most significant threats to Atlantic sturgeon are unintended catch in some commercial fisheries, dams that block access to spawning areas, poor water quality (which harms development of sturgeon offspring), dredging of spawning areas, water withdrawals from rivers, and vessel strikes. Atlantic sturgeon habitat can be disrupted or lost because of various human activities, such as dredging, dams, water withdrawals, saltwater intrusion (often caused by groundwater pumping from freshwater wells or drought), chemical contamination of sediments in rearing areas, and other development. Sturgeon need hard bottom substrates in freshwater reaches for spawning, so any activity that destroys those locations directly (e.g., dredging) or indirectly (e.g., sedimentation or saltwater intrusion) would affect Atlantic sturgeon habitat. To support all life stages, Atlantic sturgeon also require sufficient water quantities and water qualities sufficient to support all life stages, which are often impacted by the activities above.

General distribution:Source: Atlantic Sturgeon GARFO Master ESA Species Table dated 6/7/2018, found at https://www.greateratlantic.fisheries.noaa.gov/protected/section7/guidance/maps/garfo_master_esa_species_table_-_atlantic_sturgeon_06072018.pdf. Accessed on 10/10/2018)Atlantic Ocean waters and associated bays, estuaries, and coastal river systems from Hamilton Inlet, Labrador, Canada, to Cape Canaveral, Florida; only subadult and adult lifestages occur in marine waters, where they are typically found in waters 5-50 meters in depth (Stein et al. 2004; ASMFC TC 2007); subadults and adults may travel long distances in marine waters, aggregate in both ocean and estuarine areas at certain times of the year, and exhibit seasonal coastal movements in the spring and fall; distribution in rivers and inshore bays typically occurs from the estuary or river mouth generally up to the first impassible barrier (e.g., a dam or falls); Atlantic sturgeon generally use the deepest habitats available to them in rivers, but they have also been collected over shallow (2.5 meters), tidally influenced flats and substrates ranging from mud to sand and mixed rubble and cobble (Savoy and Pacileo 2003)



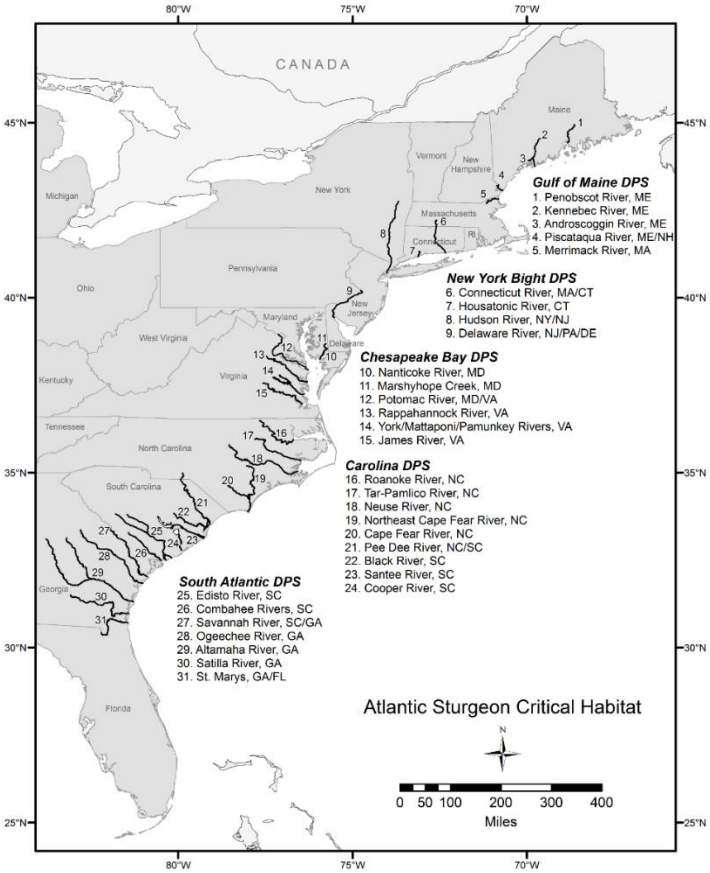
Waterbodies within the Action Areas: NMFS expect adult and sub-adult Atlantic sturgeon to use all the waters of the action area in VA for migration, foraging, and rest. The best available information indicates that spawning is limited to the James and York River systems, and as such spawning adults, ELS, and juvenile presence are limited to those water bodies.

Body of Water (State)	Distribution/Range in Watershed	Life Stages Present	Use of the Watershed	References
Chesapeake Bay (MD/VA)	Throughout the bay typically in spring through fall	juveniles, subadults, and adults	**Migration** - April-November for adults [5] and subadults [1]; year round for juveniles [2] 3]; these lifestages wander among coastal and estuarine habitats [5] **Foraging** - typically in areas where suitable forage and appropriate habitat conditions are present; typically tidally influenced flats and mud, sand and mixed cobble substrates [4]	1] Dovel and Berggren 1983; [2] Secor et al. 2000; [3] Welsh [4] Stein et al. 2004 [5] Horne and Stence 2016
Potomac River (MD/VA)	Up to Little Falls Dam (RKM 189)	juveniles, subadults, and adults potentially	**Spawning** - potentially occurs as three small juveniles [3] and a large mature female [2] have been captured and due to the presence of features necessary to support reproduction and recruitment	[1] Niklitschek and Secor 2005; [2] ASSRT 2007; [3] Kynard etal. 2007

		eggs, larvae, and YOY)	[1][2] Rearing - three juveniles have been captured [3] **Foraging** - where suitable forage and appropriate habitat conditions are present [2]	
Rappahannock River (VA)	Range not confirmed, but they have been documented in this river (likely throughout the entire river)	subadults and adults (potentially eggs, larvae, YOY, and juveniles)	**Spawning** - potentially occurs due to the capture of a male sturgeon in spawning condition in September 2015 and the presence of features necessary to support reproduction and recruitment [1][3] **Rearing** - may be used as a nursery for juveniles [2] **Foraging** - where suitable forage and appropriate habitat conditions are present [2]	[1] Bushnoe et al. 2005; [2] ASSRT 2007; [3] NMFS 2016
York River, including Mattaponi and Pamunkey River tributaries (VA)	York River - up to confluence with the Mattaponi and Pamunkey Rivers (RKM 55); Pamunkey River – up to RKM 150; Mattaponi River - up to RKM 120	eggs, larvae, YOY, juveniles, subadults, and adults	**Spawning** - potential for fall spawning due to the presence of features necessary to support reproduction in its tributaries (Mattaponi and Pamunkey Rivers) and recruitment in both the York River and its tributaries [1]; documented in the Pamunkey River through the capture of an adult female sturgeon in post-spawning condition in the fall and the presence of features necessary to support reproduction and recruitment [3]; may occur in the Pamunkey River as far al. 2014; [4] Kahn et al. 2014 Mattaponi River - up to RKM 120 upstream as RKM 150[4] **Rearing** - in freshwater reaches downstream of spawning sites; four age-0 Atlantic sturgeon were captured in the York River [2]; Juveniles likely present throughout the river year-round **Foraging** - where suitable forage and appropriate habitat conditions are present [1]	[1] Bushnoe et al. 2005; [2] Balazik et al. 2012; [3] Hager et al. 2014; [4] Kahn et al. 2014
James River (VA)	Up to Boshers Dam (RKM 182.3)	eggs, larvae, YOY, juveniles, subadults, and adults	**Staging -** likely done by fall spawners, during summer and fall in brackish water before and after the fall spawn (RKM 22- 107) [4] Spawning - both a spring (likely at RKM 90-95) [4] and fall spawning event (likely between RKM 105 and the fall line near Richmond, VA at RKM 155) [3] Rearing - freshwater reaches downstream of spawning locations[1][2]; Juveniles likely present throughout the river year-round **Foraging -** where suitable forage and appropriate habitat conditions are present [2]	[1] Florida Museum of Natural History 2004; [2] ASSRT 2007; [3] Balazik et al. 2012; [4] Balazik and Musick 2015
Appomattox River (VA), tributary of the James River	subadults and adults	Range not confirmed, but they have been documented in this river (likely up to Battersea Dam, RKM 21)	Foraging - where suitable forage and appropriate habitat conditions are present [1]	[1] The Hopewell News 2013

Critical Habitat of the Atlantic Sturgeon

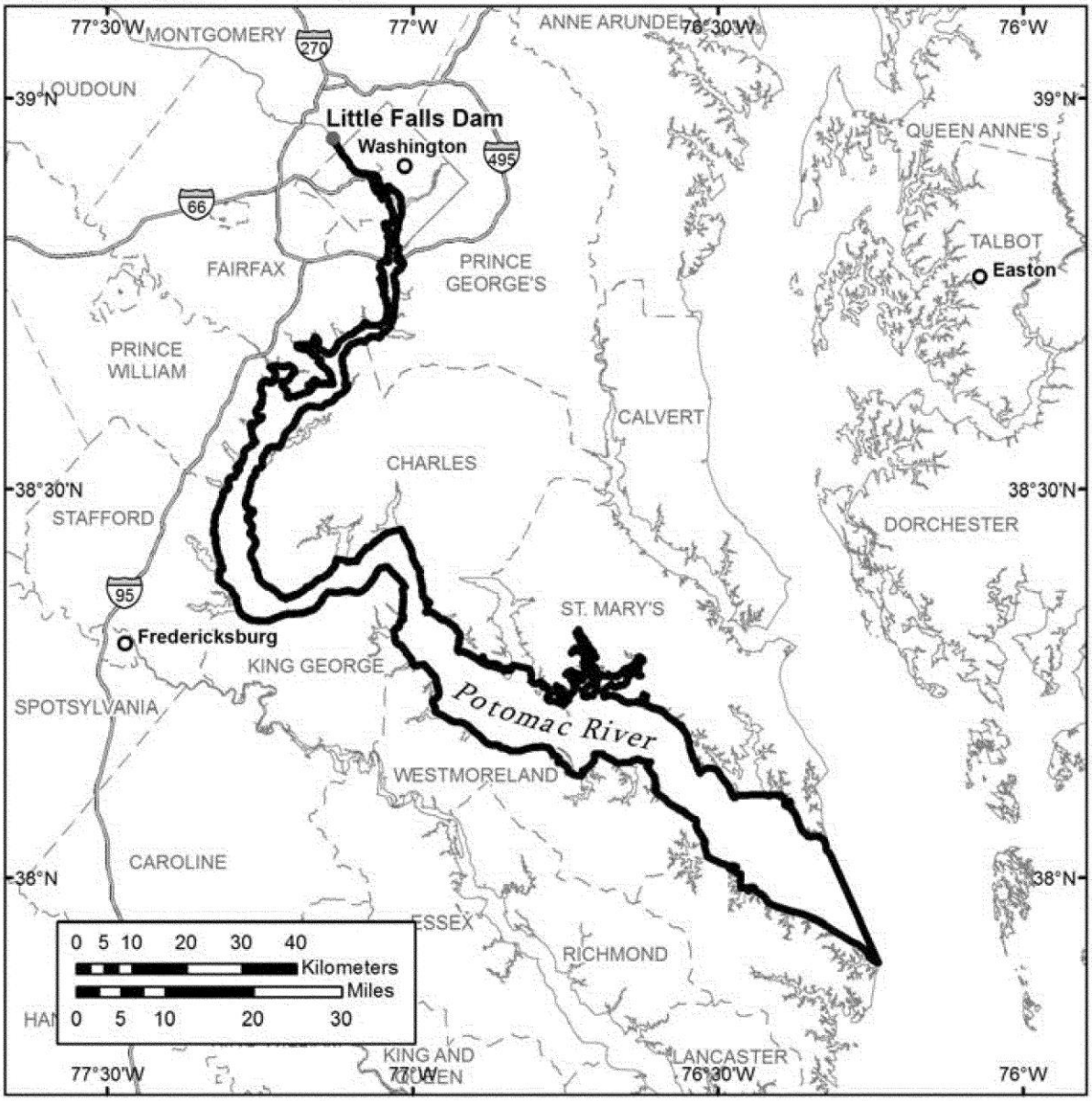
On August 17, 2017 NMFS issued a final rule to designate critical habitat for the threatened for several distinct population segment (DPS) of Atlantic sturgeon, including, the endangered Chesapeake Bay DPS of Atlantic sturgeon. The ESA authorizes USFWS and NMFS to designate critical habitat for federally-listed species, which is defined as habitat that is essential for the species' recovery.



Atlantic sturgeon critical habitat is included in the *Critical habitat boundaries of the Chesapeake Bay* distinct population segment DPS. Critical habitat for the Chesapeake Bay DPS of Atlantic sturgeon is Rappahannock River from the U.S. Highway 1 Bridge, downstream to where the river discharges at its mouth into the Chesapeake Bay; York River from its confluence with the Mattaponi and Pamunkey rivers downstream to where the main stem river discharges at its mouth into the Chesapeake Bay as well as the waters of the Mattaponi River from its confluence with the York River and upstream to the Virginia State Route 360 Bridge of the Mattaponi River, and waters of the Pamunkey River from its confluence with the York River and upstream to the Nelson's Bridge Road Route 615 crossing of the Pamunkey River; James River from Boshers Dam downstream to where the main stem river discharges at its mouth into the Chesapeake Bay at Hampton Roads; Potomac River from the Little Falls Dam downstream to where the main stem river discharges at its mouth into the Chesapeake Bay. **See Federal Register** / Vol. 82, No. 158 / Thursday, August 17, 2017 / Rules and Regulations pages **39250 - 39253**

Chesapeake Bay Unit 2
Potomac River

Map 10



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Critical Habitat Area

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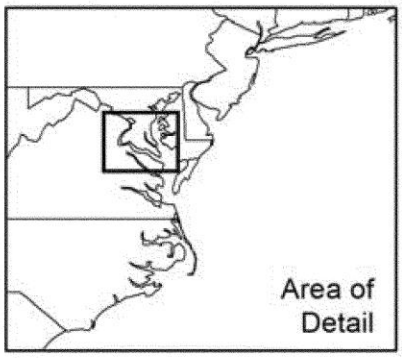
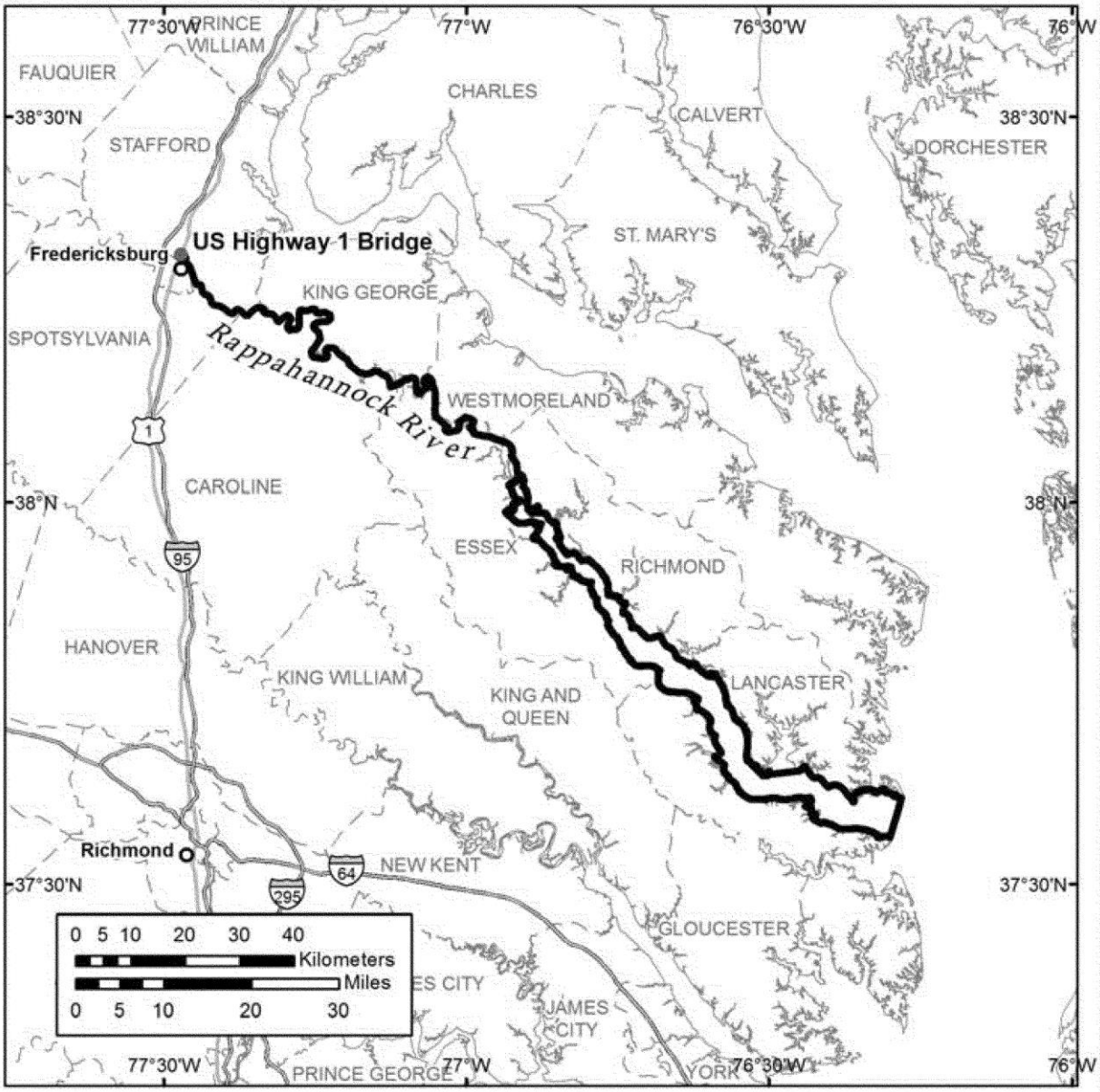


This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area; from the ordinary high water mark of one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.

Chesapeake Bay Unit 3
Rappahannock River

Map 11



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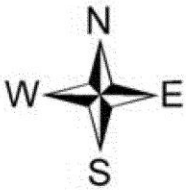
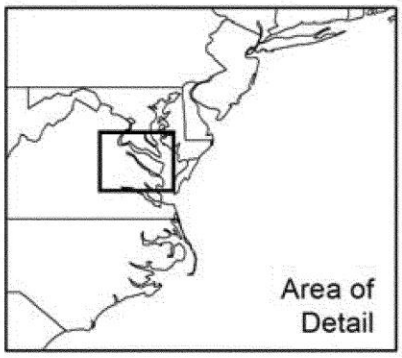
Critical Habitat Area

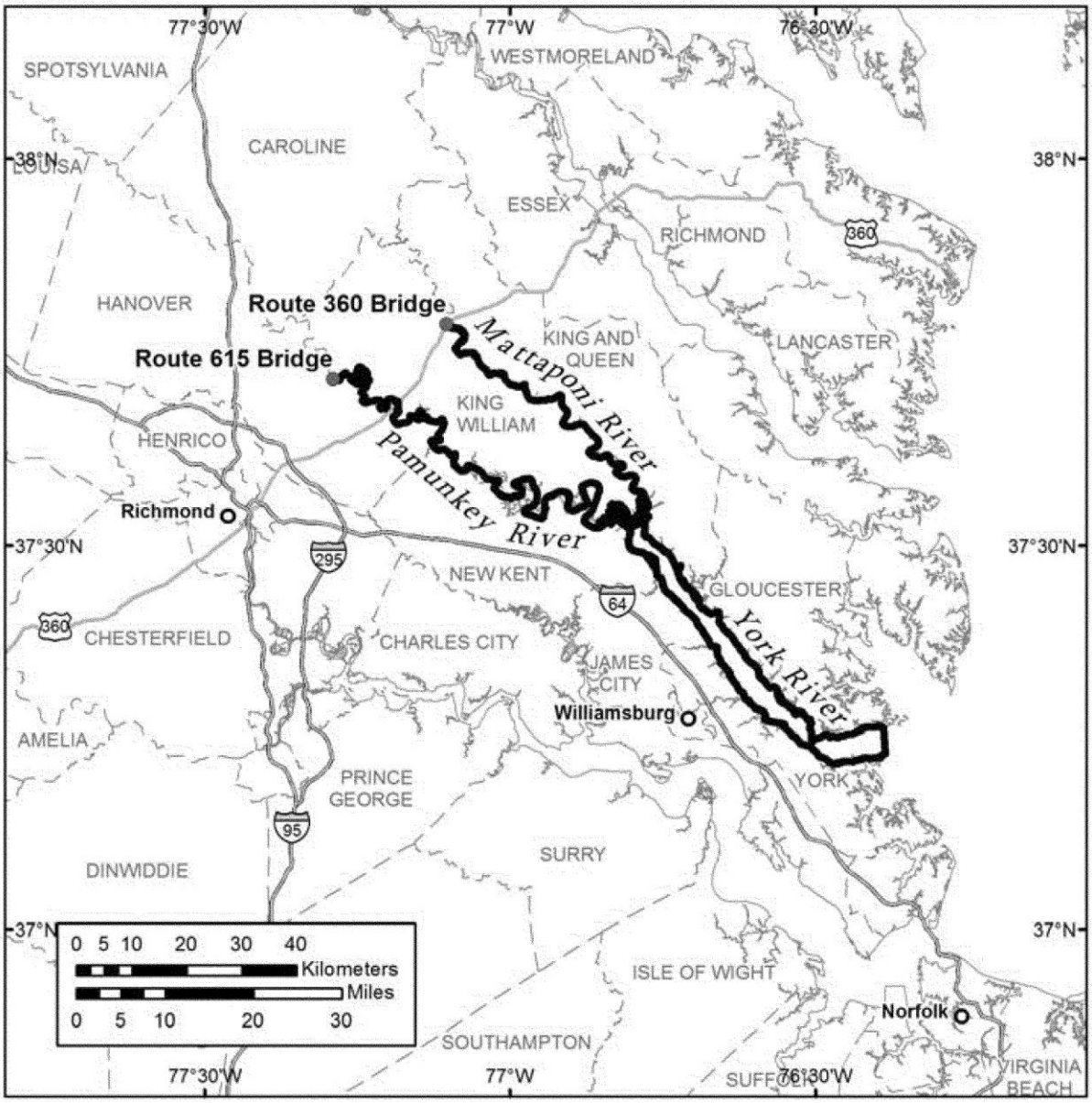




This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area; from the ordinary high water mark of one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.

Chesapeake Bay Unit 4 — Map 12

York River, Mattaponi River, and Pamunkey River



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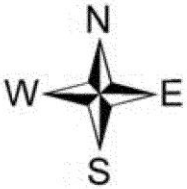
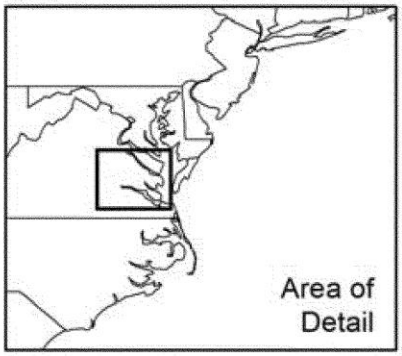
Critical Habitat Area

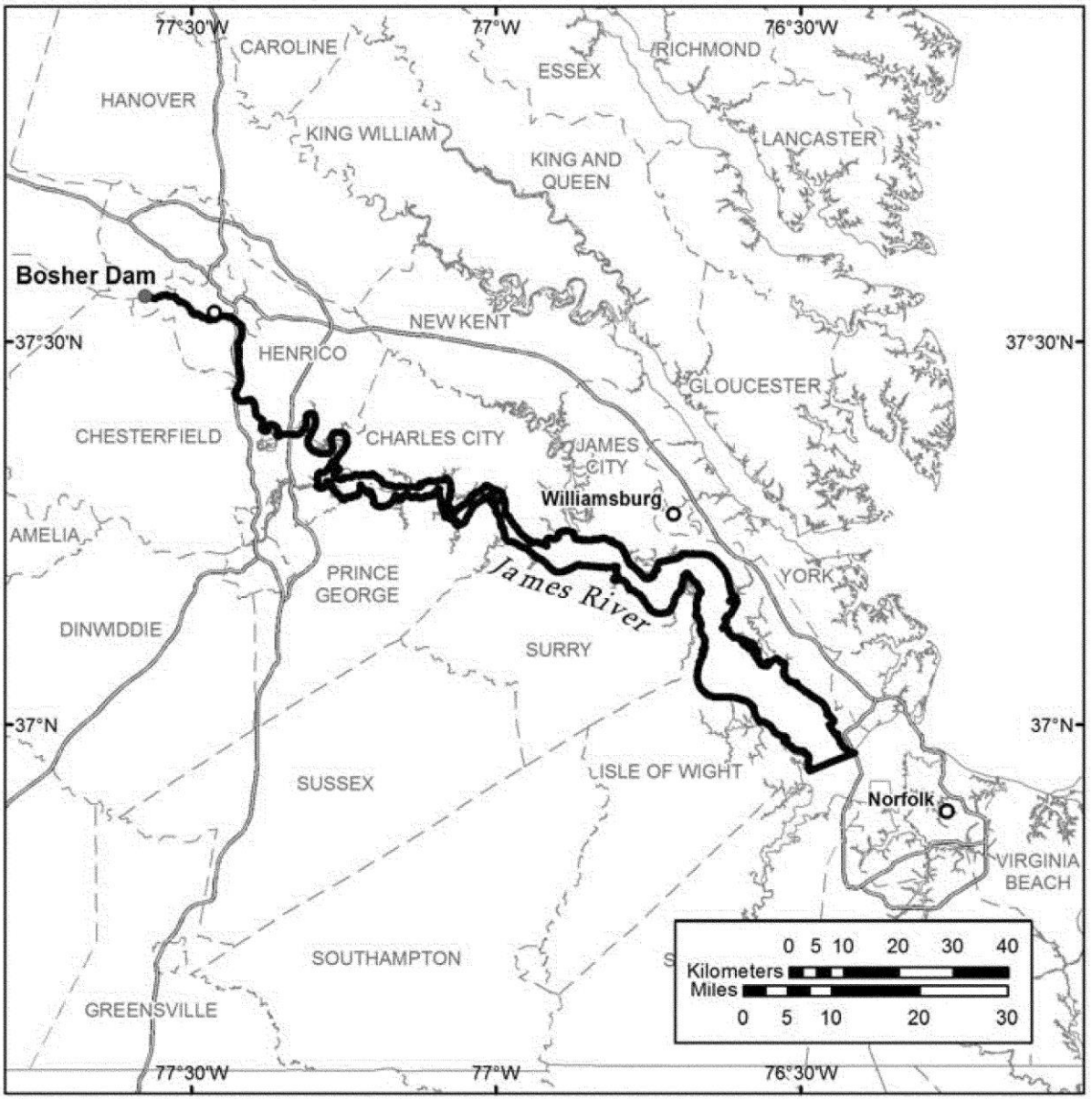




This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area; from the ordinary high water mark of one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.

Chesapeake Bay Unit 5
James River

Map 13



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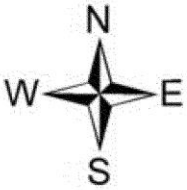
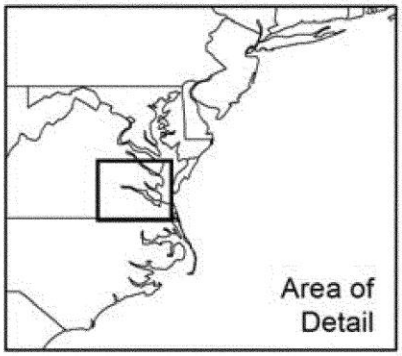
Critical Habitat Area





This map illustrates Atlantic sturgeon critical habitat. Critical habitat is all of the river within the illustrated Critical Habitat Area; from the ordinary high water mark of one riverbank to the ordinary high water mark of the opposing riverbank. For clarification of the critical habitat definition, please refer to the narrative description.

NMFS has designated the Chesapeake Bay distinct population as endangered due to protracted population decline, limited spawning and continued impacts and threats. These threats include dredging, water quality degradation (e.g., runoff from agriculture, industrialization and dams), vessel strikes and catching by fisheries.

The final rule designates the critical habitat and defines and describes the habitat and its essential features (Physical and Biological Features (PBFs)) for Atlantic Sturgeon as follows:

- PBF 1: Hard bottom substrate for settlement of fertilized eggs, refuge, growth, and development of early life stages.

- PBF 2: Aquatic habitat with a gradual downstream salinity gradient of 0.5 to 30 parts per thousand and soft substrate downstream of spawning sites for juvenile foraging and physiological development.

- PBF 3: Water of appropriate depth and absent physical barriers to passage between the river mouth and spawning sites necessary to support (l) unimpeded movement of adults to and from spawning sites, (2) seasonal and physiologically dependent movement of juvenile Atlantic sturgeon to appropriate salinity zones within the river estuary, and (3) staging, resting, or holding of subadults or spawning condition adults. Water depths in main river channels must also be deep enough to ensure continuous flow in the main channel at all times when any sturgeon life stage would be in the river.

- PBF 4: Water, especially in the bottom meter of the water column, with temperature, salinity, and oxygen values that, combined, support (1) spawning, (2) annual and interannual adult, subadult, larval, and juvenile survival, and (3) larval, juvenile, and subadult growth, development, and recruitment.

The Nature Conservancy conducted a project that synthesized available literature, data and models describing distribution and habitat suitability for Atlantic sturgeon in the Delaware River and used that information as a basis for recommended habitat conditions (Moberg and DeLucia 2016). They recommend the following water. quality characteristics in order to support successful Atlantic sturgeon recruitment:

- Instantaneous Dissolved Oxygen 5.0 mg/L
- Temperature < 28^0 Celsius
- Salinity < 0.5 ppt and
- Discharge > July Q85 (4,000 cfs @ Ben Franklin), when average daily Dissolved Oxygen < 5.5 mg/L

Even though the project specifies the Delaware River, it can be assumed that these characteristics for species survival would also be applicable in the Virginia rivers.

Because the action area includes all major tributaries and coastal waters of VA, we have determined that all four PBFs are located within the overall action area.

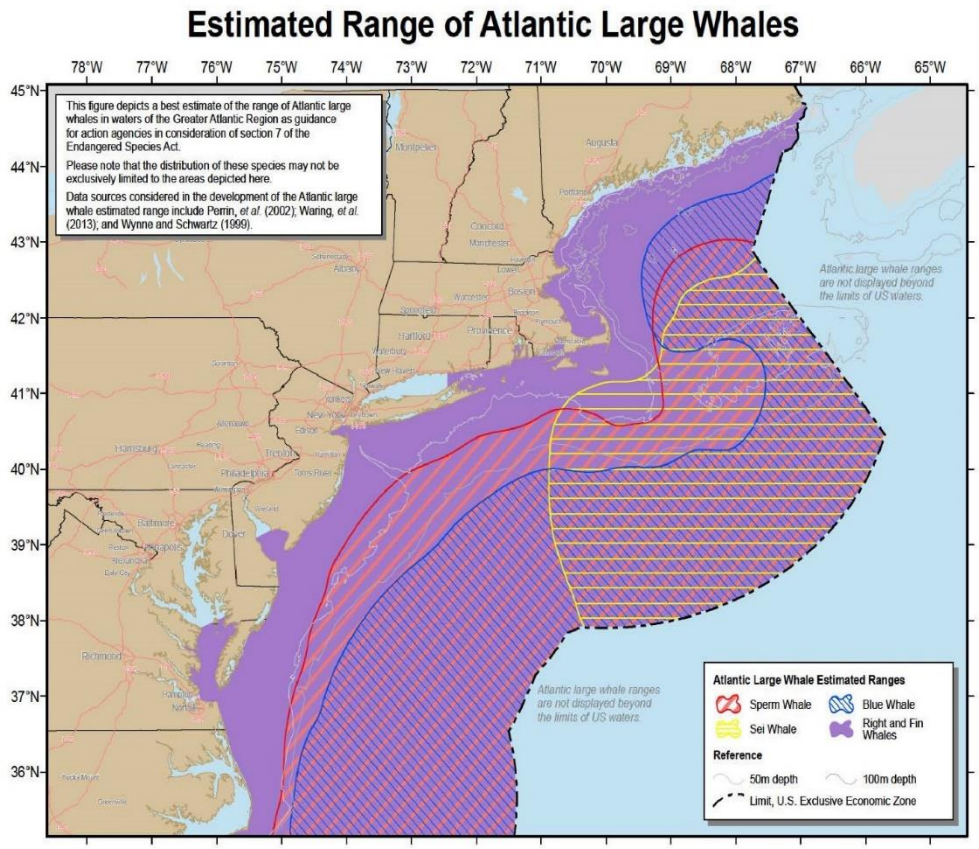
Whales

The Sei, Blue and Sperm whale are Species listed under the Endangered Species Act under the Jurisdiction of NMFS's Greater Atlantic Region (Main – Virginia) but are outside this Action Area. The Finback and North Atlantic are described below:

Finback Whale

Balaenoptera physalus

Year listed: 1970 **Status:** Endangered **General distribution:** Fin whales are common in waters of the U. S. Atlantic Exclusive Economic Zone (EEZ), principally from Cape Hatteras northward. Fin whales are migratory, moving seasonally into and out of high-latitude feeding areas, but the overall migration pattern is complex, and specific routes have not been documented. However, acoustic recordings from passive-listening hydrophone arrays indicate that a southward "flow pattern" occurs in the fall from the Labrador-Newfoundland region, past Bermuda, and into the West Indies (Clark 1995). Critical habitat in GAR: None



source: https://www.greateratlantic.fisheries.noaa.gov/protected/section7/guidance/maps/atlanticlargewhales2016.pdf Date acessed 2/28/2018

The Finback whale has a sleek streamlined body. And a distinctive coloration pattern: the back and sides of the body are black or dark brownish-gray, and the ventral surface is white. They are the second-largest species of whale, with a maximum length of about 75 feet in the Northern Hemisphere, and 85 feet in the Southern Hemisphere. Adults can weigh between 80,000-160,000 pounds (40-80 tons).

Fin whales are found in deep, offshore waters of all major oceans, primarily in temperate to polar latitudes, and less commonly in the tropics. Fin whales can be found in social groups of 2-7 whales and in the North Atlantic are often seen feeding in large groups that include humpback whales, minke whales, and Atlantic white-sided dolphins. Fin whales are large, fast swimmers and the killer whale (Orcinus orca) is their only non-human predator. During the summer, fin whales feed on krill, small schooling fish (e.g., herring, capelin, and sand lance), and squid by lunging into schools of prey with their mouth open, using their 50-100 accordion-like throat pleats to gulp large amounts of food and water. They then filter the food particles from the water

using the 260-480 "baleen" plates on each side of the mouth. Fin whales fast in the winter while they migrate to warmer waters. Fin whales can live 80-90 years.

Fin whales are found in deep, offshore waters of all major oceans, primarily in temperate to polar latitudes, and less commonly in the tropics. They occur year-round in a wide range of latitudes and longitudes, but the density of individuals in any one area changes seasonally. No critical habitat rules have been published for the Finback whale.

Historically Major Threats include commercial whaling collisions with vessels, entanglement in fishing gear, reduced prey abundance due to overfishing, habitat degradation disturbance from low-frequency noise.

We expect that fin whales will be limited to coastal VA waters along the Atlantic seaboard with occasional transit near the mouth of the Chesapeake Bay.

North Atlantic Right Whale Eubalaena *glacialis*

Year listed: 1970; Listed as two separate, endangered species in 2008 - the North Pacific right whale (Eubalaena japonica) and North Atlantic right whale (Eubalaena glacialis)
Status: Endangered **General distribution:** Population ranges primarily from calving grounds in coastal waters of the southeastern United States to feeding grounds in New England waters and the Canadian Bay of Fundy, Scotian Shelf, and Gulf of St. Lawrence. Critical habitat in GAR: Expanded to include the Gulf of Maine and Georges Bank. Non- in Virginia.

North Atlantic right Whale are large baleen whales. Distinguishing features include a stocky body, black coloration (although some have white patches on their bellies), no dorsal fin, a large head (about 1/4 of the body length), strongly bowed lower lip, and callosities (raised patches of roughened skin) on their head. Two rows of long--up to 8 feet (2.4 m) --dark baleen plates hang from their upper jaw, with about 225 plates on each side. Their tail is broad, deeply notched, and all black with a smooth trailing edge. The can weigh up to 79 tons (158,000 lbs.; 71,700 kg) and are about 50 feet (15 m) in Length. Calves are about 14 feet (4.2 m) at birth.

Right whales have occurred historically in all the world's oceans from temperate to subpolar latitudes. They primarily occur in coastal or shelf waters, although movements over deep waters are known. Right whales migrate to higher latitudes during spring and summer.

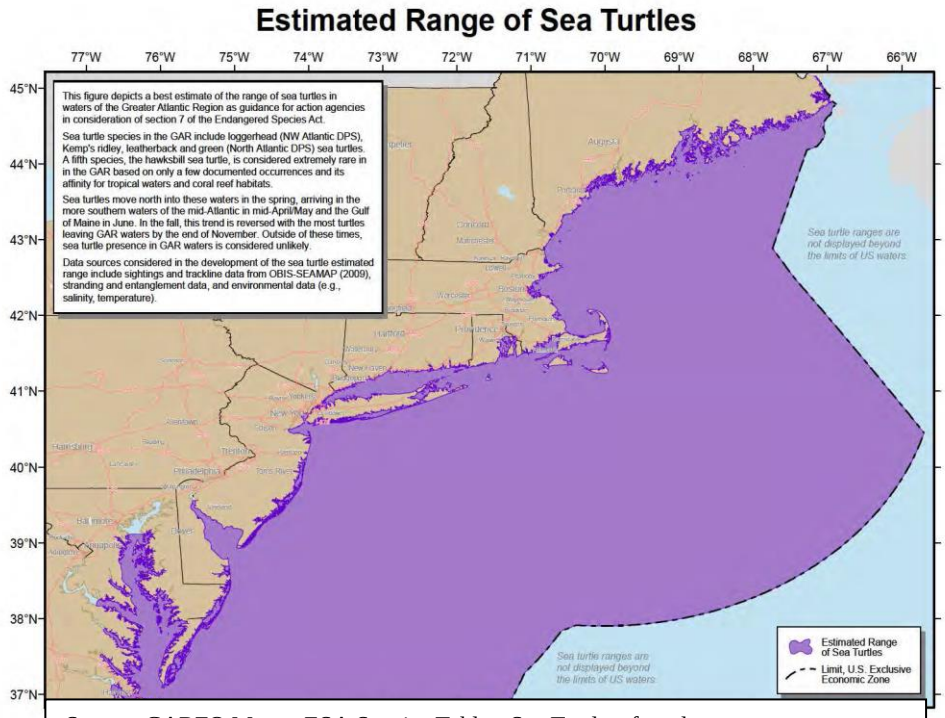
This long-lived, slowly reproducing whale species. Right whales generally feed from spring to fall, though, in certain areas, they may also feed in winter. Their primary food sources are zooplankton, including copepods, euphausiids, and cyprids. Unlike other baleen whales, right whales are skimmers; they feed by removing prey from the water using baleen while moving with their mouth open through a patch of zooplankton. Most known right whale nursery areas are in shallow, coastal waters. They Inhabit nearshore and offshore waters. Mainly coastal in the North Atlantic, occurs over the continental shelf in the North Pacific. A few of the remaining North Pacific animals concentrated in relatively warm, shallow (50 to 80 m deep), well-stratified water in an extensive coccolithophore bloom of Emiliania huxleyi. Mother-calf pairs generally concentrate their summer feeding activities in relatively secluded areas away from sites frequented by other whales. Right whales generally feed from spring to fall, though, in certain

areas, they may also feed in winter. Critical habitat in GAR: Great South Channel, east of Cape Cod and Cape Cod and Massachusetts Bays. None in Virginia.

Major Threats include: ship collisions, entanglement in fishing gear, habitat degradation, contaminants, climate and ecosystem change, disturbance from whale-watching activities, noise from industrial activities They also face natural threats from predators, such as large sharks and killer whales, which may affect the population.

NMFS expects that right whales will be limited to coastal VA waters along the Atlantic seaboard with occasional transit near the mouth of the Chesapeake Bay.

Sea Turtles



Source: GARFO Master ESA Species Table - Sea Turtles, found at https://www.greateratlantic.fisheries.noaa.gov/protected/section7/guidance/maps/garfo_master_esa_species_table_-_sea_turtles_111516.pdf. Accessed on 10/15/2018)

While sea turtles occur year-round off the southeastern United States, they are generally present in marine and estuarine waters of the GAR from April through November. As water temperatures warm in the spring, sea turtles begin to migrate to nearshore waters and up the U.S. Atlantic coast, occurring in Virginia as early as April/May and in the Gulf of Maine in June. The trend is reversed in the fall with some animals remaining in the GAR until late fall. Outside of these times, sea turtle presence in GAR waters is considered unlikely, although juvenile sea turtles routinely strand on GAR beaches during colder months (i.e., from October to January) as a result of cold-stunning. Nesting is extremely limited in the GAR. Typically, juveniles and, to a lesser extent, adults are present in the GAR. Source https://www.greateratlantic.fisheries.noaa.gov/protected/section7/guidance/maps/seaturtles2016.pdf.pdf. Accessed on 10/15/2018.

Four species (loggerhead, green, Kemp's ridley, and leatherback) found throughout continental shelf and slope waters of the Northwest Atlantic Ocean; tropical to boreal waters, preferred temperatures greater than 10°C; northward and inshore movement into waters of the Greater Atlantic Region begins in the spring, with turtles arriving into Mid-Atlantic waters in mid-

April/May and into Gulf of Maine waters in June; in the fall, this trend is reversed with most turtles leaving the region's waters by the end of November; outside of these times, sea turtle presence in the region's waters is considered unlikely aside from cold-stunned individuals that fail to migrate south (see below); a fifth species (hawksbill) is considered extremely rare in the region based on only a few documented occurrences and its affinity for tropical waters and coral reef type habitats. Below is information on the presence of sea turtles in the action area.

State	Coastal / Inshore Areas of Regular Occurrence	Likely Presence	Life Stages Present	Behaviors Anticipated to Occur
DE /MD /VA	Coastal waters off Virginia Beach, coastal waters and back bays of the DelMarVa Peninsula, Chesapeake Bay, Tangier Sound, and lower portions of southern Chesapeake Bay tributaries (e.g., James, York, Rappahannock, and Potomac Rivers)	May to November (note: cold stunning of hard-shelled sea turtles occurs annually from October to January)	Loggerhead (Northwest Atlantic DPS) -Pelagic and benthic adults, and juveniles, adults Green (North Atlantic DPS) -Juveniles and adults Kemp's ridley -Juveniles only Leatherback - Juveniles and adults	**Foraging** Loggerhead (Northwest Atlantic DPS) - Pelagic and benthic juveniles - omnivorous on bottom and surface - Sub-adults and adults - benthic invertebrates along the coast Green (North Atlantic DPS) - Juveniles - Omnivorous along coasts and in protected bays and lagoons -Adults -Herbivorous in nearshore areas Kemp's ridley - Juveniles - Benthic invertebrates in protected coastal areas Leatherback - Juveniles and adults - Primarily prey on jellyfish in offshore oceanic or coastal neritic areas **Nesting** North of North Carolina, sea turtle nesting is rare (there is occasional loggerhead nesting in Virginia, but no established nesting beaches further north)

1 Effects Assessment Methodologies

1.1 Acute Effect Assessment Methodology: Direct Effects to Freshwater Life Stages of Anadromous Species

The protectiveness of the freshwater acute ammonia and freshwater acute cadmium criteria magnitudes was assessed by identifying or estimating acute toxicity values (i.e., LC_{50}) for Virginia aquatic listed species that were then adjusted to represent protective low effect threshold concentrations as described below. Acute toxicity values used to develop the acute effects assessments were obtained from Appendix A of their respective 304(a) aquatic life criteria documents (Ammonia, USEPA 2013; Cadmium, USEPA 2016) and were specifically used to derive the acute criterion (i.e., bold values in Appendix A of USEPA 2013 and underlined values in USEPA 2016). These data were identified from EPA's ECOTOX database, the open and grey literature, and have been subjected to extensive data quality review (see Stephan et al. 1985 for data quality objectives). Acute ammonia values have been normalized to a pH of 7 (all freshwater animals), consistent with criteria derivation (USEPA 2013). Acute cadmium toxicity data have been normalized to a total hardness of 100 mg/L as $CaCO_3$ consistent with criteria derivation (USEPA 2016). Ideally, species-specific toxicity data would be available for listed species of concern to support an acute effects assessment; however, data limitations often required use of surrogate toxicity data.

EPA considered acute toxicity data at the closest taxonomic level possible to calculate geometric mean acute toxicity values for each species assessed (i.e., LC_{50}). Considering surrogate toxicity data at the most phylogenetically-related taxonomic level possible accounts for genetically-derived traits conserved across taxa that may directly influence sensitivity to a pollutant. Geometric mean acute toxicity values at the genus were calculated as the geometric mean of species-level geometric mean values, since these mean values are meant to represent the sensitivity for a particular taxon. Species-specific and surrogate acute toxicity data obtained from Appendix A of USEPA (2013) and USEPA (2016) represent sensitivity expressed as a concentration that will acutely affect half of the species population. Acute toxicity data (expressed as LC_{50}) were transformed to an acute minimum effect threshold concentration (i.e., LC_5) which represents a concentration that is expected to affect 5% of the test population of a listed species under continuous exposure conditions, typically 48 to 96 hours depending on the species tested. Representing acute minimum effect thresholds as an LC_5 value is conservative because high-quality toxicity tests are considered acceptable even when up to 10% mortality is observed in the control treatment (organisms not exposed to the pollutant). Moreover, the use of a five percent toxicity value to represent an acute minimum effect threshold to an individual is consistent with reasonable and prudent measures (RPMs) outlined in a recent biological opinion (NOAA 2012).

Raw empirical acute toxicity data may be used to calculate LC_5 values directly from the concentration-response (C-R) curves of the listed species-specific toxicity tests, when available. However, not all acute tests provide concentration-response data. Therefore, species-specific, or surrogate LC_{50} values (which represent listed species 50% effect level), were transformed to an acute minimum effect threshold concentration through an acute taxonomic adjustment factor

(TAF) or an acute mean adjustment factor (MAF). An acute TAF was calculated by averaging (geometric mean) the ratios of LC_{50}:LC_5 from chemical-specific acute toxicity tests conducted using species in the closest possible phylogenetic proximity (same species, genus, family, or order) as the listed species that is being assessed (genus-, family-, and order-level acute TAFs were calculated as the geometric mean of lower taxonomic-level geometric mean acute TAFs to ensure adequate representation of all lower-level taxa for a particular taxon). When data availability did not allow for the development of an acute TAF within the same order as the species being assessed, EPA considered applying an acute invertebrate or vertebrate TAF (depending on whether the listed species assessed was an invertebrate or vertebrate). The acute invertebrate TAF and the acute vertebrate TAF were calculated as the geometric mean of genus-level LC_{50}:LC_5 ratios of invertebrates and vertebrates, respectively. An acute MAF was used to adjust species effect concentrations (i.e., LC_{50}) to low effect threshold concentrations (i.e., LC_5) when; 1) an acute TAF was not available within the same order as the listed species being assessed and 2) when the acute invertebrate TAF and the acute vertebrate TAF were not significantly different via a two-sample t-test assuming unequal variances ($\alpha = 0.05$). The acute MAF was calculated as the geometric mean of all genus-level LC_{50}:LC_5 ratios available. Acute invertebrate and vertebrate TAFs and the acute MAF were calculated as the geometric mean of their respective genus-level LC_{50}:LC_5 ratios to limit the influence of LC_{50}:LC_5 ratios from species that are overly represented in a dataset, similar to criteria derivation (Stephan et al. 1985).

Listed species-specific or surrogate LC_{50} values were then divided by an appropriate adjustment factor (i.e., acute TAF or acute MAF depending on data availability) to derive an acute minimum effect threshold concentration. Dividing LC_{50} values by an adjustment factor to identify a minimum-level effect concentration is an approach that is fundamentally similar to acute criteria derivation[1], but is more specific to the chemical and species assessed. Acute minimum effect threshold concentrations were then compared to corresponding criteria magnitudes (i.e., criterion maximum concentration [CMC]) to assess potential direct adverse effects of ammonia or cadmium exposures at the acute criterion concentration over conservative exposure durations.

The freshwater ammonia CMC is both pH- and temperature-dependent due to ammonia speciation differences. Vertebrate sensitivity to ammonia in freshwaters, however, is only dependent on pH, with tolerance decreasing as pH increases (see USEPA 2013). At any given temperature (e.g., 20°C), the freshwater ammonia CMC decreases with increasing pH. Figure 1-1

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[1]The Final Acute Value (FAV; fifth centile of genus mean acute values) is divided by 2.0 to derive the Criterion Maximum Concentration (CMC). The FAV was divided by 2.0 to ensure the CMC is representative of a concentration that will not severely adversely affect too many organisms. To support the development of the 1985 Guidelines, a Federal Register notice published in 1978 (Vol 43, pp. 21506-21518; USEPA 1978) outlined the derivation of a generic LC_{50} to LC_{low} (i.e., 0-10% effect) adjustment factor of 0.44 (or divide by 2.27). The adjustment factor of 2.27 was derived as the "*geometric mean of the quotients of the highest concentration that killed 0-10% of the organisms divided by the LC_{50} in 219 acute toxicity tests*." The geometric mean adjustment factor (2.27) outlined in the 1978 Federal Register notice was subsequently rounded to 2.0 in the 1985 Guidelines (Stephan et al. 1985).

depicts the change in acute criterion magnitude with pH at a temperature of 20°C, and how the acute minimum effect threshold for Atlantic sturgeon (see Section 2.1.1) changes with the criterion magnitude proportionally (factor difference of 6.557 at 20°C). The acute effects assessment was developed using toxicity data normalized to reference conditions (pH = 7, temperature = 20°C) and compared to the corresponding CMC in those same reference conditions. Because species sensitivity and the CMC both change similarly across water chemistries, conclusions based on reference conditions translate to other surface waters.

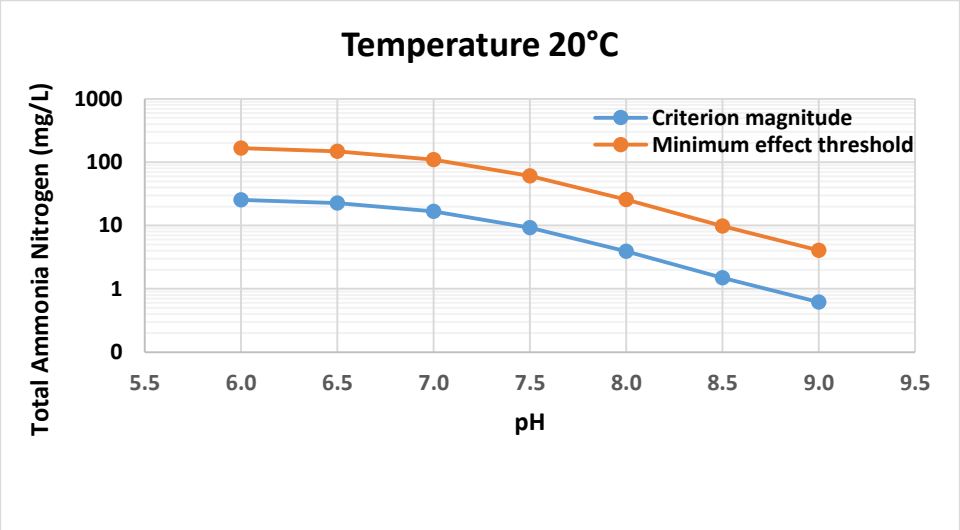

Figure 1-1. Acute ammonia criterion magnitudes extrapolated across a pH gradient at pH at a water temperature of 20°C. The acute minimum threshold concentration calculated for Atlantic sturgeon (see Section 2.1.1) is overlaid on the acute criterion magnitude. The freshwater acute ammonia criterion magnitude and the Atlantic sturgeon acute minimum effect threshold both decrease with increasing pH. The factor difference between the acute criterion magnitude and acute minimum effect threshold for Atlantic sturgeon is 6.557.

In contrast to ammonia, species sensitivity to cadmium in freshwaters is only dependent on water hardness, with tolerance increasing as hardness increases (see USEPA 2016). The freshwater cadmium CMC increases with increasing hardness across the range of hardness in typical ambient surface water (acute toxicity hardness slope 0.9789). Figure 1-2 depicts the change in the cadmium CMC across water hardness of 25 to 400 mg/L as $CaCO_3$, and how the acute minimum effect threshold for Atlantic sturgeon (from Section 3.1.1) changes with the criterion magnitude proportionally (factor difference of 7.694). The acute freshwater cadmium effects assessment was developed using toxicity data normalized to a reference condition (hardness = 100 mg/L) and compared to the corresponding CMC in those same reference conditions. Because species sensitivity to acute cadmium exposures in freshwater and the freshwater cadmium CMC both change similarly across water chemistries, conclusions based on reference conditions translate to other water chemistries.

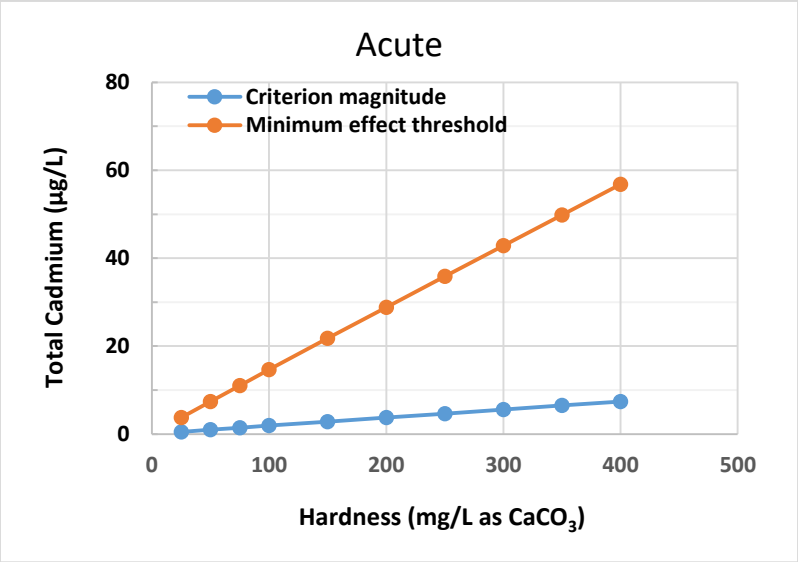

Figure 1-2. Acute cadmium criterion magnitudes extrapolated across a gradient of water hardness, overlaid with the Atlantic sturgeon acute minimum effect threshold concentration (see Section 3.1.1). The freshwater acute cadmium criterion magnitude and the Atlantic sturgeon acute minimum effect threshold both increase with increasing water hardness. The factor difference between the acute criterion magnitude and acute minimum effect threshold for Atlantic sturgeon is 7.694.

Assessing an acute criterion magnitude alone does not consider the duration and frequency components of the criterion and represents an overly conservative exposure scenario that assumes a pollutant concentration in all Virginia freshwaters will be at the acute criterion magnitude indefinitely. If a listed species acute minimum effect threshold concentration is greater than the corresponding acute criterion magnitude, then a refined assessment and consideration of the criterion duration and realistic exposure is not necessary, and approval of the acute criterion is Not Likely to Adversely Affect (NLAA) (i.e., effects are too small to be detected (insignificant) or extremely unlikely to occur (discountable)) that particular listed species through direct acute effects in freshwaters.

1.2 Chronic Effect Assessment Methodology: Direct Effects to Freshwater Life Stages of Anadromous Species

The protectiveness of the chronic freshwater ammonia and chronic freshwater cadmium criteria magnitudes was assessed by identifying or estimating chronic toxicity values (i.e., EC_{20}) for Virginia aquatic listed species that were then adjusted to represent protective low effect threshold concentrations as described below. Ammonia chronic toxicity values used to develop the chronic effects assessments were obtained from Appendix B of the ammonia 304(a) aquatic life criteria document (USEPA 2013) and cadmium chronic toxicity data were obtained from Appendix C of the cadmium criteria document (USEPA 2016). These data were specifically used to derive the ammonia and cadmium criteria (i.e., bold values in Appendix B or underlined values in Appendix C, respectively) and were identified from EPA's ECOTOX database, the open and grey literature, and have been subjected to extensive data quality review (see Stephan et al. 1985 for data quality objectives). Chronic ammonia toxicity data (i.e., EC_{20}) used to support the effects

assessment have been normalized to a pH of 7 (all freshwater species) and 20°C (freshwater invertebrates only), consistent with criteria derivation (USEPA 2013) and chronic cadmium toxicity data have been normalized to a total hardness of 100 mg/L as $CaCO_3$, consistent with criteria derivation (USEPA 2016).

Ideally, species-specific toxicity data would be available to support a chronic effects assessment; however, data limitations often required use of surrogate toxicity data. EPA considered chronic toxicity data at the closest taxonomic level to calculate geometric mean chronic toxicity values for each species assessed (i.e., EC_{20}). Considering surrogate toxicity data at the most phylogenetically-related taxonomic level possible accounts for genetically-derived traits conserved across taxa that may directly influence sensitivity to a pollutant. Geometric mean chronic toxicity values at the genus-, family-, and order-level were calculated as the geometric mean of lower taxonomic-level geometric mean values, since these mean values are meant to represent the sensitivity for a particular taxon. In certain cases, empirical chronic toxicity data were not available for surrogate species occurring within the same order as the listed species assessed. In these cases, appropriate acute data were transformed by an acute to chronic ratio (ACR) to estimate a chronic toxicity value (i.e., EC_{20}).

Unlike acute criteria derivation, which typically uses a generic LC_{50} to LC_{low} adjustment factor (i.e., 2.0[1]; Stephan et al. 1985), chronic criteria are based directly on chronic effect concentrations (e.g., EC_{20}) and do not incorporate a generic EC_x to EC_{low} adjustment factor. However, a concentration that results in chronic effects to 20% of a listed species population may not be considered acceptable for listed species. Therefore, a similar convention used for the acute assessment methodology was applied to the chronic effects assessment methodology to determine a chronic minimum effect threshold concentration (i.e., EC_5) from chronic toxicity values.

Raw empirical chronic toxicity data may be used to calculate EC_5 values directly from the concentration-response (C-R) curves of the listed species-specific toxicity tests, when available. However, not all chronic tests provide concentration-response data. Therefore, species-specific, or surrogate EC_{20} values (which represent listed species 20% effect level), were transformed to a chronic minimum effect threshold concentration through the use of a chronic taxonomic adjustment factor (TAF) or a chronic mean adjustment factor (MAF), in the same manner as the acute adjustment factors described previously. Specifically, a chronic TAF was calculated by averaging (geometric mean) the ratios of EC_{20}:EC_5 from chemical specific chronic toxicity tests conducted using species in the closest possible phylogenetic proximity (same species, genus, family, or order) as the listed species that is being assessed (genus-, family-, and order-level chronic TAFs were calculated as the geometric mean of lower taxonomic-level geometric mean chronic TAFs to ensure adequate representation of all lower-level taxa for a particular taxon). When data availability did not allow for the development of a chronic TAF within the same order as the species being assessed, EPA considered applying a chronic invertebrate or vertebrate TAF (depending on whether the species assessed was an invertebrate or vertebrate). The chronic invertebrate TAF and the chronic vertebrate TAF were calculated as the geometric mean of genus-level EC_{20}:EC_5 ratios of invertebrates and vertebrates, respectively. A chronic MAF was

used to adjust species effect concentrations (i.e., EC_{20}) to low effect threshold concentrations (i.e., EC_5) when; 1) a chronic TAF was not available within the same order as the listed species being assessed and 2) when the chronic invertebrate TAF and the chronic vertebrate TAF were not significantly different via a two-sample t-test assuming unequal variances ($\alpha = 0.05$). The chronic MAF was calculated as the geometric mean of all genus-level EC_{20}:EC_5 ratios available. Chronic invertebrate and vertebrate TAFs and the chronic MAF were calculated as the geometric mean of their respective genus-level EC_{20}:EC_5 ratios to limit the influence of EC_{20}:EC_5 ratios from species that are overly represented in a dataset, similar to criteria derivation (Stephan et al. 1985).

Listed species-specific or surrogate EC_{20} values were then divided by an appropriate adjustment factor (i.e., chronic TAF or chronic MAF depending on data availability) to derive a chronic minimum effect threshold concentration. Chronic minimum effect threshold concentrations were then compared to the corresponding criterion magnitude (i.e., criterion continuous concentration [CCC]) to assess potential adverse effects of ammonia or cadmium exposures at the chronic criterion concentration.

The freshwater ammonia CCC is pH- and temperature-dependent. Vertebrate sensitivity to ammonia in freshwaters, however, is only dependent on pH, with tolerance decreasing as pH increases (see USEPA 2013). At any given temperature (e.g., 20°C), the freshwater ammonia CCC decreases with increasing pH. Figure 1-3 depicts the change in the ammonia CCC across waters with different pH and how the chronic minimum effect threshold for Atlantic sturgeon (see Section 2.1.2) changes proportionally with the criterion magnitude (factor difference of 6.555). Because species sensitivity and the CCC both change similarly, conclusions based on reference conditions translate to other surface waters.

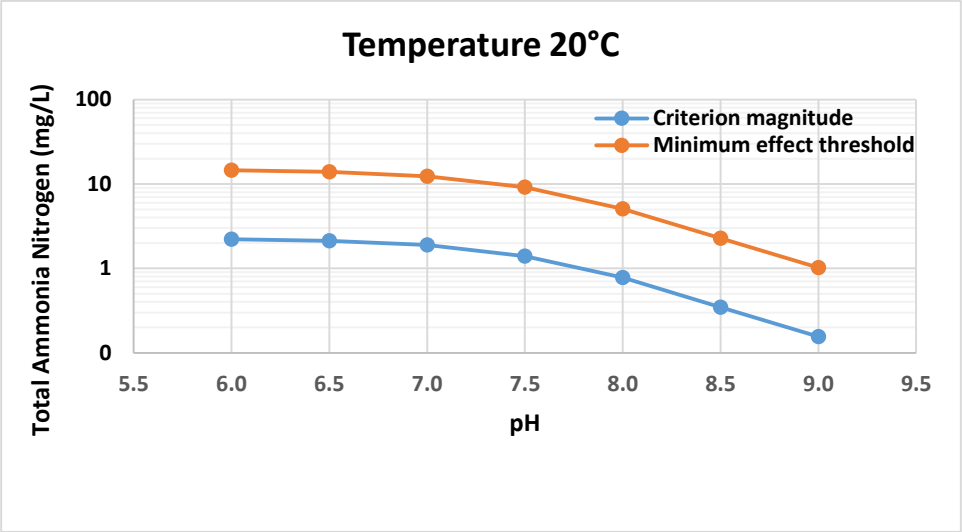

Figure 1-3. Chronic ammonia criterion magnitude extrapolated across a pH gradient (at a water temperature of 20°C) with the Atlantic sturgeon (see Section 2.1.2) chronic ammonia minimum effect threshold concentration overlaid. The factor difference between the chronic criterion magnitude and chronic minimum effect threshold for Atlantic sturgeon is 6.555.

In contrast to ammonia, species sensitivity to cadmium in freshwater is dependent on water hardness, with tolerance increasing as hardness increases (see USEPA 2016). The cadmium CCC increases with increasing hardness across the range of hardness typical of natural ambient surface water, but with a slightly shallower slope than for the CMC (chronic toxicity hardness slope 0.7977). Figure 1-4 depicts the change in the cadmium CCC across water hardness and how the Atlantic sturgeon chronic minimum effect threshold (see Section 3.1.2) changes with the chronic freshwater cadmium criterion magnitude proportionally (factor difference of 3.432). The chronic effects assessment was developed using toxicity data normalized to a reference condition (hardness = 100 mg/L) and compared to the corresponding CCC in those same reference conditions. Because species sensitivity and the CCC both change similarly across water chemistries, conclusions based on reference conditions translate to other water chemistries.

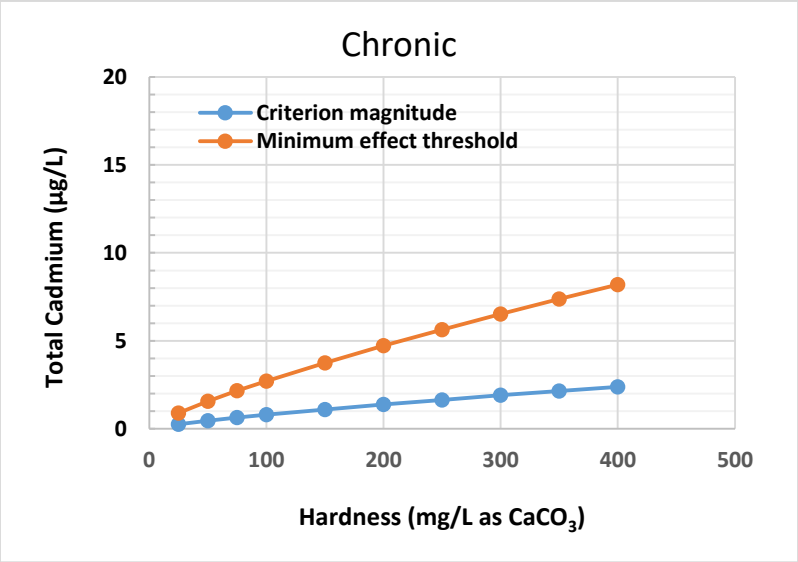

Figure 1-4. Chronic cadmium criterion magnitudes extrapolated across a gradient of water hardness overlaid with the Atlantic sturgeon chronic minimum effect threshold concentration (see Section 3.1.2). The criterion magnitude increases and the Atlantic sturgeon chronic minimum effect threshold both increase with increasing water hardness. The factor difference between the chronic criterion magnitude and chronic minimum effect threshold for Atlantic sturgeon is 3.432.

Assessing a chronic criterion magnitude alone does not consider the duration and frequency components of the criterion and represents an overly conservative exposure scenario that assumes a pollutant concentration in all Virginia freshwaters will be at the chronic criterion magnitude indefinitely. If a listed species chronic minimum effect threshold concentration is greater than the corresponding chronic criterion magnitude, then a refined assessment and consideration of the criterion duration and realistic exposure is not necessary, and approval of the chronic criterion is Not Likely to Adversely Affect (NLAA) (i.e., effects are too small to be detected (insignificant) or extremely unlikely to occur (discountable)) that particular listed species through direct chronic effects in freshwaters.

1.3 Acute and Chronic Effect Assessment Methodology: Direct Effects to Estuarine/Marine Species and Saltwater Life Stages of Anadromous Species

In additional to the freshwater cadmium criterion, Virginia has also proposed to adopt the acute and chronic cadmium criterion for estuarine/marine waters (USEPA 2016). Given relative data limitations associated with saltwater toxicity data, the acute and chronic estuarine/marine cadmium criteria were assessed together in a qualitative approach by considering limited exposure potential and previous biological opinions.

Virginia has not proposed to adopt or update estuarine/marine ammonia criteria. Freshwater and terrestrial species with range or critical habitat in Virginia waters are subject to consultation with U.S. Fish and Wildlife Service.

1.4 Indirect Effects: Assessment of Acute and Chronic Criteria

Following assessment of direct acute and chronic effects, EPA considered and assessed potential indirect effects of the water quality standard approval actions on anadromous and estuarine/marine species. To assess potential indirect effects, EPA considered conservatisms associated with criteria derivation and implementation as well as potential effects to listed animal prey items.

1.5 Listed Species: Final Effects Determinations

Final effect determinations were based on direct and/or indirect effects of EPA's approval of the acute and chronic ammonia (freshwater) and cadmium (freshwater and estuarine/marine) water quality standards in Virginia. EPA considered direct acute and chronic effects as well as indirect effects to make a final effects determination.

1.6 Critical Habitat: Effects Assessment and Final Critical Habitat Effects Determinations

Following listed species final effects determinations, EPA assessed designated critical habitats pertaining to anadromous and estuarine/marine species with critical habitats overlapping the action area. EPA considered Physical and Biological Features (PBFs, formally Primary Constituent Elements [PCEs]) essential to critical habitat and potential effects to listed species prey items (evaluated through the indirect effects assessment) to determine if the proposed action is *Likely to Adversely Modify* critical habitat or if the proposed action is *Not Likely to Adversely Modify* critical habitat.

2 Ammonia Effects Assessment

2.1 Sturgeon: Shortnose (*Acipenser brevirostrum*) and Atlantic (*Acipenser oxyrinchus oxyrinchus*)

2.1.1 Sturgeon Acute Ammonia Effects Assessment: Freshwater

2.1.1.1 Identifying Sturgeon Acute Ammonia Data

High-quality species-level acute data (i.e., bold values in Appendix A of the 2013 freshwater ammonia 304(a) aquatic life criteria document) were not available for the Atlantic sturgeon. Therefore, the species-level acute toxicity data for shortnose sturgeon were applied as a genus-level surrogate toxicity value for the Atlantic sturgeon. The shortnose sturgeon Species Mean Acute Value (SMAV) is composed of a single, definitive LC_{50} value (156.7 mg/L, normalized to pH 7) from a test with a sensitive life stage (Fontenot et al. 1998) and represents the *Acipenser* Genus Mean Acute Value (GMAV) applicable to the Atlantic sturgeon species (Table 2-1).

Table 2-1. Data used to calculate the SMAV and GMAV representative of shortnose and Atlantic sturgeon acute sensitivity to ammonia.

Order	Family	Species	SMAV (mg/L)[a]	GMAV (mg/L)[a]
Acipenseriformes	Acipenseridae	Shortnose sturgeon, *Acipenser brevirostrum*	156.7	156.7
Acipenseriformes	Acipenseridae	Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*	N/A	

[a] Normalized to pH 7 (USEPA 2013).
N/A: not available

2.1.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

The published acute toxicity study (Fontenot et al. 1998) used to calculate the shortnose sturgeon SMAV and the *Acipenser* GMAV (which is representative of Atlantic sturgeon) did not contain or report raw toxicity data. Because no raw acute toxicity data are available for fish species in the same order, no acute order-level TAF could not? be calculated. As a result, EPA obtained and analyzed raw concentration-response (C-R) data for all tests used to derive the acute criterion (bold values in Appendix A of USEPA [2013]) where such data were reported or could be obtained to inform the derivation of a vertebrate-level TAF and a MAF, if necessary (i.e., if the vertebrate and invertebrate-level acute TAFs differ from one another).

Raw acute toxicity data were fit to C-R models using EPA's Toxicity Relationship Analysis Program (TRAP, version 1.3a) to calculate LC_{50} and corresponding LC_5 values for 83 tests representing 34 species (18 invertebrates and 16 vertebrates). C-R models were excluded from TAF and MAF calculation if 1) models did not exhibit a unique solution and were flagged by TRAP as having inadequate partial effects; 2) models did not include observations in the region of interest which did not allow TRAP to accurately model a no-response plateau and; 3) models exhibited incongruities such as no or poor fit to key points or excessive noise in the C-R relationship. After exclusion of unacceptable or uncertain LC_{50}:LC_5 ratios, 44 ratios remained resulting in nine genus-level LC_{50}:LC_5 ratios for invertebrate species (arithmetic mean = 2.157 mg/L, variance = 0.4447 mg/L) and 11 genus-level LC_{50}:LC_5 ratios for vertebrate species (arithmetic mean = 1.440 mg/L, variance = 0.0491 mg/L). Analysis of the two arithmetic means via a two-sample t-test assuming unequal variances ($\alpha = 0.05$) indicated that the means are different *(t stat [3.088] > t critical for two tail [2.262]*). Therefore, an acute vertebrate TAF is more appropriate than an acute MAF to transform the *Acipenser* GMAV applicable to the shortnose and Atlantic sturgeon (156.7 mg/L) to an acute minimum effect threshold concentration.

Table 2-2 provides the 11 genus-level LC_{50}:LC_5 ratios used to derive the acute vertebrate TAF. Individual test ratios ranged from 1.034 to 1.925. The acute vertebrate TAF calculated as the geometric mean of all genus-level LC_{50}:LC_5 ratios is 1.426 (n = 11; see Appendix A.1 for raw toxicity test data, TRAP models and outputs for the 17 acute ammonia toxicity tests used to derive the acute vertebrate TAF; Appendix A.2 includes the raw toxicity data, TRAP models and outputs for all unacceptable and uncertain ammonia C-R models).

Table 2-2. Acute LC_{50}:LC_5 ratios from analysis of 17 high-quality acute ammonia toxicity tests with freshwater aquatic vertebrates used to derive an acute vertebrate adjustment factor (acute vertebrate TAF) for the shortnose and Atlantic sturgeon.

(Note: the acute vertebrate TAF is the geometric mean of all available genus-level LC_{50}:LC_5 ratios for vertebrates)**.**

Order	Family	Species	LC_{50} (mg/L)	LC_{05} (mg/L)	LC_{50}: LC_{05}	C-R Curve Label	Reference	Species-level TAF (LC_{50}:LC_{05})	Genus-level TAF (LC_{50}:LC_{05})
Salmoniformes	Salmonidae	Rainbow trout (40.0 g; resting fish), *Oncorhynchus mykiss*	202.2	105.1	1.925	Am-Acute-56	Wicks et al. 2002	1.925	1.925
Cypriniformes	Cyprinidae	Rainbow dace, *Cyprinella lutrensis*	21.14	15.04	1.406	Am-Acute-58	Hazel et al. 1979	1.387	1.387
Cypriniformes	Cyprinidae	Rainbow dace, *Cyprinella lutrensis*	7.040	5.144	1.369	Am-Acute-59	Hazel et al. 1979		
Cypriniformes	Cyprinidae	Common carp (299 mg), *Cyprinus carpio*	51.65	40.37	1.279	Am-Acute-62	Hasan and MacIntosh 1986	1.279	1.279
Cypriniformes	Cyprinidae	Rio Grande silvery minnow (3-5 d old), *Hybognathus amarus*	17.52	12.52	1.399	Am-Acute-63	Buhl 2002	1.399	1.399
Cypriniformes	Cyprinidae	Fathead minnow (0.2 g), *Pimephales promelas*	43.46	42.03	1.034	Am-Acute-69	Swigert and Spacie 1983	1.188	1.188
Cypriniformes	Cyprinidae	Fathead minnow (0.5 g), *Pimephales promelas*	42.76	31.33	1.365	Am-Acute-70	Swigert and Spacie 1983		
Cypriniformes	Catostomidae	White sucker (92 mm, 6.3 g), *Catostomus commersonii*	29.27	20.35	1.439	Am-Acute-71	Reinbold and Pescitelli 1982c	1.439	1.439
Siluriformes	Ictaluridae	Channel catfish, *Ictalurus punctatus*	32.17	21.66	1.485	Am-Acute-74	Reinbold and Pescitelli 1982d	1.485	1.485
Perciformes	Centrarchidae	Pumpkinseed (4.13-9.22 g), *Lepomis gibbosus*	10.60	6.504	1.629	Am-Acute-77	Jude 1973	1.629	1.425
Perciformes	Centrarchidae	Bluegill, *Lepomis macrochirus*	6.752	5.940	1.137	Am-Acute-80	Hazel et al. 1979	1.247	
Perciformes	Centrarchidae	Bluegill (0.9 g), *Lepomis macrochirus*	57.29	46.32	1.237	Am-Acute-83	Swigert and Spacie 1983		
Perciformes	Centrarchidae	Bluegill (1.2 g), *Lepomis macrochirus*	37.54	27.22	1.379	Am-Acute-84	Swigert and Spacie 1983		
Perciformes	Percidae	Orangethroat darter, *Etheostoma spectabile*	35.15	19.97	1.760	Am-Acute-85	Hazel et al. 1979	1.620	1.620
Perciformes	Percidae	Orangethroat darter, *Etheostoma spectabile*	8.151	5.465	1.491	Am-Acute-86	Hazel et al. 1979		
Perciformes	Cichlidae	Mozambique tilapia (juvenile), *Oreochromis mossambicus*	118.2	106.2	1.113	Am-Acute-87	Rani et al. 1998	1.113	1.113
Anura	Hylidae	Pacific tree frog (embryo), *Pseudacris regilla*	62.51	39.45	1.584	Am-Acute-89	Schuytema and Nebeker 1999a	1.584	1.584

2.1.1.3 Calculating Sturgeon Acute Ammonia Minimum Effect Threshold

Dividing the shortnose sturgeon LC_{50} value (156.7 mg/L; genus-level surrogate value for Atlantic sturgeon) by the acute vertebrate TAF (1.426) results in an acute ammonia minimum effect threshold concentration of 109.9 mg/L (normalized to pH 7) for both sturgeon species.

2.1.1.4 Sturgeon: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 (17 mg/L), is approximately 6.5 times lower than the sturgeon acute ammonia minimum effect threshold of 109.9 mg/L. The sturgeon acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary. As such, the effects of approval of the freshwater acute ammonia water quality standard are extremely unlikely to occur based on the fact that the established thresholds are below levels shown to have an effect, and thus all direct acute effects to shortnose and Atlantic sturgeons are discountable.

2.1.2 Sturgeon Chronic Ammonia Effects Assessment: Freshwater

2.1.2.1 Identifying Sturgeon Chronic Ammonia Data

High-quality empirical chronic toxicity data within the Order Acipenseriformes are not available to serve as chronic toxicity data representative of the shortnose and Atlantic sturgeon. As a result, the shortnose sturgeon SMAV (which also represents the *Acipenser* GMAV applicable to Atlantic sturgeon) was transformed to represent a chronic toxicity value (i.e., EC_{20}) of 17.46 mg/L (Table 2-3). This representative chronic value for the two sturgeon species was calculated by dividing the acute toxicity value for shortnose sturgeon (156.7 mg/L; surrogate value for Atlantic sturgeon) by the reported vertebrate ammonia acute: chronic ratio (Vert-ACR; USEPA 2013). The Vert-ACR (8.973) is based on ACRs representing five families of freshwater fishes which range from 4.8 to 14.75 (Appendix F of USEPA 2013).

Table 2-3. Data used to calculate the chronic toxicity values (i.e., EC_{20}) representative of sturgeon chronic sensitivity to ammonia.

Order	Family	Species	SMAV (mg/L)[a]	GMAV (mg/L)[a]	VERT-ACR	GMCV (mg/L)[a]
Acipenseriformes	Acipenseridae	Shortnose sturgeon, *Acipenser brevirostrum*	156.7	156.7	8.973	17.46
Acipenseriformes	Acipenseridae	Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*	N/A			

[a] Normalized to pH 7 (USEPA 2013). N/A: not available

2.1.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

High-quality chronic toxicity data were not available for the shortnose and Atlantic sturgeon or species within the Order Acipenseriformes, and therefore, no raw toxicity data are available to support the derivation of a sturgeon-specific EC_{20}:EC_5 adjustment factor at or below the order-level. As a result, EPA obtained and analyzed raw C-R data for all tests used to derive the chronic criterion (USEPA 2013 Appendix B bold values) where such data were reported or could be obtained to derive a chronic vertebrate-level TAF and a MAF, if necessary (i.e., if the vertebrate and invertebrate-level chronic TAFs differ from one another).

Raw chronic toxicity data were fit to C-R models using EPA's TRAP software to calculate EC_{20} and corresponding EC_5 values for 31 tests representing 20 species (10 invertebrate and 10 fish species). C-R models were excluded from TAF and MAF calculation if 1) models did not exhibit a unique solution and were flagged by TRAP as having inadequate partial effects; 2) models did not include observations in the region of interest which did not allow TRAP to accurately model a no-response plateau and; 3) models exhibited incongruities such as no or poor fit to key points or excessive noise in the C-R relationship. After exclusion of unacceptable or uncertain EC_{20}:EC_5 ratios for use in calculating a chronic MAF, 20 ratios remained resulting in five genus-level EC_{20}:EC_5 ratios for invertebrate species (arithmetic mean = 1.341 mg/L, variance = 0.01208 mg/L) and seven genus-level EC_{20}:EC_5 ratios for vertebrate species (arithmetic mean = 1.472 mg/L, variance = 0.01326 mg/L). Analysis of the two means via a two-sample t-test assuming unequal variances ($\alpha = 0.05$) indicated that the means are the same *(t stat [-2.004] < t critical for two tail [2.262]*). As a result, the chronic MAF was used to transform the GMCV applicable to the shortnose and Atlantic sturgeon (17.46 mg/L) to a chronic minimum effect threshold concentration.

Table 2-4 provides the 12 genus-level EC_{20}:EC_5 ratios used to derive the chronic MAF. Individual test ratios ranged from 1.183 to 1.881 (Table 2-4). The chronic MAF calculated as the geometric mean of all genus-level EC_{20}:EC_5 ratios is 1.412 (see Appendix A.3 for raw toxicity test data, TRAP models and outputs for the 20 chronic ammonia toxicity tests used to derive the chronic MAF; Appendix A.4 includes the raw toxicity data, TRAP models and outputs for all unacceptable and uncertain ammonia toxicity tests).

Table 2-4. Chronic EC_{20}:EC_5 ratios from analysis of 20 high-quality chronic ammonia toxicity tests with freshwater aquatic organisms used to derive a chronic ammonia MAF representative of the shortnose and Atlantic sturgeon.
(Note: the chronic MAF is the geometric mean of all available genus-level EC_{20}:EC_5 ratios).

Order	Family	Species	EC_{20} (mg/L)	EC_{05} (mg/L)	EC_{20}: EC_{05}	C-R Curve Label	Reference	Species-level TAF (EC_{20}:EC_{05})	Genus-level TAF (EC_{20}:EC_{05})
Veneroida	Pisidiidae	Long fingernailclam, *Musculium transversum*	6.049	4.626	1.308	Am-Chronic-4	Anderson et al. 1978	1.308	1.308
Neotaenioglossa	Hydrobiidae	Pebblesnail (1.81 mm juvenile), *Fluminicola* sp.	2.269	1.559	1.455	Am-Chronic-6	Besser 2011	1.455	1.455
Diplostraca	Daphniidae	Water flea, *Ceriodaphnia acanthina*	49.59	41.21	1.203	Am-Chronic-7	Mount 1982	1.203	1.322
Diplostraca	Daphniidae	Water flea, *Ceriodaphnia dubia*	15.57	10.36	1.503	Am-Chronic-8	Nimmo et al. 1989	1.453	
Diplostraca	Daphniidae	Water flea, *Ceriodaphnia dubia*	5.720	4.072	1.405	Am-Chronic-9	Willingham 1987		
Diplostraca	Daphniidae	Water flea, *Daphnia magna*	8.265	5.026	1.645	Am-Chronic-10	Gersich et al. 1985	1.436	1.436
Diplostraca	Daphniidae	Water flea, *Daphnia magna*	20.86	16.64	1.254	Am-Chronic-11	Reinbold and Pescitelli 1982a		
Plecoptera	Pteronarcyidae	Stonefly, *Pteronarcella badia*	133.8	113.0	1.183	Am-Chronic-13	Thurston et al. 1984b	1.183	1.183
Salmoniformes	Salmonidae	Lahontan cutthroat trout (fertilized), *Oncorhynchus clarkii henshawi*	19.32	10.83	1.784	Am-Chronic-15	Koch et al. 1980	1.784	1.497
Salmoniformes	Salmonidae	Rainbow trout, *Oncorhynchus mykiss*	8.982	7.148	1.257	Am-Chronic-16	Brinkman et al. 2009	1.257	
Esociformes	Esocidae	Northern pike (fertilized), *Esox lucius*	14.81	10.91	1.357	Am-Chronic-17	Harrahy et al. 2004	1.357	1.357
Cypriniformes	Cyprinidae	Common carp (fertilized), *Cyprinus carpio*	8.246	5.612	1.469	Am-Chronic-18	Mallet and Sims 1994	1.469	1.469
Cypriniformes	Cyprinidae	Fathead minnow (embryo-larvae), *Pimephales promelas*	4.656	3.361	1.385	Am-Chronic-19	Mayes et al. 1986	1.565	1.565
Cypriniformes	Cyprinidae	Fathead minnow (embryo-larvae), *Pimephales promelas*	7.396	5.561	1.330	Am-Chronic-20	Adelman et al. 2009		
Cypriniformes	Cyprinidae	Fathead minnow, *Pimephales promelas*	5.795	3.081	1.881	Am-Chronic-21	Swigert and Spacie 1983		
Cypriniformes	Cyprinidae	Fathead minnow, *Pimephales promelas*	1.903	1.099	1.732	Am-Chronic-22	Thurston et al. 1986		
Cypriniformes	Catostomidae	White sucker (3 d old embryo), *Catostomus commersonii*	1.296	0.783	1.656	Am-Chronic-23	Reinbold and Pescitelli 1982a	1.656	1.656
Perciformes	Centrarchidae	Bluegill, *Lepomis macrochirus*	1.855	1.402	1.323	Am-Chronic-27	Smith et al. 1984	1.323	1.323

Order	Family	Species	EC_{20} (mg/L)	EC_{05} (mg/L)	EC_{20}: EC_{05}	C-R Curve Label	Reference	Species-level TAF (EC_{20}:EC_{05})	Genus-level TAF (EC_{20}:EC_{05})
Perciformes	Centrarchidae	Smallmouth bass, *Micropterus dolomieu*	8.395	5.585	1.503	Am-Chronic-30	Broderius et al. 1985	1.440	1.440
Perciformes	Centrarchidae	Smallmouth bass, *Micropterus dolomieu*	1.610	1.168	1.379	Am-Chronic-31	Broderius et al. 1985		

2.1.2.3 Calculating Sturgeon Chronic Ammonia Minimum Effect Threshold

Dividing the estimated sturgeon EC_{20} value (17.46 mg/L) by the chronic MAF (1.412) results in a chronic minimum effect threshold concentration of 12.37 mg/L (normalized to pH 7).

2.1.2.4 Sturgeon: Chronic Ammonia Effects Determination

The chronic ammonia CCC at pH 7 (1.9 mg/L), is 6.5 times lower than the Atlantic and shortnose sturgeons chronic minimum effect threshold concentration of 12.37 mg/L. The sturgeon chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary. As such, the effects of approval of the freshwater acute ammonia water quality standard are extremely unlikely to occur based on the fact that the established thresholds are below levels shown to have an effect, and thus all direct chronic effects to shortnose and Atlantic sturgeons are discountable.

2.1.3 Sturgeon Ammonia Indirect Effects Assessment: Freshwater

Aquatic life criteria are conservatively implemented in National Pollution Discharge Elimination System (NPDES) permit limits by assuming receiving streams are continually at low-flow conditions which significantly limits the probability of *in situ* pollutant concentrations reaching criteria magnitudes and durations. NPDES permit limits based on the acute ammonia criterion typically assume a receiving stream is continually at 1Q10 low-flow conditions, while the probability of these low-flow conditions occurring is exceedingly rare (i.e., 1-day average lowest flow over the course of a 10-year period). Similarly, NPDES permit limits based on the chronic ammonia criterion typically assume receiving streams are continually at 30Q10 or 30Q5 low-flow conditions (i.e., 30-day average lowest flow over the course of a 5 or 10-year period). As a result, excess dilution limits instream ammonia concentrations and drastically decreases the probability *in situ* ammonia concentrations will reach criteria magnitudes and durations. Independent of assuming low flow conditions, NPDES permits also layer on an additional level of conservatism by ensuring facilities discharge ammonia at Long Term Average concentrations (LTAs), which are based on Waste Load Allocations[2] (WLAs) set as the 99th centile of a log-normal distribution that describes effluent variability. Setting WLAs as the 99th centile of an effluent distribution ensures a 99% chance facilitates discharge ammonia at concentrations less than those that would cause receiving stream ammonia concentrations to reach criteria magnitudes under critical flow conditions (which are independent and also exceedingly rare events; USEPA 1991). Additionally, even if *in situ* exposures were to match the acute or chronic criteria magnitudes, the broad aquatic community, including sturgeon prey items, will be adequately protected because aquatic life criteria are based on the fifth centile of sensitive genera.

Shortnose and Atlantic sturgeon broadly rely on benthic invertebrates, including mussels, crustaceans, and insects as primary food sources. Freshwater unionid mussels are among the

[2] A Waste Load Allocation (WLA) is the maximum allowable pollutant concentration in an effluent from a discharger that, after accounting for available dilution under critical low flow conditions (e.g., 1Q10, 30Q5, 30Q10), will meet an applicable water quality criterion (USEPA 1991).

most sensitive genera to acute and chronic ammonia exposures, with aquatic insects and crustaceans being relatively insensitive (USEPA 2013). The acute and chronic ammonia criteria are both primarily driven by mussel sensitivity. If ammonia concentrations in Virginia freshwater ecosystems were to occur at acute or chronic criteria magnitudes and durations (which is highly unlikely based the conservative implementation of criteria in NPDES permit limits), a small portion of individuals in the most sensitive mussel populations may experience short-term effects. Further, if ammonia were to exist at criteria concentrations indefinitely in Virginia freshwaters (which is not the intent of the action considering the full definition of criteria include magnitude, duration, and frequency), shortnose sturgeon and Atlantic sturgeon would not be indirectly affected because only a small portion of mussels would experience effects and sturgeon do not rely exclusively on mussels as a food source, with additional sturgeon food sources (e.g., insects and benthic worms) remaining tolerant to acute and chronic ammonia exposures (USEPA 2013). As such, the effects of approval of the freshwater acute and chronic ammonia water quality standard are too small to be detected and thus any indirect chronic or acute effects to shortnose and Atlantic sturgeons are insignificant.

3 Cadmium Effects Assessment

3.1 Sturgeon: Shortnose (*Acipenser brevirostrum*) and Atlantic (*Acipenser oxyrinchus oxyrinchus*)

3.1.1 Sturgeon Acute Cadmium Effects Assessment: Freshwater

3.1.1.1 Identifying Sturgeon Acute Cadmium Data

High quality species-level acute data were not available for either sturgeon species. Therefore, genus-level acute toxicity data are used to represent the sensitivity of shortnose and Atlantic sturgeons to acute cadmium exposures. The GMAV is based on a single SMAV for the white sturgeon (Table 3-1). The SMAV is composed of a single, non-definitive LC_{50} value (<33.78 µg/L, normalized to a total hardness of 100 mg/L as $CaCO_3$) from a test with a sensitive life stage (Calfee et al. 2014). The non-definitive LC_{50} value introduces uncertainty in the GMAV estimate and it is reasonable to consider how much lower a definitive LC_{50} value would be compared to the non-definitive LC_{50} estimate. EPA was able to independently evaluate the C-R curve used to calculate the white sturgeon-based GMAV (which is representative of shortnose and Atlantic sturgeon) from Calfee et al. (2014). Acute toxicity data were provided in Table A-2 of the parent USGS report (Ingersoll and Mebane 2014), which provided sufficient supplemental information to create the C-R curve for the test (see Cd-Acute-93 in Appendix B.2). The TRAP model generated from the data is unacceptable for deriving an LC_{50} to LC_5 ratio due to no effect within the area of concern, especially at low-levels (i.e., 5%), but provides a definitive LC_{50} value of 23.14 total cadmium (normalized to a hardness of 100 mg/L). The LC_{50} value calculated from Ingersoll and Mebane (2014; see Cd-Acute-93 in Appendix B.2) contains some underlying uncertainty because the lowest test concentrations (beside the negative control group) resulted in 70% mortality.

Nevertheless, use of the definitive LC_{50} (23.14 total cadmium, normalized to a hardness of 100 mg/L) for white sturgeon as the *Acipenser* GMAV may be appropriate for several reasons. First,

Calfee et al. (2014) tested six different sturgeon life stages ranging from 2 to 89 days post hatch (dph) and reported normalized (hardness = 100 mg/L) LC_{50} values ranging from >11.65 to >355.0 µg total Cd/L. Of the six life stages tested, EPA concluded white sturgeon tested at 61 dph were the most sensitive to acute cadmium toxicity, and the non-definitive LC_{50} value (reported by Calfee et al. [2014] as <33.78 µg/L; hardness = 100 mg/L; total cadmium) for white sturgeon of this age was among the most sensitive of LC_{50} values available for sturgeon. Second, Calfee et al. (2014) comparatively assessed sturgeon and rainbow trout sensitivities to cadmium and concluded, "*Rainbow trout were more sensitive to cadmium exposure than white sturgeon for all life stages tested."* Calfee et al. (2014) further states, "*Rainbow trout in the present study were especially sensitive to cadmium relative to other species*," which is consistent with salmonid genera ranking among the most sensitive in the species sensitivity distribution (SSD) used to derive the acute cadmium criterion (USEPA 2016). The acute cadmium criterion is based on the fifth centile of sensitive genera and is largely influenced by salmonid sensitivity. Because Calfee et al. (2014) determined salmonids are more sensitive to cadmium than sturgeon, and the acute criterion is based on salmonid sensitivity, the acute criterion is expected to be protective of sturgeon and the use of a definitive acute toxicity estimate that contains some underlying uncertainty given the lack of low-level effects in the C-R curve (see Cd-Acute-93 in Appendix B.2) will not result in spurious conclusions.

Table 3-1. Data used to calculate the *Acipenser* GMAV representative of shortnose and Atlantic sturgeon acute sensitivity to cadmium.

Order	Family	Species	SMAV (µg/L)[a]	GMAV (µg/L)[a]
Acipenseriformes	Acipenseridae	White sturgeon, *Acipenser transmontanus*	23.24	23.14
Acipenseriformes	Acipenseridae	Shortnose sturgeon, *Acipenser brevirostrum*	N/A	
Acipenseriformes	Acipenseridae	Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*	N/A	

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016).
N/A: not available

3.1.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

As previously described, the TRAP model (see Cd-Acute-93 in Appendix B.2) produced by analysis of the data from the acute toxicity test with 61 dph white sturgeon (Calfee et al. 2014) is unacceptable for use as a *Acipenser*-specific (genus-level) taxonomic adjustment factor because of a lack of low-level effects resulting in no responses in the area of interest along the C-R curves (i.e., 5% - 50%). No other acute toxicity tests with C-R data are available for the Order Acipenseriformes. As a result, EPA obtained and analyzed raw C-R data for all tests used to derive the acute cadmium criterion (underlined values in Appendix A of USEPA 2016; Table 3-2) where such data were reported or could be obtained to derive an acute vertebrate TAF or acute MAF, if necessary (i.e., if the vertebrate and invertebrate-level acute TAFs differ from one another).

Raw acute toxicity data were fit to C-R models using EPA's TRAP software to calculate LC_{50} and corresponding LC_5 values for 69 tests representing 28 species (18 invertebrate and 10 vertebrates, including an amphibian). C-R models were excluded from TAF and MAF calculation if 1) models did not exhibit a unique solution and were flagged by TRAP as having inadequate partial effects; 2) models did not include observations in the region of interest which did not allow TRAP to accurately model a no-response plateau and; 3) models exhibited incongruities such as no or poor fit to key points or excessive noise in the C-R relationship. After exclusion of these unacceptable or uncertain LC_{50}:LC_5 ratios for use in calculating an acute MAF, 35 ratios remained resulting in seven genus-level LC_{50}:LC_5 ratios for invertebrate species (arithmetic mean = 2.857 µg/L, variance = 2.186 µg/L) and six genus-level LC_{50}:LC_5 ratios for vertebrate species (arithmetic mean = 2.106 µg/L, variance = 0.2589 µg/L). Analysis of the two arithmetic means via a two-sample t-test assuming unequal variances ($\alpha = 0.05$) indicated the means are the same *(t stat [1.259] < t critical for two tail [2.306]*). As a result, the acute MAF was used to transform the *Acipenser* GMAV representative of shortnose and Atlantic sturgeon (<33.78 µg/L) to an acute minimum effect threshold concentration.

Table 3-2 provides the 13 genus-level LC_{50}:LC_5 ratios used to derive the cadmium acute MAF. The acute MAF calculated as the geometric mean of all genus-level LC_{50}:LC_5 ratios is 2.310 (see Appendix B.3 for raw toxicity test data, TRAP models and outputs for the 35 acute cadmium toxicity tests used to derive the acute MAF; Appendix B.4 includes the raw toxicity data, TRAP models and output for all unacceptable and uncertain cadmium toxicity tests).

Table 3-2. Acute LC_{50}:LC_5 ratios from analysis of 35 high-quality acute cadmium toxicity tests with freshwater aquatic organisms used to derive an acute mean adjustment factor (MAF) for the shortnose and Atlantic sturgeons.

Order	Family	Species	LC_{50} (µg/L)	LC_{05} (µg/L)	LC_{50}: LC_{05}	C-R Curve Label	Reference	Species-level TAF (LC_{50}:LC_{05})	Genus-level TAF (LC_{50}:LC_{05})
Tubificida	Naididae	Tubificid worm, *Tubifex tubifex*	56,141	27,732	2.024	Cd-Acute-2	Rathore and Khangarot 2002	2.278	2.278
Tubificida	Naididae	Tubificid worm, *Tubifex tubifex*	26,650	10,289	2.590	Cd-Acute-5	Rathore and Khangarot 2002		
Tubificida	Naididae	Tubificid worm, *Tubifex tubifex*	423.3	299.5	1.414	Cd-Acute-6	Rathore and Khangarot 2003		
Tubificida	Naididae	Tubificid worm, *Tubifex tubifex*	6,463	1,778	3.634	Cd-Acute-8	Rathore and Khangarot 2003		
Basommatophora	Lymnaeidae	Pond snail (juvenile, stage II, 9 wk), *Lymnaea stagnalis*	1,735	718.0	2.416	Cd-Acute-9	Coeurdassier et al. 2004	2.016	2.016
Basommatophora	Lymnaeidae	Pond snail (adult, 20 wk), *Lymnaea stagnalis*	1,670	1,051	1.590	Cd-Acute-10	Coeurdassier et al. 2004		
Basommatophora	Lymnaeidae	Pond snail (juvenile, 25 mm), *Lymnaea stagnalis*	350.8	164.3	2.135	Cd-Acute-12	Pais 2012		
Basommatophora	Physidae	Snail (adult, 3.3-15 mm), *Physa acuta*	1,619	1,375	1.177	Cd-Acute-14	Woodard 2005	1.177	1.177
Diplostraca	Daphniidae	Cladoceran (<24 hr), *Ceriodaphnia dubia*	30.54	13.76	2.220	Cd-Acute-17	Shaw et al. 2006	2.220	2.220
Diplostraca	Daphniidae	Cladoceran (<24 hr), *Daphnia magna*	170.8	13.67	12.49	Cd-Acute-19	Shaw et al. 2006	4.580	4.580
Diplostraca	Daphniidae	Cladoceran (<24 hr), *Daphnia magna*	517.6	308.3	1.679	Cd-Acute-22	Perez and Beiras 2010		
Decapoda	Cambaridae	Crayfish (adult), *Orconectes virilis*	6,007	2,427	2.475	Cd-Acute-30	Mirenda 1986	2.475	2.475
Ephemeroptera	Heptageniidae	Mayfly (nymph), *Rhithrogena hageni*	10,924	2,080	5.251	Cd-Acute-35	Brinkman and Vieira 2007; Brinkman and Johnston 2008	5.251	5.251
Salmoniformes	Salmonidae	Rainbow trout (8.8 g), *Oncorhynchus mykiss*	3.055	1.759	1.737	Cd-Acute-47	Phipps and Holcombe 1985	2.067	2.067
Salmoniformes	Salmonidae	Rainbow trout	1.682	0.5849	2.876	Cd-Acute-48	Stubblefield 1990		

Order	Family	Species	LC_{50} (µg/L)	LC_{05} (µg/L)	LC_{50}: LC_{05}	C-R Curve Label	Reference	Species-level TAF (LC_{50}:LC_{05})	Genus-level TAF (LC_{50}:LC_{05})
		(juvenile, 18.3 g), *Oncorhynchus mykiss*							
Salmoniformes	Salmonidae	Rainbow trout (36 g), *Oncorhynchus mykiss*	2.679	1.683	1.591	Cd-Acute-49	Davies et al. 1993		
Salmoniformes	Salmonidae	Rainbow trout (36 g), *Oncorhynchus mykiss*	7.052	3.007	2.345	Cd-Acute-53	Davies et al. 1993		
Salmoniformes	Salmonidae	Rainbow trout (fry, 1.0 g), *Oncorhynchus mykiss*	2.773	1.726	1.606	Cd-Acute-55	Davies and Brinkman 1994b		
Salmoniformes	Salmonidae	Rainbow trout (fry, 1.0 g), *Oncorhynchus mykiss*	2.152	1.116	1.928	Cd-Acute-58	Davies and Brinkman 1994b		
Salmoniformes	Salmonidae	Rainbow trout (fry, 2.5 g), *Oncorhynchus mykiss*	10.14	5.298	1.914	Cd-Acute-60	Davies and Brinkman 1994b		
Salmoniformes	Salmonidae	Rainbow trout (263 mg), *Oncorhynchus mykiss*	0.6500	0.3493	1.861	Cd-Acute-61	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Rainbow trout (659 mg), *Oncorhynchus mykiss*	0.4134	0.2108	1.961	Cd-Acute-62	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Rainbow trout (1,150 mg), *Oncorhynchus mykiss*	0.4634	0.2174	2.132	Cd-Acute-63	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Rainbow trout (1,130 mg), *Oncorhynchus mykiss*	0.3528	0.2237	1.577	Cd-Acute-64	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Rainbow trout (299 mg), *Oncorhynchus mykiss*	1.210	0.3198	3.784	Cd-Acute-65	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Rainbow trout (289 mg), *Oncorhynchus mykiss*	2.548	1.042	2.445	Cd-Acute-66	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Brown trout (fingerling, 22.4 g), *Salmo trutta*	2.732	0.9770	2.797	Cd-Acute-76	Stubblefield 1990	2.797	2.797
Salmoniformes	Salmonidae	Bull trout (0.200 g), *Salvelinus confluentus*	0.9828	0.4530	2.169	Cd-Acute-79	Stratus Consulting 1999	2.402	2.402
Salmoniformes	Salmonidae	Bull trout (0.221 g), *Salvelinus confluentus*	0.9994	0.3656	2.734	Cd-Acute-80	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Bull trout (0.0842 g), *Salvelinus confluentus*	3.200	1.254	2.552	Cd-Acute-82	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Bull trout (0.0727 g), *Salvelinus confluentus*	5.942	2.700	2.201	Cd-Acute-83	Stratus Consulting 1999		

Order	Family	Species	LC_{50} (µg/L)	LC_{05} (µg/L)	LC_{50}: LC_{05}	C-R Curve Label	Reference	Species-level TAF (LC_{50}:LC_{05})	Genus-level TAF (LC_{50}:LC_{05})
Cypriniformes	Cyprinidae	Red shiner (adult, 0.80-2.0 g), *Cyprinella lutrensis*	6,731	4,903	1.373	Cd-Acute-85	Carrier 1987; Carrier and Beitinger 1988a	1.373	1.373
Cypriniformes	Cyprinidae	Zebrafish (adult), *Danio rerio*	15,631	8,012	1.951	Cd-Acute-86	Vergauwen 2012; Vergauwen et al. 2013	1.710	1.710
Cypriniformes	Cyprinidae	Zebrafish (adult), *Danio rerio*	12,384	8,263	1.499	Cd-Acute-87	Vergauwen 2012; Vergauwen et al. 2013		
Anura	Pipidae	African clawed frog, *Xenopus laevis*	3,314	1,447	2.290	Cd-Acute-101	Sunderman et al. 1991	2.290	2.290

3.1.1.3 Calculating Sturgeon Acute Cadmium Minimum Effect Threshold

Dividing the white sturgeon LC_{50} value (23.14 µg/L; genus-level surrogate value for shortnose and Atlantic sturgeon) by the acute MAF (2.310) results in an acute cadmium minimum effect threshold concentration of 10.02 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$) for both sturgeon species.

3.1.1.4 Sturgeon: Acute Cadmium Effects Determination

The acute cadmium CMC at hardness of 100 mg/L as $CaCO_3$ (1.9 µg/L total Cd), is over five times lower than the sturgeon acute cadmium minimum effect threshold of 10.02 µg/L total cadmium. The sturgeon acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary. As such, the effects of approval of the freshwater acute cadmium water quality standard are extremely unlikely to occur based on the fact that the established thresholds are below levels shown to have an effect, and thus all direct acute effects to shortnose and Atlantic sturgeons are discountable.

3.1.2 Sturgeon Chronic Cadmium Effects Assessment: Freshwater

3.1.2.1 Identifying Sturgeon Chronic Cadmium Data

High-quality empirical chronic toxicity data within the Order Acipenseriformes are not available to serve as chronic toxicity data representative of the shortnose and Atlantic sturgeon. As a result, the *Acipenser* GMAV (23.14 µg/L; Table 3-1) was transformed to represent a chronic toxicity value (i.e., EC_{20}) of 2.79 µg/L (Table 3-3). This representative chronic value for the two sturgeon was calculated by dividing the acute toxicity value for white sturgeon (23.14 µg/L; representative of shortnose and Atlantic sturgeon) by the Final Acute-to-Chronic Ratio (FACR) reported in the cadmium criteria document (USEPA 2016). Unlike the ammonia effects assessment that relied on an ACR calculated (geometric mean) from all available vertebrate ACRs, the FACR was used here because ACRs reported in USEPA (2016) vary by more than a factor of ten, even when only considering ACRs from vertebrate species. Additionally, USEPA (2016), states *"... none of the four methods suggested in the 1985 Guidelines (Stephan et al. 1985) for calculating the FACR are appropriate for cadmium... Thus, an alternate approach was used to determine the FACR. The recommended FACR of 8.291 was obtained from the geometric mean of seven genus-level ACRs... Americamysis (7.070), Ceriodaphnia (19.84), Daphnia (23.90), Cottus (11.22), Oncorhynchus (2.0), Salmo (2.0) and Pimephales (17.90).*" The FACR is intended to broadly relate a species acute effect concentration to an estimated chronic effect concentration (EC_{20}).

Table 3-3. Data used to calculate the GMCV representative of sturgeon sensitivity to cadmium.

Order	Family	Species	SMAV (µg/L)[a]	GMAV (µg/L)[a]	FACR	GMCV (µg/L)[a]
Acipenseriformes	Acipenseridae	White sturgeon, *Acipenser transmontanus*	23.14	23.14	8.291	2.79
Acipenseriformes	Acipenseridae	Shortnose sturgeon, *Acipenser brevirostrum*	N/A			
Acipenseriformes	Acipenseridae	Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*	N/A			

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016).
N/A: not available

3.1.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

High-quality chronic toxicity data were not available for the shortnose and Atlantic sturgeon or surrogate species within the Order Acipenseriformes, and therefore, no raw toxicity data are available to support the derivation of a sturgeon-specific EC_{20}:EC_5 adjustment factor at or below the order-level. As a result, EPA obtained and analyzed raw C-R data for all tests used to derive the chronic criterion (USEPA 2016 Appendix C underlined values) where such data were reported or could be obtained to derive a chronic vertebrate TAF or chronic MAF, if necessary (i.e., if the vertebrate and invertebrate-level chronic TAFs differ from one another).

Raw chronic toxicity data were fit to C-R models using EPA's TRAP software to calculate EC_{20} and corresponding EC_5 values for 40 tests representing 17 species (8 invertebrate and 9 fish species). C-R models were excluded from TAF and MAF calculation if 1) models did not exhibit a unique solution and were flagged by TRAP as having inadequate partial effects; 2) models did not include observations in the region of interest which did not allow TRAP to accurately model a no-response plateau and; 3) models exhibited incongruities such as no or poor fit to key points or excessive noise in the C-R relationship. After exclusion of unacceptable or uncertain EC_{20}:EC_5 ratios, 13 ratios remained resulting in three genus-level EC_{20}:EC_5 ratios for invertebrate species (arithmetic mean = 1.779 µg/L, variance = 0.07706 µg/L) and four genus-level EC_{20}:EC_5 ratios for vertebrate species (arithmetic mean = 1.332 µg/L, variance = 0.008872 µg/L). Analysis of the two means via a two-sample t-test assuming unequal variances ($\alpha = 0.05$) indicated that the means are the same (*t stat [2.677] < t critical for two tail [4.303]*). As a result, the chronic MAF was used to transform the GMCV applicable to the shortnose and Atlantic sturgeon (<4.074 µg/L) to a chronic minimum effect threshold concentration.

Table 3-4 provides the seven genus-level EC_{20}:EC_5 ratios used to derive the chronic MAF. Individual test ratios ranged from 1.229 to 2.097. The chronic MAF calculated as the geometric mean of all genus-level EC_{20}:EC_5 ratios is 1.502 (see Appendix B.3 for raw toxicity test data, TRAP models and outputs for the 13 chronic cadmium toxicity tests used to derive the chronic MAF; Appendix B.4 includes the raw toxicity data, TRAP models and outputs for all unacceptable and uncertain cadmium toxicity tests).

Table 3-4. Chronic EC_{20}:EC_5 ratios from analysis of 13 high-quality chronic cadmium toxicity tests with freshwater aquatic organisms used to derive a chronic cadmium MAF representative of the shortnose and Atlantic sturgeon.

Order	Family	Species	EC_{20} (µg/L)	EC_{05} (µg/L)	EC_{20}: EC_{05}	C-R Curve Label	Reference	Species-level TAF (EC_{20}:EC_{05})	Genus-level TAF (EC_{20}:EC_{05})
N/A[a]	Aeolosomatidae	Oligochaete, *Aeolosoma headleyi*	57.35	27.35	2.097	Cd-Chronic-1	Niederlehner et al. 1984	2.097	2.097
Diplostraca	Daphniidae	Cladoceran, *Ceriodaphnia dubia*	4.940	3.352	1.474	Cd-Chronic-12	Southwest Texas State University 2000	1.584	1.584
Diplostraca	Daphniidae	Cladoceran, *Ceriodaphnia dubia*	5.505	3.235	1.702	Cd-Chronic-13	Southwest Texas State University 2000		
Diplostraca	Daphniidae	Cladoceran, *Daphnia magna*	0.2118	0.1059	2.000	Cd-Chronic-15	Chapman et al. Manuscript	1.657	1.657
Diplostraca	Daphniidae	Cladoceran, *Daphnia magna*	6.166	4.489	1.374	Cd-Chronic-17	Bodar et al. 1988b		
Salmoniformes	Salmonidae	Rio Grande cutthroat trout *Oncorhynchus clarkii virginalis*	2.354	1.659	1.419	Cd-Chronic-24	Brinkman 2012	1.419	1.365
Salmoniformes	Salmonidae	Rainbow trout, *Oncorhynchus mykiss*	2.283	1.774	1.287	Cd-Chronic-26	Davies et al. 1993	1.312	
Salmoniformes	Salmonidae	Rainbow trout, *Oncorhynchus mykiss*	4.956	3.719	1.333	Cd-Chronic-27	Davies et al. 1993		
Salmoniformes	Salmonidae	Rainbow trout, *Oncorhynchus mykiss*	4.315	3.272	1.319	Cd-Chronic-28	Davies et al. 1993		
Salmoniformes	Salmonidae	Brown trout, *Salmo trutta*	5.187	4.221	1.229	Cd-Chronic-42	Brinkman and Hansen 2004a; 2007	1.229	1.229
Cyprinodontiformes	Cyprinodontidae	Flagfish, *Jordanella floridae*	5.018	3.470	1.446	Cd-Chronic-48	Spehar 1976	1.446	1.446
Scorpaeniformes	Cottidae	Mottled sculpin, *Cottus bairdii*	1.762	1.329	1.326	Cd-Chronic-52	Besser et al. 2007	1.289	1.289
Scorpaeniformes	Cottidae	Mottled sculpin, *Cottus bairdii*	1.285	1.026	1.252	Cd-Chronic-53	Besser et al. 2007		

[a] N/A; not available, no order listed in the Integrated Taxonomic Information System (www.itis.gov) for the species.

3.1.2.3 Calculating Sturgeon Chronic Cadmium Minimum Effect Threshold

Dividing the estimated sturgeon EC_{20} value (2.79 µg/L) by the chronic MAF (1.502) results in chronic minimum effect threshold concentration of 1.86 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$) for both sturgeon species.

3.1.2.4 Sturgeon: Chronic Cadmium Effects Determination

The cadmium CCC of 0.79 µg/L total Cd (at a hardness of 100 mg/L as $CaCO_3$), is 2.3 times lower than the sturgeon chronic cadmium minimum effect threshold concentration of 1.86 µg/L total cadmium, suggest sturgeon are tolerant to chronic cadmium exposures.

The threshold concentration is based on an acute value calculated from a relatively uncertain C-R curve (e.g., lowest test concentrations [excluding control groups] resulted in 70% mortality; see Cd-Acute-93 in Appendix B.2; see section 3.1.1.1). When deriving criteria and developing effects assessments, EPA relies on the most relevant and high-quality data possible to inform scientifically-sound conclusions. In certain cases, however, EPA may consider lower-quality toxicity data as supportive auxiliary information. Appendix H of the Cadmium 304(a) Aquatic Life Criteria document (USEPA 2016) contains "Other Toxicity Data" for freshwater species and consists of studies that do not meet the rigorous data quality, type, and documentation requirements specified in the 1985 Guidelines (Stephen et al. 1985), yet may contain quality portions that may be considered as supportive auxiliary data.

Appendix H of USEPA (2016) contains four white sturgeon (genus-level surrogate for shortnose and Atlantic sturgeons) chronic toxicity assays obtained from two different publications (Vardy et al. 2011; Wang et al. 2014a). Data from Vardy et al. (2011) are not further considered here because the two chronic toxicity assays reported by Vardy et al. (2011) did not include negative control groups, representing a critical flaw in the underlying study design. Chronic toxicity data for the white sturgeon reported by Wang et al. (2014a) did not contain critical flaws in the study design but were excluded from criteria derivation because reported exposure durations were either too short (EC_{20} < 11 µg/L; hardness = 100 mg/L; endpoint = survival) or were started too late in the sturgeon life stage to constitute an appropriate early life stage test (ELS test; EC_{20} = 3.2 µg/L; hardness = 100 mg/L; endpoint = biomass). Calfee et al. (2014), EPA (2016), and Ingersoll and Mebane (2014) report sturgeon sensitivity to acute cadmium exposures generally increases with increasing days post hatch (up until sturgeon reach a certain age around 72 dph), suggesting it may be appropriate to further consider the EC_{20} (3.2 µg/L) that was excluded from criteria derivation because exposures were started to late to constitute an ELS test. Therefore, EPA divided the EC_{20} value of 3.2 µg/L (Wang et al. 2014a) by the chronic MAF (chronic MAF = 1.502; see Section 3.1.2.2) to calculate a secondary chronic low effect threshold of 2.13 µg/L (hardness = 100 mg/L). The secondary chronic low effect threshold of 2.13 µg/L is similar to the primary chronic low effect threshold of 1.86 µg/L and provides an additional line of evidence to support that sturgeon are tolerant to cadmium at the chronic criterion magnitude (CCC = 0.79 µg/L; hardness = 100 mg/L).

The sturgeon chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. Furthermore, supportive data from less-certain chronic toxicity studies were used to calculate a secondary chronic low effect

threshold that is also greater than the corresponding criterion magnitude, providing an additional line of evidence to suggest sturgeon are relatively tolerant to chronic cadmium exposures. As a result, refined assessment and consideration of the criterion duration is not necessary. As such, the effects of approval of the freshwater chronic cadmium water quality standard are extremely unlikely to occur based on the fact that the established thresholds are below levels shown to have an effect, and thus all direct chronic effects to shortnose and Atlantic sturgeons are discountable.

3.1.3 Sturgeon Acute and Chronic Cadmium Effects Assessment: Estuarine/Marine

Acceptable acute saltwater toxicity data for cadmium criteria derivation were available for 94 different estuarine/marine species representing 79 genera, while only two chronic studies conducted on mysid species were available for consideration in deriving the chronic criterion for cadmium in estuarine/marine water. Therefore, the acute estuarine/marine cadmium final acute value (FAV) was transformed by a FACR to derive the chronic criterion magnitude for cadmium in estuarine/marine waters. The four most sensitive genera to acute cadmium exposures were all invertebrates, suggesting vertebrate species, including sturgeon, are relatively insensitive to cadmium toxicity in estuarine/marine waters.

Empirical acute and chronic toxicity data for saltwater life stages of shortnose and Atlantic and sturgeons, or appropriate surrogate species (i.e., members of the Order Acipenseriformes), are not available. Freshwater data, however, suggest sturgeon are most sensitive to cadmium exposures as young fry in freshwaters, and quickly becoming relatively insensitive as they age and migrate toward estuarine and marine waters. USEPA (2016) states, "*Several life stages of the white sturgeon, Acipenser transmontanus, were exposed in flow-through measured exposures by Calfee et al. (2014) and Wang et al. (2014a). The most sensitive life stage were the 61 day post hatch fish with a non-definitive normalized acute value of <33.78 µg/L total cadmium. However, all other life stages were much less sensitive...*" Calfee et al. (2014) reported normalized (hardness = 100 mg/L) white sturgeon LC_{50} values increasing from <33.78 µg/L at 61 days post hatch (dph) to >150.9 µg/L total cadmium at 72 dph, with white sturgeon becoming increasingly tolerant to cadmium at 89 dph with an LC_{50} exceeding 278.6 µg/L. Therefore, Atlantic and shortnose sturgeon life stages occurring in estuarine and marine environments are expected to be relatively insensitive to cadmium.

Because estuarine/marine acute and chronic cadmium criteria are based the fifth centile of sensitive genera (i.e., invertebrates) and designed to protect sensitive genera, the criteria will also protect less sensitive taxa, including sturgeon. Because of their tolerance to the cadmium levels proposed for approval, any effects of the approval of the acute and chronic cadmium estuarine/marine water quality criteria are extremely unlikely to occur and are discountable.

3.1.4 Sturgeon Cadmium Indirect Effects Assessment: Freshwater and Estuarine/Marine

Aquatic life criteria are based on the fifth centile of sensitive genera to protect aquatic communities, including listed species and their prey items. Further, aquatic life criteria are conservatively implemented in National Pollution Discharge Elimination System (NPDES) permit limits by assuming receiving streams are continually at low-flow conditions which

significantly limits the probability of *in situ* pollutant concentrations reaching criteria magnitudes and durations. NPDES permit limits based on the acute cadmium criterion typically assume a receiving stream is continually at 1Q10 low-flow conditions, while the probability of these low-flow conditions occurring is exceedingly rare (i.e., 1-day average lowest flow over the course of a 10-year period). Similarly, NPDES permit limits based on the chronic cadmium criterion typically assume receiving streams are continually at 7Q10 low-flow conditions (i.e., 7-day average lowest flow over the course of a 10-year period). As a result, excess dilution limits instream cadmium concentrations and drastically decreases the probability *in situ* cadmium concentrations will reach criteria magnitudes and durations. Independent of assuming low flow conditions, NPDES permits also layer on an additional level of conservatism by ensuring facilities discharge cadmium at Long Term Average concentrations (LTAs), which are based on Waste Load Allocations[2] (WLAs) set as the 99th centile of a log-normal distribution that describes effluent variability. Setting WLAs as the 99th centile of an effluent distribution ensures a 99% chance facilitates discharge cadmium at concentrations less than those that would cause receiving stream cadmium concentrations to reach criteria magnitudes under critical flow conditions (which are independent and also exceedingly rare events; USEPA 1991). Additionally, even if *in situ* exposures were to match the acute or chronic criteria magnitudes, the broad aquatic community, including sturgeon prey items, will be adequately protected because aquatic life criteria are based on the fifth centile of sensitive genera.

Atlantic and shortnose sturgeon broadly rely on benthic invertebrates, including mussels, crustaceans, and insects as primary food sources, all of which are relatively insensitive to acute and chronic cadmium exposures in freshwaters. For example, the most sensitive genera to acute cadmium exposures includes salmonids (*Oncorhynchus*, *Salvelinus* and *Salmo*), sculpin (*Cottus*), and striped bass (*Morone*; Table 7 of USEPA 2016), with pelagic crustaceans (*Hyalella* and *Ceriodaphnia*), sculpin (*Cottus*), and a midge (*Chironomu*s) comprising the four most-sensitive genera to chronic exposures in freshwater (Table 9 of USEPA 2016). In estuarine/marine water, the most sensitive species to acute cadmium exposures (and by extension, chronic cadmium exposure given limited chronic estuarine/marine data) include two mysid genera (*Neomysis* and *Americamysis*), a copepod (*Tigriopus*), and a jellyfish (*Aurelia*). Remaining acute estuarine/marine cadmium toxicity data indicate primary sturgeon prey items, including gastropods, bivalves, oligochaetes, and benthic crustaceans, are also insensitive to acute and chronic cadmium exposures in marine/estuarine environments (Table 10 of USEPA 2016). Even if certain components of shortnose and Atlantic sturgeon diets were among the most-sensitive genera, the sturgeon would not experience any appreciable indirect effects because they are broad opportunistic feeders. Sturgeon consume a wide range of inveterate taxa, which are adequately protected by the cadmium criteria, considering criteria are typically based on the fifth centile of sensitive genera and implemented under conservative exposure conditions.

EPA approval of the freshwater (acute and chronic) and estuarine/marine cadmium criteria (acute and chronic) as Virginia water quality standards is Not Likely to Adversely Affect (NLAA) Atlantic and shortnose sturgeon through indirect effects because: 1) criteria are implemented conservatively; 2) sturgeon prey items are relatively insensitive to cadmium compared to those genera that drive the criteria magnitudes; and 3) sturgeon are not specialized feeders relying on a

specific prey item that may be affected by cadmium exposures. As such, the effects of approval of the freshwater acute and chronic cadmium water quality standard are too small to be detected and thus any indirect chronic or acute effects to shortnose and Atlantic sturgeons are insignificant.

3.2 Sea Turtles: Green (*Chelonia mydas*), Leatherback (*Dermochelys coriacea*), Hawksbill (*Eretmochelys imbricate*), Kemp's Ridley (*Lepidochelys kempii*), and Loggerhead (*Caretta caretta*)

3.2.1 Sea Turtle Acute and Chronic Cadmium Effects Assessment: Estuarine/Marine

Sea turtles are expected to experience no effects associated with approval to the freshwater acute and chronic cadmium criteria due to no co-occurrence of sea turtles and cadmium in Virginia freshwaters. Given the immense dilution associated with marine environments, co-occurrence of sea turtles and cadmium at exposure concentrations and durations associated with the acute and chronic estuarine/marine criteria is also unlikely. For example, NOAA fisheries (NMFS 2012) previously assessed the protectiveness of earlier, less stringent, cadmium criteria (USEPA 2001; CMC = 40.28 µg/L; CCC = 8.9 µg/L; hardness = 100 mg/L) for estuarine/marine waters in Oregon and concluded:

> "*the proposed action is not likely to adversely affect (NLAA)… loggerhead sea turtles, green sea turtles, leatherback sea turtles, or Olive Ridley sea turtles. The above identified marine…sea turtle species are distributed in coastal areas and may be exposed to effects related to the proposed numeric criteria. Similar to Southern Resident killer whales, effects would be indirect and would include reduced prey availability, reduced prey quality, and potential accumulation in the individuals exposed. However, the occurrence of the subject ESA-listed sea turtles and large whales would be rare, infrequent, and transitory in the action area*."

Moreover, juveniles of all turtle species occurring within Virginia waters forage and mature for several years after hatching in open ocean habitats far from shore (see section 3.2.2), limiting exposure to early life stages, which tend to be the most-sensitive life stage of many taxa to pollutant exposures. Listed sea turtles in estuarine/marine waters of Virginia are not expected to be exposed to cadmium at criteria magnitudes and durations, especially as early life stages. As a result, the effects of approval of the acute and chronic estuarine/marine cadmium criteria on the green sea turtle, leatherback turtle, Kemp's ridley turtle, and loggerhead turtle are extremely unlikely to occur, and discountable.

3.2.2 Sea Turtle Cadmium Indirect Effects Assessment: Freshwater and Estuarine/Marine

Broadly, all listed sea turtles occurring within the action area share fundamentally similar life cycles and diets. After hatching, green sea turtles swim to offshore areas where they reside for several years feeding close to the surface on a variety of pelagic plants and animals. As adults, green sea turtles travel to foraging grounds closer to shore, feeding primarily on algae and grasses in benthic habitats. As adults they are almost exclusively herbivorous, primarily consuming seagrasses and algae. Leatherback turtles spend the majority of their life in open

ocean, except when females must migrate to near shore habitat to lay eggs on sandy, tropical beaches. After nesting season, leatherbacks migrate from tropical waters to more temperate latitudes, which support high densities of jellyfish prey in the summer. Juvenile hawkshill turtles are initially pelagic- sheltering on floating mats of algae and foraging on the surface. As adults, they enter coastal foraging areas near reefs where they feed primarily on algae, sponges, and other invertebrates associated with coral reef environments (NOAA 2017).

After hatching, Kemp's ridley turtles enter water and swim quickly from near shore to escape predators, remaining in open ocean for about two years then return to coastal zones as sub-adults and adults where they forage for prey, including crabs, fish, jellyfish, and mollusks, in muddy or sandy bottom substrates. Loggerhead hatchlings move from their nest to the surf and are swept through the surf zone, and continue swimming away from land for up to several days. Post-hatchling loggerheads reside in areas where surface waters converge to form local down-wellings. Post-hatchlings are observed to be low-energy float-and-wait foragers that feed on a wide variety of floating items. As post-hatchlings, loggerheads may linger for months in waters near the nesting beach or become transported by ocean currents within the Gulf of Mexico and North Atlantic. Somewhere between 7-12 years old, oceanic juveniles migrate back to nearshore coastal areas, foraging on clams, whelks and conch (NOAA 2017).

Listed turtles occurring in Virginia estuarine/marine waters broadly rely on benthic invertebrates, including mussels, crustaceans, and plants as primary food sources, all of which are relatively insensitive to acute and chronic cadmium exposures in freshwaters. In estuarine/marine water, the most sensitive species to acute cadmium exposures (and by extension, chronic cadmium exposure given limited chronic estuarine/marine data) include two mysid genera (*Neomysis* and *Americamysis*), a copepod (*Tigriopus*), and a jellyfish (*Aurelia*). Remaining acute estuarine/marine cadmium toxicity data indicate sea turtle prey items, bivalves, plants, crustaceans, and other invertebrates, are insensitive to acute and chronic cadmium exposures in marine/estuarine environments (Table 10 of USEPA 2016).

Jellyfish rank among the most sensitive genera to acute cadmium exposures in estuarine/marine waters and serve as valuable prey for leatherback turtles; however, aquatic life criteria are based on the fifth centile of sensitive genera and are derived to protect aquatic communities, including jellyfish. For example, members of the genus *Aurelia*, and potentially other members of the order Semaeostomeae, may be sensitive to cadmium exposures in estuarine/marine waters relative to other genera, but are not appreciably sensitive relative to the acute estuarine criterion itself because the *Aurelia* GMAV (61.75 µg/L total cadmium) is nearly two times greater than the estuarine CMC of 33.13 µg/L total cadmium. Similarly, NOAA fisheries (NMFS 2012) previously assessed the protectiveness of earlier, less stringent, cadmium criteria (USEPA 2001; CMC = 40.28 µg/L; CCC = 8.9 µg/L; hardness = 100 mg/L) on leatherback turtle critical habitat in Oregon and concluded:

> "*The PCEs that NMFS identified as essential for the conservation of leatherback sea turtles…(1) A sufficient quantity and quality of their jellyfish prey…Based on the best scientific and commercial data available, as discussed previously, NMFS does not expect that the proposed action would adversely affect the quantity,*

quality, or availability of any of the constituent elements of critical habitat, or the physical, chemical, or biotic phenomena that give the designated area value for the conservation of the species…"

Sea turtle food resources will not be measurably affected by cadmium at criteria magnitudes and durations associated with the acute and chronic estuarine/marine criteria (USEPA 2016). Further, sea turtles are migratory species and generalist feeders, relying on a range of food resources, both within and outside of the action area, which mitigates any resultants effects of limiting a large portion of a single food resource (which is not the expected outcome of the action). As a result, the effects of the approval of the acute and chronic estuarine/marine cadmium criteria the green sea turtle, leatherback turtle, hawksbill turtle, Kemp's ridley turtle, and loggerhead turtle are too small to be detected, and therefore insignificant.

3.3 Whales: Finback (*Balaenoptera physalus*) and North Atlantic Right (*Eubalaena glacialis*)

3.3.1 Whale Acute and Chronic Cadmium Effects Assessment: Estuarine/Marine

Whales will experience no effects associated with approval to the freshwater acute and chronic cadmium criteria due to no expected co-occurrence of whales and cadmium in Virginia freshwaters. Given the immense dilution associated with marine environments, co-occurrence of whales and cadmium at exposure concentrations and durations associated with the acute and chronic estuarine/marine criteria is also unlikely. For example, NOAA fisheries (NMFS 2012) previously assessed the protectiveness of earlier, less stringent, cadmium criteria (USEPA 2001; CMC = 40.28 µg/L; CCC = 8.9 µg/L; hardness = 100 mg/L) for estuarine/marine waters in Oregon and concluded:

"*In this opinion NMFS concludes that the proposed action is not likely to adversely affect (NLAA) Steller sea lions, humpback whales, blue whales, fin whales, Sei whales, sperm whales, North Pacific Right whales…The above identified marine mammal and sea turtle species are distributed in coastal areas and may be exposed to effects related to the proposed numeric criteria. Similar to Southern Resident killer whales, effects would be indirect and would include reduced prey availability, reduced prey quality, and potential accumulation in the individuals exposed. However, the occurrence of the subject ESA-listed sea turtles and large whales would be rare, infrequent, and transitory in the action area. For example, the blue whale and Sei whale are likely to have limited exposure to contaminant sources as their migratory patterns are circumglobal with definite seasonal movements to offshore areas outside the likely extent of effects.*"

The finback whale is unlikely to be exposed to cadmium, or other pollutants, at acute or chronic criterion magnitudes (USEPA 2016) because fin whales are primarily found in deep water, rather than near-shore habitat, significantly reducing exposure potential. Similarly, NOAA Fisheries (NOAA 2017) cited the same rationale to concur finback whales are not likely to be adversely affected by three pesticide contaminants, stating:

> *Direct effects to listed cetaceans from the action are not expected due to dilution of the three a.i.s* (i.e., diazanon, chlorpyrifos, or malathion) *in the marine environments (resulting in a very low potential for exposure) and the cetaceans' very large size (very low potential for effects). Additionally, some of the listed cetaceans are found primarily in deep, ocean waters [i.e., Sei whale (Balaenoptera borealis), Bryde's whale (Balaenoptera edemi), blue whale (Balaenoptera musculus), fin whale (Balaenoptera physalus), humpback whale (Megaptera novaeangliae), and sperm whale (Physeter microcephalus (=icrocephalus)], and/or are circumpolar [i.e., the bowhead whale (Balaena mysticetus)]. Species that are found primarily in deep waters or are circumpolar (i.e., found at high latitudes around the earth's Polar Regions) are expected to range far from any potential application sites – further limiting the potential for exposure.*

While the North Atlantic right whale relies on coastal waters more than the fin whale, exposure potential to cadmium remains negligible, especially because the North Atlantic right whale primarily uses Virginia estuarine/marine waters for migration purposes, as they travel between calving grounds south of Cape Fear, NC, to wintering grounds off of the New England coast (NOAA Fisheries, Species Directory: www.fisheries.noaa.gov/species/north-atlantic-right-whale; Accessed 7/12/2018). Given limited exposure potential and relatively large sizes (limiting potential effects), effects of the approval of the acute and chronic estuarine/marine cadmium criteria to the finback whale or North Atlantic right whale are extremely unlikely to occur and therefore discountable.

3.3.2 Whale Cadmium Indirect Effects Assessment: Freshwater and Estuarine/Marine

North Atlantic right whales consume zooplankton and copepods, filtering pelagic organisms from the water column through their baleen (NOAA Fisheries, Species Directory: www.fisheries.noaa.gov/species/north-atlantic-right-whale; Accessed 7/12/2018), while finback whales consume krill, herring, sand lance, capelin, and squid (NOAA Fisheries, Species Directory: www.fisheries.noaa.gov/species/fin-whale; Accessed 7/12/2018). Finback whale range is circum-global and the North Atlantic right whale tend to occupy Virginia marine waters only during migration, providing extensive food resources outside of pelagic organisms occurring in near-shore habitats within the action area. Given available food resources outside of near-shore habitats within Virginia and because aquatic life criteria are based on the 5th centile of sensitive genera to ensure aquatic communities, including whale dietary resources, are protected from acute and chronic cadmium exposures, effects of cadmium exposure to whale prey items within Virginia will be negligible and would insignificantly translate to dietary resources as a whole. For example, NOAA Fisheries (NOAA 2017) cited similar considerations to determine the finback and North Atlantic right whales are not likely to be adversely affected through indirect effects by three pesticides contaminants, stating:

> *For indirect effects (i.e., reductions in whales' prey), due to the effect of dilution in the types of marine environments in which the listed cetaceans are found and distance from potential use sites, risks from the potential loss of marine*

invertebrate and vertebrate prey are not expected. Therefore, for the listed cetaceans that rely wholly on marine prey [i.e.,…fin(back) *whale, North Atlantic right whale…), we do not expect indirect effects from the potential loss of prey. For these species, we consider the risk for indirect effects to be low (due to limited exposure) and we have high confidence in this risk assessment.*

Given minimal anticipated effects to whale prey items within and outside of the action area, the effects of approval of the acute and chronic estuarine/marine cadmium criteria to the finback whale or North Atlantic right whale are extremely unlikely to occur and therefore discountable.

4 Conclusion: Final Effects Determinations

Listed sturgeon, turtles, and whales occurring in Virginia freshwaters and/or estuarine/marine waters are insensitive to acute and chronic freshwater ammonia and cadmium exposures at the respective criteria magnitudes under conservative exposure conditions. Further, aquatic life criteria are implemented conservatively and are based on the fifth centile of sensitive genera to ensure aquatic communities, including listed species prey items, are adequately protected. As a result, the indirect or direct effects of approval of the acute and chronic ammonia (freshwater) and cadmium (freshwater and estuarine/marine) criteria as Virginia state water quality standards are insignificant and/or discountable and the action is Not Likely to Adversely Affect (NLAA) these species (Table 4-1).

Table 4-1. Final effect determinations for aquatic listed species occurring in Virginia that may be affected by the approval action. Final effects determinations for listed species are based on direct and indirect effects.

Species	Final Effects Determination
Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*)	***NLAA*** (direct and indirect effects)
Shortnose Sturgeon (*Acipenser brevirostrum*)	***NLAA*** (direct and indirect effects)
Green Sea Turtle (*Chelonia mydas*)	***NLAA*** (direct and indirect effects)
Leatherback Turtle (*Dermochelys coriacea*)	***NLAA*** (direct and indirect effects)
Kemp's Ridley Turtle (*Lepidochelys kempii*)	***NLAA*** (direct and indirect effects)
Loggerhead Turtle (*Caretta caretta*)	***NLAA*** (direct and indirect effects)
Finback Whale (Balaenoptera physalus)	***NLAA*** (direct and indirect effects)
North Atlantic Right (*Eubalaena glacialis*)	***NLAA*** (direct and indirect effects)

5 Critical Habitat: Effects Assessment and Final Critical Habitat Effects Determinations

5.1 Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) Critical Habitat

Critical habitat for the Atlantic sturgeon Chesapeake Bay distinct population segment was designated in 2017 and encompasses lower reaches of several Virginia Rivers, including the Potomac, Rappahannock, York, Mattaponi, and Pamunkey Rivers (NOAA 2015). NOAA identifies a key objective for the Chesapeake Bay DPS is to increase the abundance of each DPS by facilitating increased successful reproduction and recruitment to the marine environment. The Physical or biological features (PBFs) that require special management considerations concerning any proposed action in the proposed critical habitat for the Atlantic sturgeon are discussed below. PBFs considered present within this action area are outlined below.

PBF 1: Hard bottom substrate (e.g., rock, cobble, gravel, limestone, boulder, etc.) in low salinity waters (i.e., 0.0-0.5 parts per thousand range) for settlement of fertilized eggs, refuge, growth, and development of early life stages;

The revisions to the ammonia and cadmium criteria focus solely on the allowable levels of those pollutants throughout the action area. Waters with ammonia and/or cadmium at or under the magnitude of the criteria would have no effect on actual hard bottom substrate, nor would they shift salinity levels in waters of the action area that may possess this PBF. Therefore, there would also be no effects of the criteria on the settlement of fertilized eggs, refuge, growth, and development of early life stages.

PBF 2: Aquatic habitat with a gradual downstream salinity gradient of 0.5-30 parts per thousand and soft substrate (e.g., sand, mud) downstream of spawning sites for juvenile foraging and physiological development;

The revisions to the ammonia and cadmium criteria focus solely on the allowable levels of those pollutants throughout the action area. Because of the tendency for cadmium to bind readily with soft sediments, cadmium may be bioavailable to benthic feeders such as sturgeon, and it may become a part of the actual physical feature (soft sediment within a downstream salinity gradient of 0.5 to 30 parts per thousand) protected under PBF 2. However, any effects are extremely unlikely to occur because the cadmium criteria is set below levels that could potentially affect juvenile and foraging Atlantic sturgeon. As such any effects to the value of this PBF to the conservation of the species is discountable.

PBF 3: Water of appropriate depth and absent physical barriers to passage (e.g., locks, dams, reservoirs, gear, etc.) between the river mouth and spawning sites necessary to support: (1) unimpeded movements of adults to and from spawning sites; (2) seasonal and physiologically-dependent movement of juvenile Atlantic sturgeon to appropriate salinity zones within the river estuary, and; (3) staging, resting, or holding of subadults or spawning condition adults. Water depths in the main river channels must also be deep enough (e.g., ≥1.2 m) to ensure continuous

flow in the main channel at all times when any sturgeon life stage would be in the river, and;

The revisions to the ammonia and cadmium criteria focus solely on the allowable levels of those pollutants throughout VA waters. The effects of the criteria on appropriate water depth and physical barriers to passage to support unimpeded movement of adults to and from spawning sites, seasonal and physiologically dependent movement of juvenile Atlantic sturgeon to appropriate salinity zones within the river estuary and staging, and resting or holding of subadults or spawning condition adults are extremely unlikely to occur. Because the water quality criteria have been set at a level that is not likely to adversely affect the listed species, any waters with ammonia or cadmium at or below the criteria magnitude would be below levels detectable by sturgeon and as such any effects to the value of the PBF to the conservation of the species would be extremely unlikely to occur and discountable.

PBF 4: Water, especially in the bottom meter of the water column, with the temperature, salinity, and oxygen values that, combined, support: (1) spawning; (2) annual and inter-annual adult, subadult, larval, and juvenile survival; and (3) larval, juvenile, and subadult growth, development, and recruitment (e.g., 13° C to 26° C for spawning habitat and no more than 30° C for juvenile rearing habitat, and 6 mg/L dissolved oxygen for juvenile rearing habitat).

The revisions to the ammonia and cadmium criteria focus solely on the allowable levels of those pollutants throughout VA waters. Waters with ammonia and/or cadmium at or under the magnitude of the criteria would have no effect on temperature, salinity, and oxygen values between the river mouth and spawning sites, especially in the bottom meter of the water column, that, combined, support spawning, annual and interannual adult, subadult, larval and juvenile survival; larval, juvenile and subadult growth, development and recruitment.

To determine whether EPA's approval of VA's water quality criteria for ammonia and cadmium is likely to adversely affect critical habitat, EPA evaluated the effects of ammonia and cadmium relative to the essential features of habitat. In evaluating the effects of the action on critical habitat, EPA concluded that the essential features of the critical habitat relate to physical structures of the river such as water depth, substrate composition, barriers to passage, water velocity, instream cover, etc. as well as dissolved oxygen and salinity, will not be adversely affected by the ammonia and cadmium criteria approval. There are no effects of the proposed action on PBFs 1 and 4; while the effects of the proposed criteria on PBF 3 and PBF 4 are extremely unlikely to occur and discountable. Additionally, the proposed criteria will not affect the sound, habitat structure and disturbance, dredging, water quality (turbidity), in-water structures, prey quality/quantity, or vessel traffic for any of the listed species. As such, the action is not likely to adversely affect critical habitat for Atlantic sturgeon.

6 Conclusion

EPA views the ammonia and cadmium criteria revisions as insignificant and/or discountable to the conservation and protection of aquatic life, including listed species and their food sources in Virginia. EPA recognizes the need to revise its decision if this consultation identifies situations where the criteria may not be adequately protective of listed species populations. If this should be the case, EPA will coordinate with NMFS to determine a reasonable approach.

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September 17, 2018

GARFO Species List

(Proceed to page 2 for complete reference list)

Whales:

North Atlantic right whale (*Eubalaena glacialis*)(73 FR 12024; Recovery plan: NMFS 2005)
Fin whale (*Balaenoptera physalus*)(35 FR 18319; Recovery plan: NMFS 2010a)
Sei whale (*Balaenoptera borealis*)(35 FR 18319; Recovery plan: NMFS 2011)
Sperm whale (*Physeter macrocephalus*)(35 FR 18319; Recovery plan: NMFS 2010b) Blue whale (*Balaenoptera musculus*)(35 FR 18319; Recovery plan: NMFS 1998b) Sea Turtles:

Loggerhead turtle (*Caretta caretta*)(76 FR 58868; Recovery plan: NMFS & USFWS 2008) [4]
Leatherback turtle (*Dermochelys coriacea*)(35 FR 8491; Recovery plan: NMFS & USFWS 1992a) Green turtle (*Chelonia mydas*)(81 FR 20057; Recovery plan: NMFS & USFWS 1991) [5]
Kemp's ridley turtle (*Lepidochelys kempii*)(35 FR 18319; Recovery plan: NMFS *et al.* 2011) Hawksbill turtle (*Eretmochelys imbricata*)(35 FR 8491; Recovery plan: NMFS & USFWS 1992b) Fish:

Shortnose sturgeon (*Acipenser brevirostrum*)(32 FR 4001; Recovery plan: NMFS 1998a)

Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*)(77 FR 5880 and 77 FR 5914)[6]

Atlantic salmon (*Salmo salar*)(74 FR 29344; Recovery plan: NMFS & USFWS 2005)[7]

Critical Habitat:

North Atlantic right whale (81 FR 4837)
Loggerhead turtle (79 FR 4837)
Atlantic sturgeon (82 FR 39160)
Atlantic salmon (74 FR 29300) ***ESA Listing Rules:***

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[4] For loggerhead turtles, only the Northwest Atlantic Distinct Population Segment (DPS) occurs in the Greater Atlantic Region

[5] For green turtles, only the North Atlantic DPS occurs in the Greater Atlantic Region

[6] For Atlantic sturgeon, there are five listed DPSs that may occur in the Greater Atlantic Region: (1) Gulf of Maine, (2) New York Bight, (3) Chesapeake Bay, (4) Carolina, and (5) South Atlantic

[7] For Atlantic salmon, there is one listed DPS: the Gulf of Maine DPS

North Atlantic right whale:
(73 FR 12024; March 6, 2008)

Fin, Sei, Sperm, and Blue whales:
(35 FR 18319; December 2, 1970)

Loggerhead turtle:
(76 FR 58868; September 20, 2011)

Leatherback turtle:
(35 FR 8491; June 2, 1970)

Green turtle:
(81 FR 20057; April 6, 2016)

Kemp's ridley and Hawksbill turtles:
(35 FR 18319; December 2, 1970)

Shortnose sturgeon:
(32 FR 4001; March 8, 1967)

Atlantic sturgeon:
(77 FR 5880; February 6, 2012)

(77 FR 5914; February 6, 2012)

Atlantic salmon:
(74 FR 29344; June 19, 2009) ***Species Recovery Plans:***

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Attachment 1

Species Listed Under the Endangered Species Act Under the Jurisdiction of NMFS' Greater Atlantic Region (MAINE through VIRGINIA). https://www.greateratlantic.fisheries.noaa.gov/protected/section7/listing/gar_sp_present_table_mar172016.pdf. Accessed on 10/10/2018.

SPECIES LISTED UNDER THE ENDANGERED SPECIES ACT UNDER THE JURISDICTION OF NMFS's GREATER ATLANTIC REGION (MAINE - VIRGINIA)

For a list of Candidate Species in the Greater Atlantic Region (GAR), please visit https://www.greateratlantic.fisheries.noaa.gov/protected/pcp/cs/index.html
For a list of Species of Concern in the GAR, please visit https://www.greateratlantic.fisheries.noaa.gov/protected/pcp/soc/index.html

FISH

Atlantic Salmon (Salmo salar) (Gulf of Maine DPS)

Year listed: 2000; More recent listing for Gulf of Maine Atlantic salmon as a Distinct Population Segment (DPS) encompassing a wider range in the state of Maine in 2009; Atlantic salmon are listed jointly with U.S. Fish and Wildlife Service.
Status: Endangered
General distribution: The distribution of endangered Atlantic salmon extends from the Androscoggin River in South Western Maine to the Dennys River in Eastern Maine.
Critical habitat in GAR: Critical habitat for Atlantic salmon was designated in 2009. Forty-five specific areas containing over 19,000 kilometers of rivers and streams and 799 square kilometers of lakes and ponds were identified as having the physical and biological features essential to the conservation of the species, which may require special management or protections. For more information, please visit the map book at https://www.greateratlantic.fisheries.noaa.gov/protected/atlsalmon/ **Additional Information**: For additional distribution information, select references, and other relevant information, please visit https://www.greateratlantic.fisheries.noaa.gov/protected/atlsalmon/ and http://www.fisheries.noaa.gov/pr/species/fish/atlantic-salmon.html

Shortnose Sturgeon (Acipenser brevirostrum)

Year listed: 1967
Status: Endangered
General distribution: Shortnose sturgeon occur in marine and estuarine habitat, including freshwater reaches of large rivers with access to the sea, which extends from the Minas Basin, Nova Scotia to the St. Johns River, Florida. There have been documented coastal movements between some of the major rivers.
Critical habitat in GAR: None
Additional Information: For additional distribution information, select references, and other relevant information, please visit https://www.greateratlantic.fisheries.noaa.gov/protected/snsturgeon/index.html and http://www.nmfs.noaa.gov/pr/species/fish/shortnose-sturgeon.html

Atlantic Sturgeon (Acipenser oxyrinchus oxyrinchus)

Year listed: 2012 (Effective April 6, 2012)
Status: Five Distinct Population Segments (DPSs) designated along the U.S. East Coast. The Gulf of Maine population is listed as threatened while the New York Bight, Chesapeake Bay, Carolina, and South Atlantic populations are listed as endangered.
General distribution: Atlantic sturgeon belonging to each of the five DPSs occur in marine and estuarine habitat, including freshwater reaches of large rivers with access to the sea, from Hamilton Inlet, Labrador, Canada to Cape Canaveral, Florida, U.S. The range of all five DPSs overlap.
Critical habitat in the GAR: In select rivers from Maine through Virginia; Please visit: http://sero.nmfs.noaa.gov/protected_resources/sturgeon/documents/critical_habitat_maps.pdf
Additional Information: For additional distribution information, select references, and other relevant information, please visit https://www.greateratlantic.fisheries.noaa.gov/protected/atlsturgeon/index.html and http://www.fisheries.noaa.gov/pr/species/fish/atlantic-sturgeon.html

MARINE MAMMALS

Blue Whale (Balaenoptera musculus musculus)

Year listed: 1970
Status: Endangered
General distribution: The distribution of the blue whale in the western North Atlantic generally extends from the Arctic to at least mid-latitude waters. The blue whale is best considered as an occasional visitor in U.S. Atlantic Exclusive Economic Zone (EEZ) waters, which may represent the current southern limit of its feeding range (CETAP 1982; Wenzel et al. 1988). The actual southern limit of the species' range is unknown.
Critical habitat in GAR: None
Additional Information: For additional distribution information, select references, and other relevant information, please visit http://www.fisheries.noaa.gov/pr/species/mammals/whales/blue-whale.html and http://www.nmfs.noaa.gov/pr/pdfs/sars/ao2010whbl-wn.pdf

Fin Whale (Balaenoptera physalus)

Year listed: 1970
Status: Endangered
General distribution: Fin whales are common in waters of the U. S. Atlantic Exclusive Economic Zone (EEZ), principally from Cape Hatteras northward. Fin whales are migratory, moving seasonally into and out of high-latitude feeding areas, but the overall migration pattern is complex, and specific routes have not been documented. However, acoustic recordings from passive-listening hydrophone arrays indicate that a southward "flow pattern" occurs in the fall from the Labrador-Newfoundland region, past Bermuda, and into the West Indies (Clark 1995).
Critical habitat in GAR: None
Additional Information: For additional distribution information, select references, and other relevant information, please visit http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/finwhale.htm and http://www.nmfs.noaa.gov/pr/sars/pdf/stocks/atlantic/2015/f2015_finwhale.pdf

North Atlantic Right Whale (Eubalaena glacialis)

Year listed: 1970; Listed as two separate, endangered species in 2008 - the North Pacific right whale (Eubalaena japonica) and North Atlantic right whale (Eubalaena glacialis)
Status: Endangered
General distribution: Population ranges primarily from calving grounds in coastal waters of the southeastern United States to feeding grounds in New England waters and the Canadian Bay of Fundy, Scotian Shelf, and Gulf of St. Lawrence.
Critical habitat in GAR: Expanded to include the Gulf of Maine and Georges Bank. Please see: http://www.fisheries.noaa.gov/pr/species/critical%20habitat%20files/ne_narw_ch.pdf **Additional Information:** For additional distribution information, select references, and other relevant information, please visit http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/rightwhale_northatlantic.htm and http://www.nmfs.noaa.gov/pr/sars/pdf/stocks/atlantic/2015/f2015_rightwhale.pdf

Sei Whale (Balaenoptera borealis)

Year listed: 1970
Status: Endangered
General distribution: The range of the Nova Scotia stock includes the continental shelf waters of the northeastern U.S., and extends northeastward to south of Newfoundland. Indications are that, at least during the feeding season, a major portion of the Nova Scotia sei whale stock is centered in northerly waters, perhaps on the Scotian Shelf (Mitchell and Chapman 1977). The southern portion of the species' range during spring and summer includes the northern portions of the U.S. Atlantic Exclusive Economic Zone (EEZ) — the Gulf of Maine and Georges Bank. Spring is the period of greatest abundance in U.S. waters, with sightings concentrated along the eastern margin of Georges Bank and into the Northeast Channel area, and along the southwestern edge of Georges Bank in the area of Hydrographer Canyon (CETAP 1982).
Critical habitat in GAR: None
Additional Information: For additional distribution information, select references, and other relevant information, please visit http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/seiwhale.htm and http://www.nmfs.noaa.gov/pr/sars/pdf/stocks/atlantic/2015/f2015_seiwhale.pdf

Sperm Whale (Physeter macrocephalus)

Year listed: 1970
Status: Endangered
General distribution: Sperm whales feed on larger organisms that inhabit the deeper ocean regions (Whitehead 2002). Calving for the species occurs in low latitude waters. The distribution of the sperm whale in the U.S. Exclusive Economic Zone (EEZ) occurs primarily on the continental shelf edge, over the continental slope, and into mid-ocean regions.
C**ritical habitat in GAR:** None
Additional Information: For additional distribution information, select references, and other relevant information, please visit http://www.fisheries.noaa.gov/pr/species/mammals/whales/sperm-whale.html and http://nefsc.noaa.gov/publications/tm/tm231/63_spermwhale_F2014July.pdf

SEA TURTLES

While sea turtles occur year-round off the southeastern United States, they are generally present in marine and estuarine waters of the GAR from April through November. As water temperatures warm in the spring, sea turtles begin to migrate to nearshore waters and up the U.S. Atlantic coast, occurring in Virginia as early as April/May and in the Gulf of Maine in June. The trend is reversed in the fall with some animals remaining in the GAR until late fall. Outside of these times, sea turtle presence in GAR waters is considered unlikely, although juvenile sea turtles routinely strand on GAR beaches during colder months (i.e., from October to January) as a result of cold-stunning. Nesting is extremely limited in the GAR. Typically, juveniles and, to a lesser extent, adults are present in the GAR. Sea turtles are listed jointly with U.S. Fish and Wildlife Service. For additional distribution information, select references, and other relevant information, please visit https://www greateratlantic.fisheries.noaa.gov/protected/seaturtles/index.html and http://www.nmfs.noaa gov/pr/species/turtles/

Green Sea Turtle (Chelonia mydas)

Year listed: 1978; Eleven Distinct Population Segments (DPSs) designated in 2016
Status: The Central North Pacific, East Indian-West Pacific, East Pacific, North Atlantic, North Indian, South Atlantic, Southwest Indian, and Southwest Pacific DPSs are listed as threatened.
The Central South Pacific, Central West Pacific, and Mediterranean DPSs are listed as endangered. Only the North Atlantic DPS is present in the GAR.
General Distribution: In the U.S. Atlantic, green turtles are occasionally found as far north as New England, but are more commonly seen from New York south. They occur seasonally in GAR waters, including but not limited to the Chesapeake Bay and Long Island Sound, which serve as foraging and developmental habitats.
Critical habitat in GAR: None
Additional Information: http://www.nmfs.noaa.gov/pr/species/turtles/green.html

Hawksbill Turtle (Eretmochelys imbricata)

Year listed: 1970
Status: Endangered
General Distribution: Hawksbill turtles are circumtropical. In the U.S. Atlantic, they are found primarily in Florida and Texas, though they have been recorded along the east coast as far north as Massachusetts. Hawksbills are rare visitors to the waters of the GAR.
Critical habitat in GAR: None
Additional Information: http://www.nmfs.noaa.gov/pr/species/turtles/hawksbill.html

Kemp's Ridley Turtle (Lepidochelys kempii)

Year listed: 1970
Status: Endangered **General Distribution:** Kemp's ridleys typically occur only in the Gulf of Mexico and the northwestern Atlantic. In the U.S. Atlantic, they are found as far north as New England seasonally. Foraging areas in the GAR include, but are not limited to, Chesapeake Bay, Delaware Bay, Cape Cod Bay, and Long Island Sound.
Critical habitat in GAR: None
Additional Information: http://www.nmfs.noaa.gov/pr/species/turtles/kempsridley.html

Leatherback Turtle (*Dermochelys coriacea*)

Year listed: 1970
Status: Endangered
General Distribution: Leatherback sea turtles are globally distributed. They range farther than any other sea turtle species. Although frequently thought of as an oceanic species, they are also known to use coastal waters of the U.S. continental shelf. Juveniles and adults are present in the GAR seasonally and are distributed as far north as Canada.
Critical habitat in GAR: None
Additional Information: http://www.nmfs.noaa.gov/pr/species/turtles/leatherback.html

Loggerhead Turtle (*Caretta caretta*)

Year listed: 1978; Nine Distinct Population Segments (DPSs) designated in 2011
Status: The Northwest Atlantic, South Atlantic, Southeast Indo-Pacific, and Southwest Indian Ocean DPSs are listed as threatened. The Northeast Atlantic, Mediterranean, North Indian, North Pacific, and South Pacific Ocean DPSs are listed as endangered. Only the Northwest Atlantic DPS is present in the GAR.
General Distribution: Loggerheads, the most abundant species of sea turtle in U.S. waters, have a temperate and subtropical distribution, including offshore waters, continental shelves, bays, estuaries, and lagoons. In the U.S. Atlantic, their range extends north to southern Canada. They most commonly occur throughout the inner continental shelf from Florida to Massachusetts. As with other sea turtle species, their presence in the GAR varies seasonally.
Critical habitat in GAR: Sargassum critical habitat in offshore waters associated with the Gulf Stream current off Maryland and Virginia.
Additional Information: http://www.nmfs.noaa gov/pr/species/turtles/loggerhead.html and http://www.nmfs.noaa.gov/pr/species/turtles/criticalhabitat_loggerhead.htm

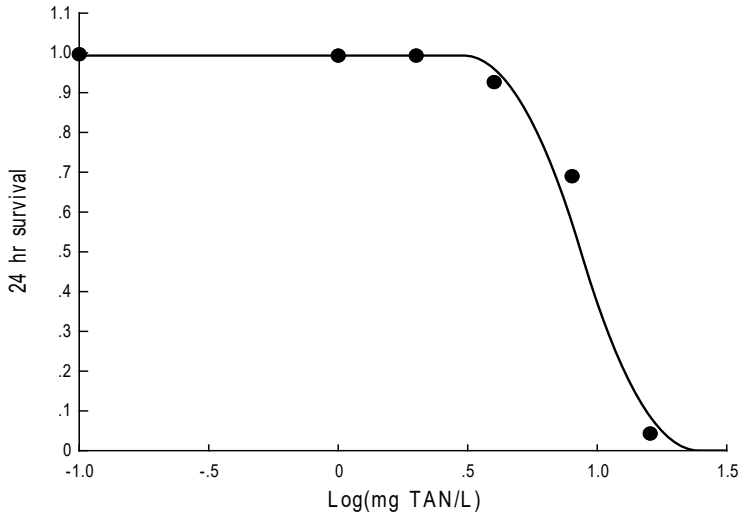
Appendix A

Test Information, C-R Data and Resulting TRAP models for Acute and Chronic Ammonia Toxicity Tests Considered Acceptable or Unacceptable for TAF and MAF Calculation

Appendix A.1

Test Information, C-R Data and Resulting TRAP models for Acute Ammonia Toxicity Tests Acceptable for TAF and MAF Calculation

Wang et al. 2007b	
Species: *Actinonaias ligamentina* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-2	
Test: #4 (May 2004)	
TAN, mg/L	**Proportion Surviving**
0.1	1.00
1	0.99
2	0.99
4	0.93
8	0.69
16	0.04

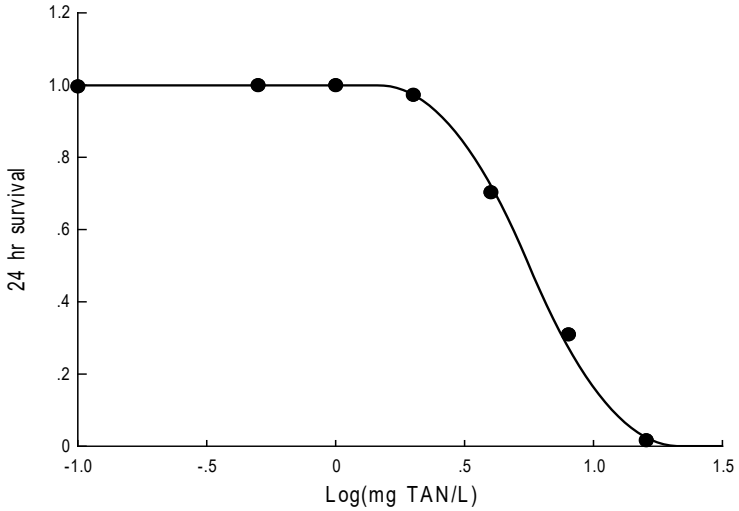


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	0.93857	0.009828	0.91925	0.9579
StDev	0.15	0.18521	0.008317	0.17024	0.20308
Y0	0.99	0.99306	0.002758	0.98521	0.99737
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**8.6811**	8.3032	9.0761	0.009828	0.93857
20	5.9133	5.5987	6.2456	0.012049	0.77183
10	4.873	4.5603	5.2071	0.014581	0.68779
5	**4.2498**	3.9383	4.5859	0.016693	0.62837
0	3.0543	2.7563	3.3845	0.022336	0.48491

LC50:LC5 = 2.043

Notes: Acceptable model fit.

Wang et al. 2007b	
Species: *Actinonaias ligamentina* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-3	
Test: #2 (repeat)	
TAN, mg/L	**Proportion Surviving**
0.1	1.00
0.5	1.00
1	1.00
2	0.97
4	0.70
8	0.31
16	0.02



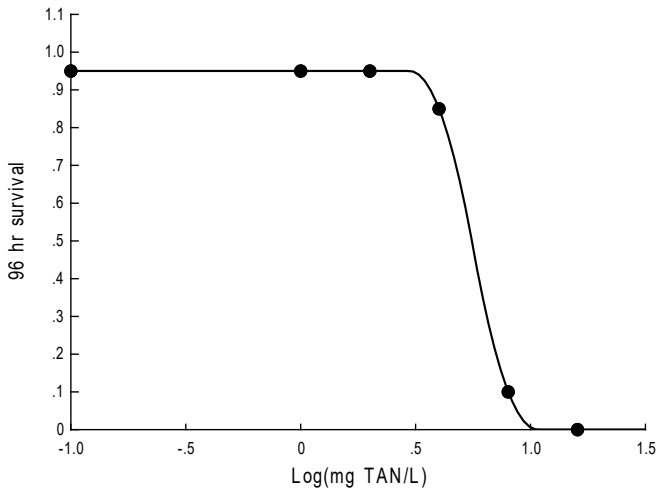
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.75	0.75079	1.09E-02	0.72933	0.77225
StDev	0.24	0.23728	8.23E-03	0.22218	0.2546
Y0	0.99	0.99888	1.11E-03	0.99382	0.99997

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**5.6337**	5.3621	5.9191	1.09E-02	0.75079
20	3.4449	3.2421	3.6602	1.34E-02	0.53717
10	2.6885	2.4997	2.8915	1.60E-02	0.42951
5	**2.2562**	2.0806	2.4466	1.78E-02	0.35338
0	1.4777	1.3299	1.6419	2.31E-02	0.16958

LC50:LC5 = 2.497

Notes: Acceptable model fit.

Wang et 2007b	
Species: *Epioblasma capsaeformis* (new juvenile)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-6	
Test: Single	
TAN, mg/L	**% Survival**
0.1	95
1	95
2	95
4	85
8	10
16	0



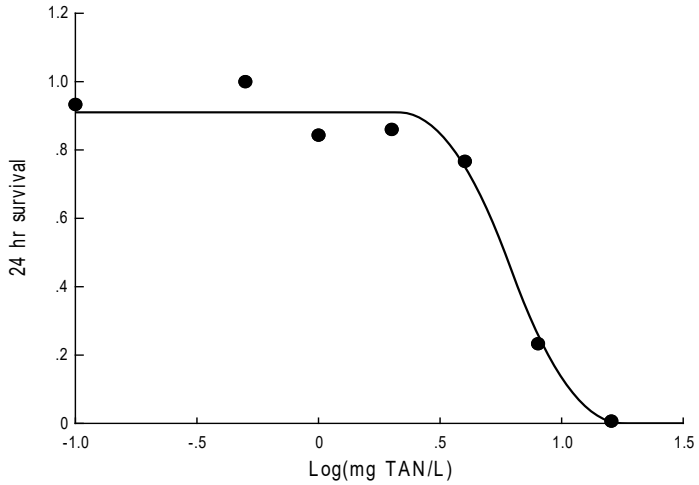
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.75	0.75255	0.034464	0.67656	0.82853
StDev	0.11	0.11353	0.025659	0.079324	0.19923
Y0	0.95	0.95	0.028137	0.86075	0.98957

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**5.6565**	4.7486	6.7379	0.034464	0.75255
20	4.4703	3.5024	5.7057	0.045464	0.65034
10	3.9703	2.9064	5.4236	0.053986	0.59882
5	**3.6509**	2.5026	5.326	0.060716	0.5624
0	2.9817	1.5767	5.6385	0.078497	0.47446

LC50:LC5 = 1.549

Notes: No errors.

Wang et al. 2007b	
Species: *Epioblasma capsaeformis* (glochidia)	
Test Endpoint: 6 hr Survival	
C-R Curve Label: Am-Acute-7	
Test: #1	
TAN, mg/L	**Proportion Surviving**
0.1	0.93
0.5	1.00
1	0.84
2	0.86
4	0.77
8	0.23
16	0.01



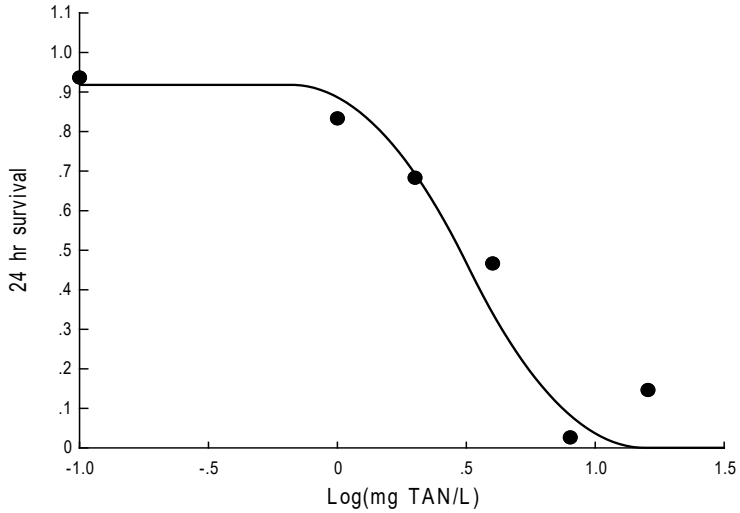
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.8	0.78992	0.013044	0.76421	0.81564
StDev	0.2	0.18742	0.009212	0.17098	0.2074
Y0	0.96667	0.90987	0.00825	0.89227	0.92543

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**6.1649**	5.8104	6.541	0.013044	0.78992
20	4.1801	3.8162	4.5787	0.020016	0.62119
10	3.4367	3.1033	3.806	0.022361	0.53614
5	**2.9923**	2.6691	3.3547	0.024973	0.47601
0	2.1421	1.8533	2.4758	0.031329	0.33083

LC50:LC5 = 2.060

Notes: Acceptable model fit. Acceptable noise at low level effects.

Wang et al. 2007b	
Species: *Epioblasma capsaeformis* (glochidia)	
Test Endpoint: 6 hr Survival	
C-R Curve Label: Am-Acute-8	
Test: #2	
TAN, mg/L	**Proportion Surviving**
0.1	0.94
1	0.83
2	0.68
4	0.47
8	0.03
16	0.15



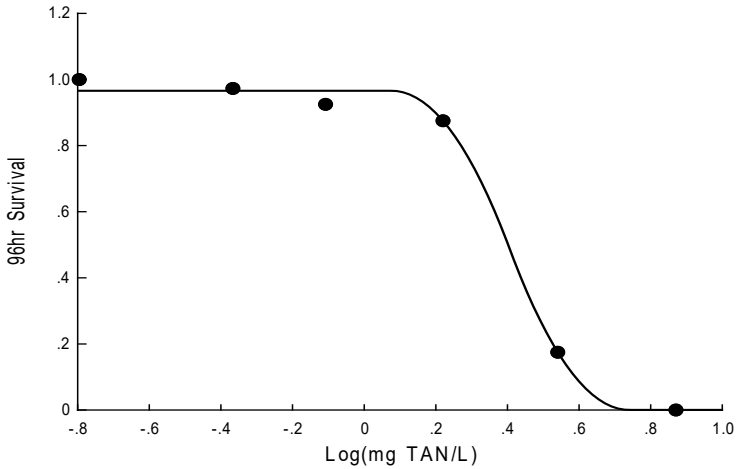
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.5	0.50716	0.018114	0.47148	0.54285
StDev	0.28	0.27994	0.017198	0.24991	0.31825
Y0	0.94	0.91793	0.014673	0.88407	0.94447

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**3.2149**	2.9613	3.4902	0.018114	0.50716
20	1.7994	1.5815	2.0474	0.028359	0.25513
10	1.3431	1.1433	1.5778	0.035207	0.12811
5	**1.0922**	0.90698	1.3152	0.040435	0.038292
0	0.6629	0.51582	0.85193	0.053785	-0.17855

LC50:LC5 = 2.944

Notes: Acceptable model fit.

Wang et al. 2007a	
Species: *Lampsilis abrupta* (2 month old)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-10	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.16	1.00
0.43	0.97
0.78	0.93
1.66	0.88
3.47	0.18
7.42	0



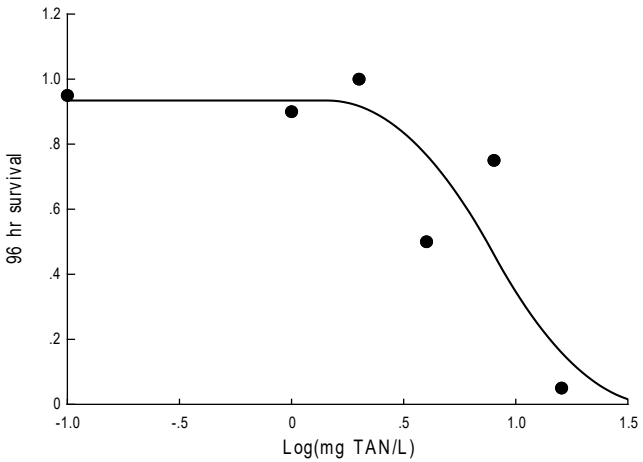
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.4	0.40814	0.02711	0.3523	0.46397
StDev	0.13	0.13554	0.023196	0.10176	0.20299
Y0	0.97	0.96581	0.0168	0.91478	0.99061

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**2.5594**	2.2506	2.9105	0.02711	0.40814
20	1.9324	1.6275	2.2946	0.035129	0.28611
10	1.6773	1.3506	2.0829	0.042577	0.2246
5	**1.5175**	1.1734	1.9623	0.048613	0.18112
0	1.1916	0.79606	1.7836	0.066543	0.076123

LC50:LC5 = 1.687

Notes: Acceptable model fit. Acceptable noise at low level effects.

Wang et al. 2007b	
Species: *Lampsilis fasciola* (<5 d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-12	
Test: Single	
TAN, mg/L	**Proportion Surviving**
0.1	0.95
1	0.90
2	1.00
4	0.50
8	0.75
16	0.05

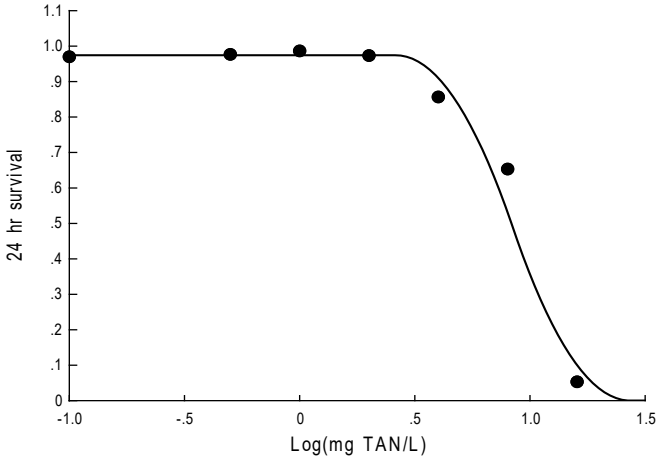


Log X50	0.85	0.89742	6.39E-02	0.76489	1.0299
StDev	0.125	0.30069	7.56E-02	0.2101	0.52769
Y0	0.95	0.93385	3.71E-02	0.81789	0.98629
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**7.8962**	5.8196	10.714	6.39E-02	0.89742
20	4.2336	2.5558	7.0128	0.10028	0.62671
10	3.0922	1.5358	6.2258	0.12962	0.49027
5	**2.4762**	1.0251	5.9816	0.15227	0.39379
0	1.4484	0.18444	11.374	0.27561	0.16088

LC50:LC5 = 3.189

Notes: Acceptable model fit. Acceptable noise at low level effects.

Wang et al. 2007b	
Species: *Lampsilis fasciola* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-13	
Test: #1	
TAN, mg/L	**Proportion Surviving**
0.1	0.97
0.5	0.98
1	0.99
2	0.97
4	0.86
8	0.65
16	0.05

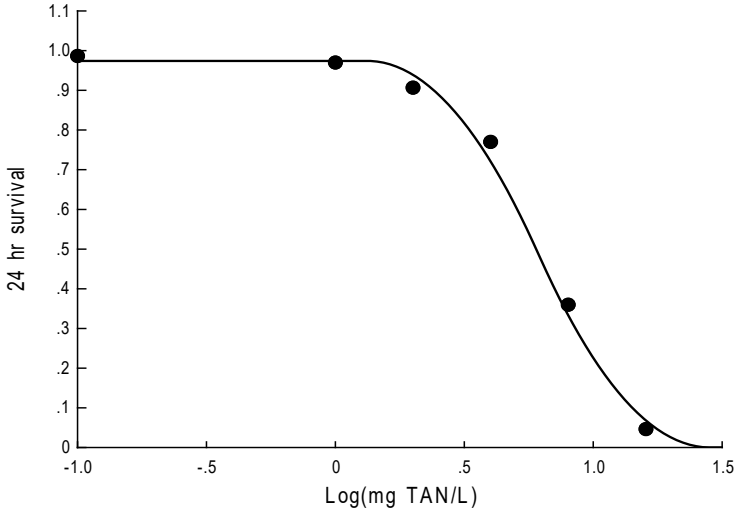


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.9	0.92607	0.011188	0.90406	0.94808
StDev	0.2	0.20774	0.010788	0.18858	0.23128
Y0	0.975	0.97421	0.004558	0.96363	0.98239
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**8.4347**	8.018	8.8731	0.011188	0.92607
20	5.4833	5.1181	5.8744	0.015175	0.73904
10	4.4134	4.0495	4.81	0.018886	0.64477
5	**3.7855**	3.4256	4.1832	0.021857	0.57812
0	2.6134	2.2794	2.9963	0.029602	0.4172

LC50:LC5 = 2.228

Notes: Acceptable model fit.

Wang et al. 2007b	
Species: *Lampsilis fasciola* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-14	
Test: #2	
TAN, mg/L	**Proportion Surviving**
0.1	0.99
1	0.97
2	0.91
4	0.77
8	0.36
16	0.05



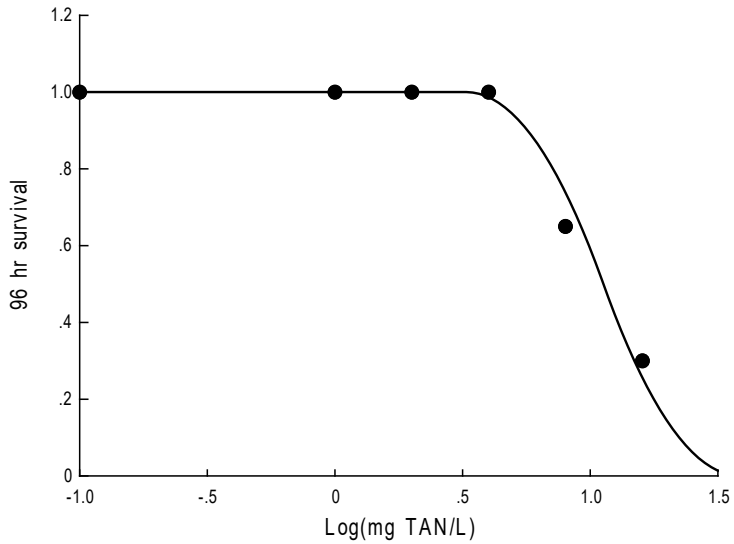
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.8	0.78769	0.013841	0.76048	0.8149
StDev	0.27	0.27148	0.012501	0.24903	0.29841
Y0	0.975	0.97397	0.006384	0.95819	0.98499

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**6.1333**	5.7607	6.5299	0.013841	0.78769
20	3.4937	3.2015	3.8124	0.019247	0.54328
10	2.6309	2.3628	2.9294	0.023628	0.4201
5	**2.1527**	1.9025	2.4359	0.027097	0.33299
0	1.3265	1.1245	1.5648	0.035932	0.12271

LC50:LC5 = 2.849

Notes: Acceptable model fit.

Wang et 2007b	
Species: *Lampsilis rafinesqueana* (<5-d old juvenile)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-16	
Test: #2	
TAN, mg/L	**Proportion Surviving**
0.1	1.00
1	1.00
2	1.00
4	1.00
8	0.65
16	0.30



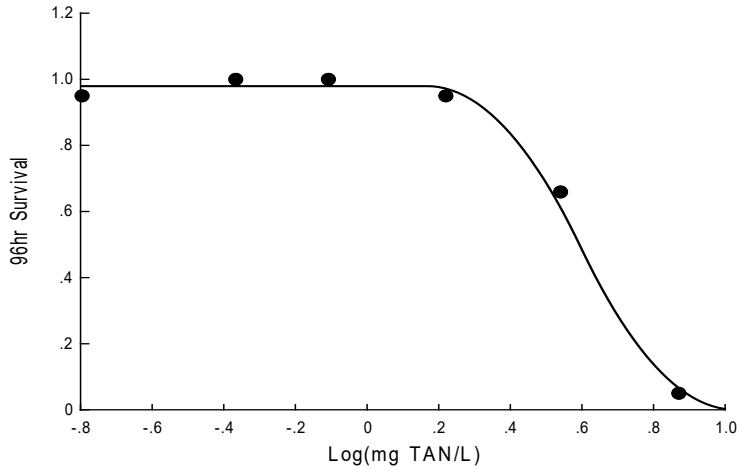
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.05	1.0514	0.049466	0.94814	1.1548
StDev	0.22	0.21914	0.040601	0.16127	0.34185
Y0	1	0.9999	0.001302	0.93921	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**11.258**	8.8744	14.281	0.049466	1.0514
20	7.1476	5.6646	9.0188	0.046632	0.85416
10	5.685	4.2663	7.5754	0.054905	0.75473
5	**4.8352**	3.4138	6.8486	0.063538	0.68442
0	3.271	1.8264	5.858	0.090157	0.51468

LC50:LC5 = 2.328

Notes: Acceptable model fit.

Wang et al. 2007a	
Species: *Lampsilis siliquoidea* (2 month old)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-21	
Test: Single	
TAN, mg/L	**Proportion Surviving**
0.16	0.95
0.43	1.00
0.78	1.00
1.66	0.95
3.47	0.66
7.42	0.05

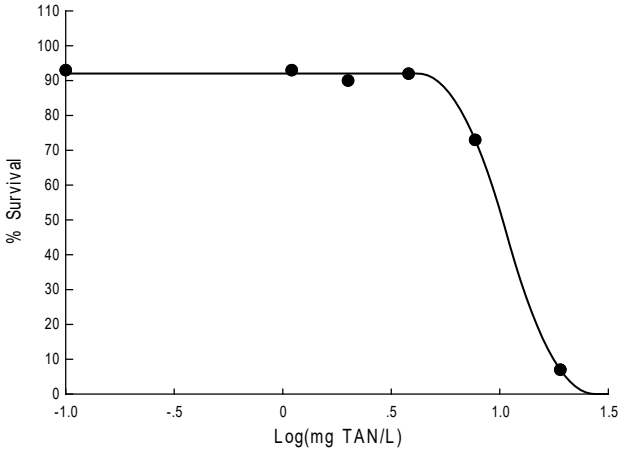


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.6	0.59762	0.029248	0.53831	0.65693
StDev	0.175	0.17581	0.02571	0.13689	0.24582
Y0	0.975	0.97917	0.012371	0.93808	0.99605
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**3.9593**	3.4539	4.5387	0.029248	0.59762
20	2.75	2.261	3.3448	0.041028	0.43934
10	2.2886	1.7887	2.9281	0.0502	0.35956
5	**2.0098**	1.5037	2.6862	0.057487	0.30315
0	1.4688	0.96539	2.2348	0.07565	0.16697

LC50:LC5 = 1.970

Notes: Acceptable model fit.

Wang et al. 2008	
Species: *Lampsilis siliquoidea* (7 d old juvenile)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-22	
Test: Experiment 1- pH=7.5	
TAN, mg/L	**% Survival**
Control (0.1)	93
1.1	93
2	90
3.8	92
7.7	73
19	7



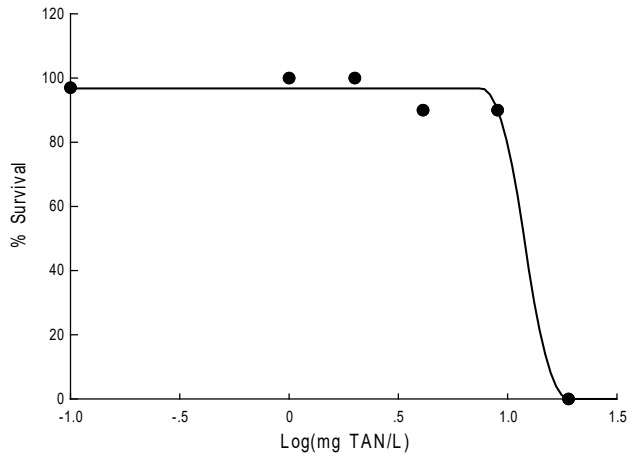
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	1.0314	0.008905	1.0031	1.0597
S	2.5	2.4657	0.11927	2.0862	2.8453
Y0	93	92	0.70711	89.75	94.25

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**10.75**	10.071	11.475	0.008905	1.0314
20	7.6268	7.0596	8.2396	0.010547	0.88234
10	6.4153	5.7742	7.1275	0.014367	0.80722
5	**5.6767**	4.6074	6.9941	0.02848	0.75409
0	4.2252	3.4558	5.1659	0.027431	0.62585

LC50:LC5 = 1.894

Notes: Acceptable model fit.

Wang et al. 2008	
Species: *Lampsilis siliquoidea* (7 d old juvenile)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-27	
Test: Experiment 2- pH=8.0	
TAN, mg/L	**% Survival**
Control	97
1	100
2	100
4.1	90
9	90
19	0



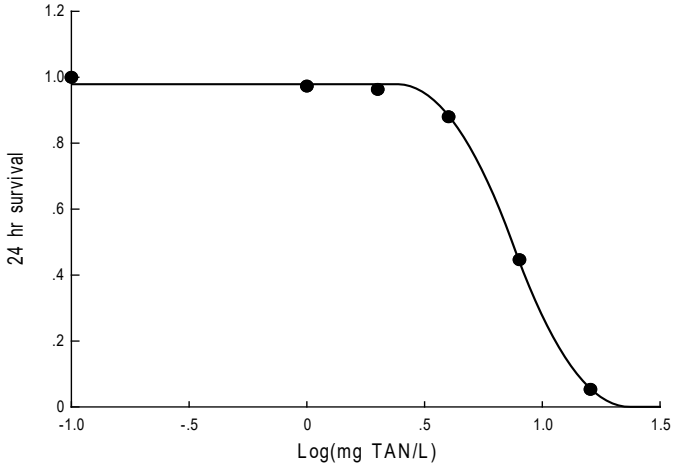
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.94835	1.0794	2.1634	-5.8056	7.9643
S	1.7806	5.0067	86.564	-270.48	280.49
Y0	99	96.75	2.3585	89.244	104.26

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**12.005**			2.1634	1.0794
20	10.138	8.2192	12.505	0.028634	1.006
10	9.3102	7.6099	11.39	0.027518	0.96896
5	**8.7659**	7.0464	10.905	0.029797	0.94279
0	7.5794	5.8344	9.8462	0.035706	0.87963

LC50:LC5 = 1.370

Notes: Acceptable model fit. Acceptable noise at low level effects.

Wang et al. 2007b	
Species: *Lampsilis siliquoidea* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-32	
Test: #7 (September 2004)	
TAN, mg/L	**Proportion surviving**
0.1	1.00
1	0.97
2	0.96
4	0.88
8	0.45
16	0.05



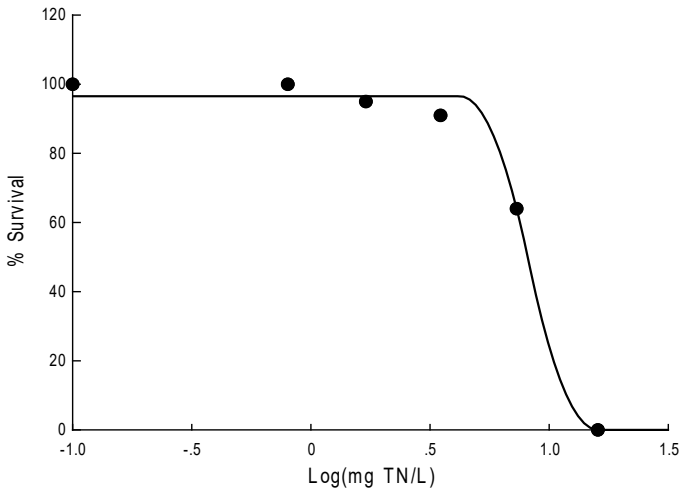
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.88	0.87718	0.010836	0.85587	0.8985
StDev	0.2	0.20119	0.009775	0.18371	0.22236
Y0	0.99	0.97877	0.004793	0.96712	0.98713

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**7.5367**	7.1758	7.9158	0.010836	0.87718
20	4.9666	4.6296	5.3281	0.015477	0.69606
10	4.025	3.69	4.3904	0.019086	0.60477
5	**3.4691**	3.1373	3.8361	0.022024	0.54022
0	2.4232	2.1222	2.7668	0.028782	0.38438

LC50:LC5 = 2.173

Notes: Acceptable model fit.

Wang et al. 2017	
Species: *Margaritifera falcata*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-34	
Test: Single	
TN, mg/L	**% Survival**
0.1	100
0.8	100
1.7	95
3.5	91
7.3	64
16	0



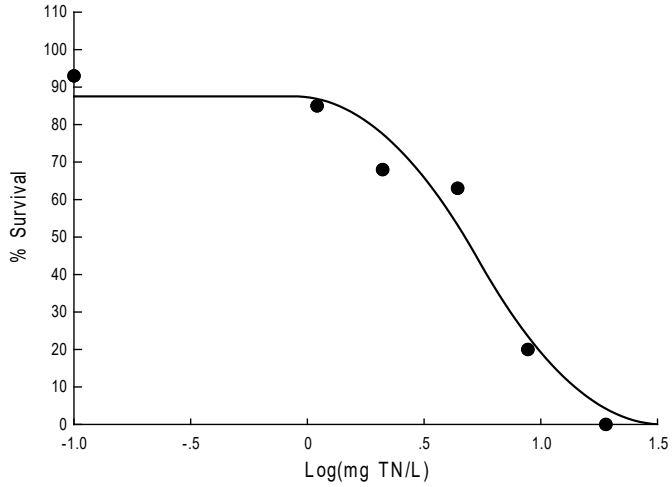
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	0.91515	5.1505	-15.476	17.306
S	2.5	3.4592	343.77	-1090.6	1097.5
Y0	98.333	96.5	2.1794	89.564	103.44

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**8.2253**			5.1505	0.91515
20	6.4402	5.2384	7.9177	0.028186	0.8089
10	5.6931	4.5833	7.0716	0.02959	0.75535
5	**5.2178**	4.1803	6.5127	0.030252	0.71748
0	4.2274	3.3245	5.3755	0.032788	0.62607

LC50:LC5 = 1.576

Notes: Acceptable model fit. Acceptable noise at low level effects.

Wang et al. 2017	
Species: *Megalonaias nervosa*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-35	
Test: Single	
TAN, mg/L	**% Survival**
0.1	93
1.1	85
2.1	68
4.4	63
8.8	20
19	0



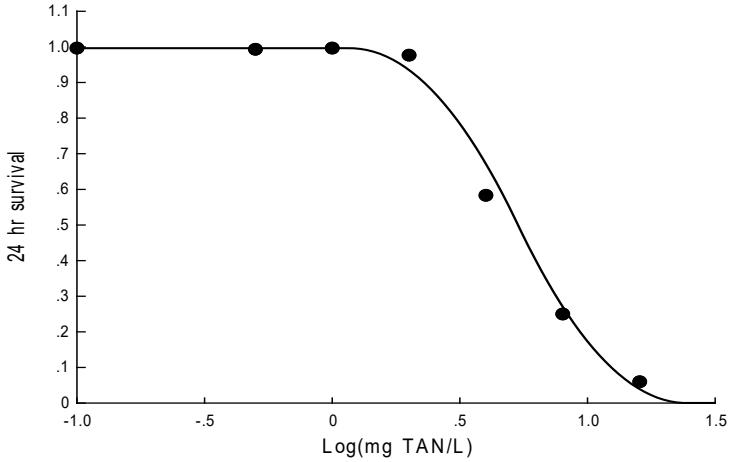
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.75	0.73401	0.080828	0.47678	0.99124
S	1.5	1.2681	0.37768	0.066098	2.47
Y0	89	87.512	7.1908	64.628	110.4

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**5.4202**	2.9977	9.8004	0.080828	0.73401
20	2.7808	1.0003	7.73	0.13952	0.44416
10	1.9865	0.47138	8.3713	0.1963	0.29808
5	**1.566**	0.24759	9.9044	0.25171	0.19478
0	0.88187	0.090045	8.6367	0.31138	-0.0546

LC50:LC5 = 3.461

Notes: Acceptable model fit. Acceptable noise at low level effects. New acute value added since 2013 ALC document.

Wang et al. 2007b	
Species: *Venustaconcha ellipsiformis* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-40	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.1	1.00
0.5	0.99
1	1.00
2	0.98
4	0.58
8	0.25
16	0.06



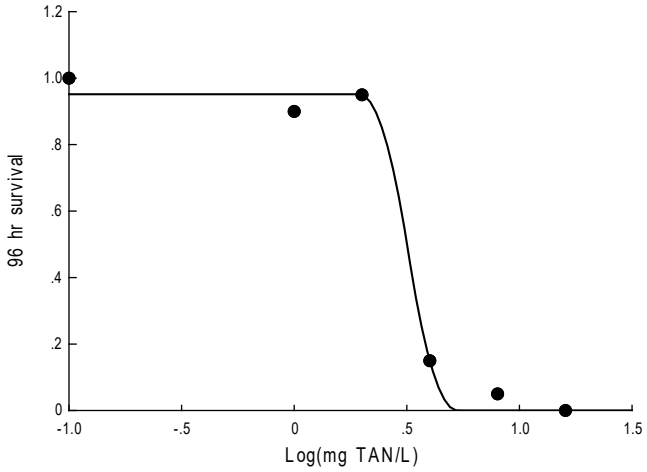
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.73	0.72917	0.012311	0.70498	0.75336
StDev	0.27	0.26901	0.010504	0.24991	0.29131
Y0	0.99	0.99604	0.002091	0.98937	0.99902

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**5.3601**	5.0697	5.6671	0.012311	0.72917
20	3.0689	2.8519	3.3023	0.016182	0.48698
10	2.3169	2.1193	2.533	0.019642	0.36491
5	**1.8993**	1.7137	2.1051	0.022613	0.2786
0	1.1755	1.0274	1.345	0.029442	0.070222

LC50:LC5 = 2.822

Notes: Acceptable model fit.

Wang et al. 2007b	
Species: *Villosa iris* (2 month old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-41	
Test: #1	
TAN, mg/L	**Proportion surviving**
0.1	1.00
1	0.90
2	0.95
4	0.15
8	0.05
16	0



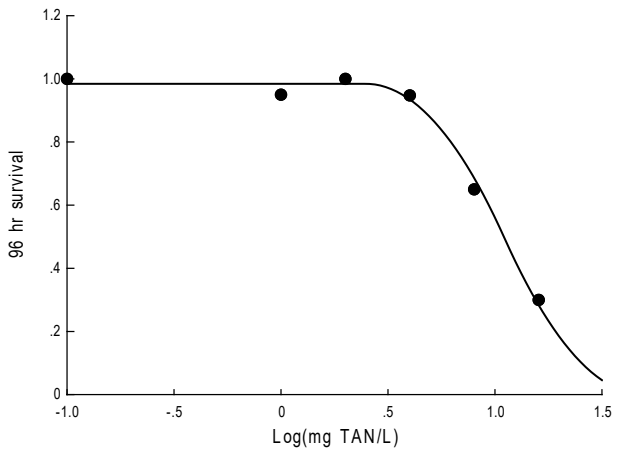
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.61275	0.50693	0.088136	0.31056	0.70331
StDev	0.1	0.088552	0.078816	0.061873	0.1554
Y0	0.95	0.95122	0.034059	0.83256	0.99427

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**3.2132**	2.0443	5.0503	0.088136	0.50693
20	2.6743	1.1454	6.2443	0.15626	0.42721
10	2.438	0.79667	7.4608	0.19134	0.38703
5	**2.2836**	0.58506	8.9134	0.2163	0.35862
0	1.95	0.19949	19.06	0.27698	0.29003

LC50:LC5 = 1.407

Notes: Large SE for StDev, but acceptable model fit. Acceptable noise at low level effects.

Wang et al. 2007b	
Species: *Villosa iris* (2 month old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-42	
Test: #2	
TAN, mg/L	**Proportion surviving**
0.1	1.00
1	0.95
2	1.00
4	0.95
8	0.65
16	0.30

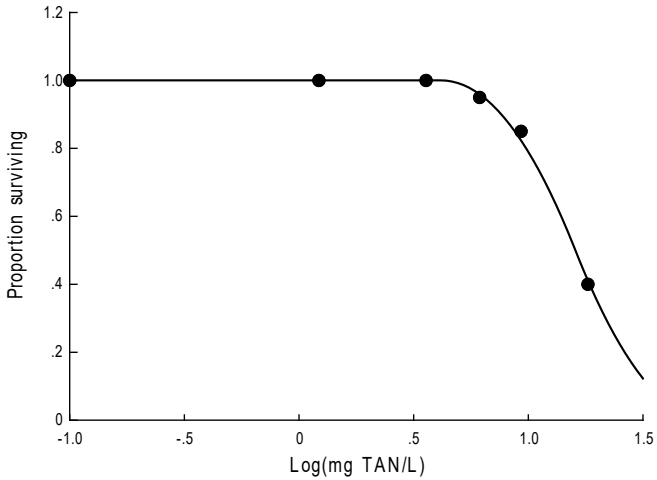


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.05	1.0467	0.059845	0.92174	1.1716
StDev	0.27	0.26597	0.065	0.18584	0.46676
Y0	0.98	0.98412	0.015963	0.91316	0.99963
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**11.135**	8.351	14.846	0.059845	1.0467
20	6.4154	4.5375	9.0704	0.068312	0.80722
10	4.8589	3.003	7.8618	0.088451	0.68654
5	**3.9921**	2.1499	7.4129	0.106	0.6012
0	2.4842	0.77312	7.982	0.15465	0.39518

LC50:LC5 = 2.789

Notes: Acceptable model fit.

Scheller et al 1997	
Species: *Villosa iris*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-43	
Test: 5-d old juveniles	
TAN, mg/L	**Proportion surviving**
Control	1.00
1.22	1.00
3.58	1.00
6.13	0.95
9.29	0.85
18.18	0.40



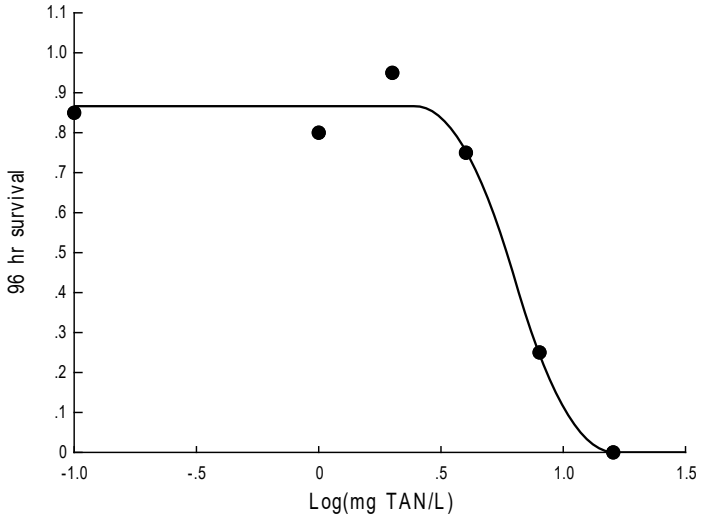
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.2	1.2051	0.05971	1.0785	1.3317
S	0.24	0.23856	0.056116	0.16668	0.41865
Y0	1	0.9999	0.001291	0.94017	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**16.036**	11.981	21.464	0.05971	1.2051
20	9.7799	7.5985	12.587	0.04898	0.99033
10	7.6224	5.4563	10.648	0.060406	0.88209
5	**6.3907**	4.13	9.8889	0.073434	0.80555
0	4.176	1.7273	10.097	0.11456	0.62076

LC50:LC5 = 2.509

Notes: Acceptable model fit.

Wang et 2007b	
Species: *Villosa iris* (<5-d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-44	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.1	0.85
1	0.80
2	0.95
4	0.75
8	0.25
16	0



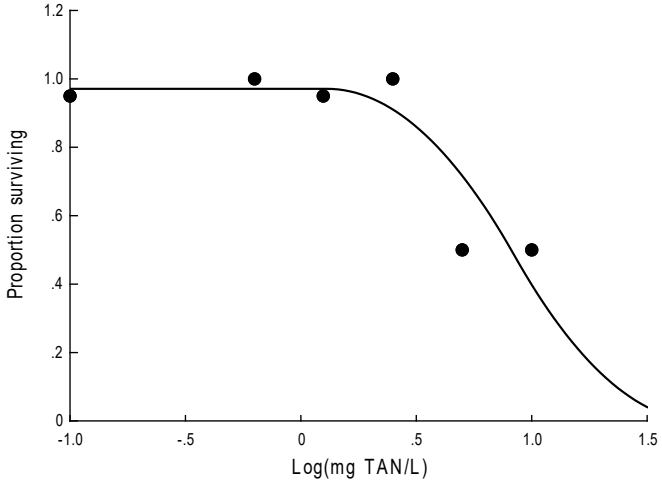
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.8	0.80187	0.051785	0.68692	0.91682
StDev	0.17	0.16609	0.040031	0.11605	0.29147
Y0	0.875	0.86624	0.04369	0.75437	0.94

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**6.3368**	4.8632	8.2569	0.051785	0.80187
20	4.491	3.0289	6.6588	0.072866	0.65234
10	3.7755	2.2949	6.2114	0.085519	0.57698
5	**3.3396**	1.8435	6.0497	0.094785	0.52369
0	2.4834	0.95129	6.4828	0.11716	0.39504

LC50:LC5 = 1.897

Notes: Acceptable model fit. Acceptable noise at low level effects.

Scheller 1997	
Species: *Villosa iris*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-46	
Test: <3-d old juveniles	
TAN, mg/L	**Proportion surviving**
Control	0.95
0.63	1.00
1.25	0.95
2.5	1.00
5	0.50
10	0.50



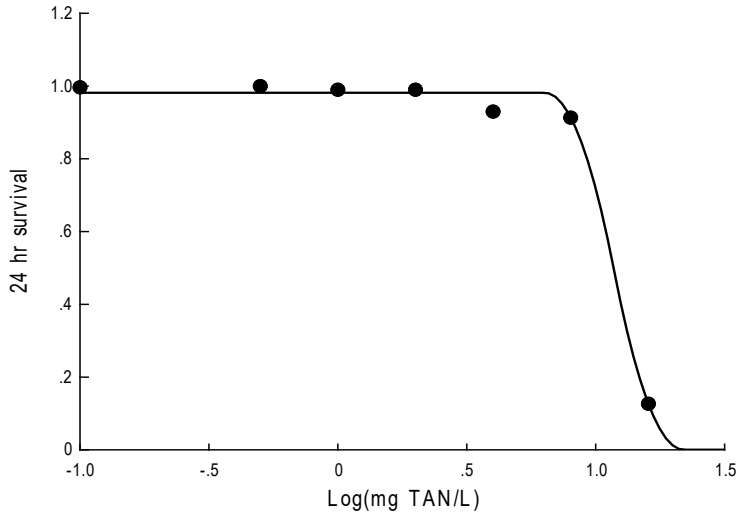
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.9	0.92326	0.081508	0.75087	1.0956
S	0.3	0.33081	0.099296	0.23114	0.58054
Y0	0.975	0.97062	0.021752	0.89091	0.99708

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**8.3803**	5.6347	12.464	0.081508	0.92326
20	4.2212	2.7089	6.5777	0.086312	0.62543
10	2.9877	1.5575	5.7309	0.11802	0.47533
5	**2.3399**	0.98411	5.5634	0.14611	0.36919
0	1.297	0.23122	7.2759	0.22453	0.11295

LC50:LC5 = 3.581

Notes: Acceptable model fit. Acceptable noise at low level effects.

Wang et al. 2007b	
Species: *Villosa iris* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-48	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.1	1.00
0.5	1.00
1	0.99
2	0.99
4	0.93
8	0.91
16	0.13

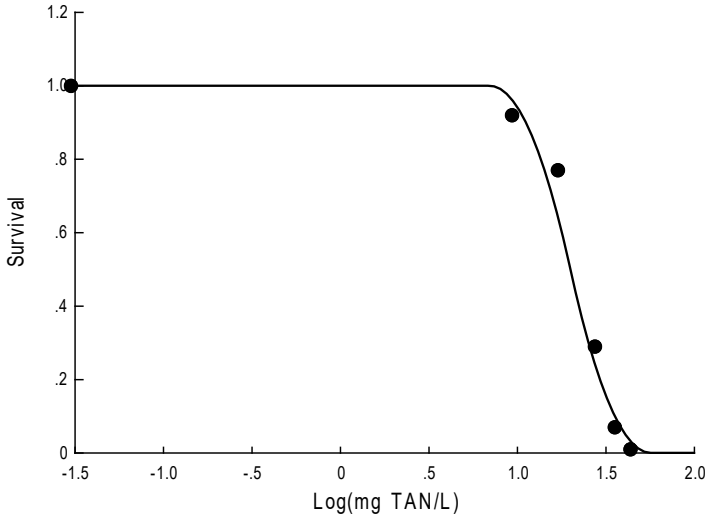


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.05	1.0718	0.007919	1.0562	1.0875
StDev	0.11	0.10975	0.005819	0.09943	0.12247
Y0	0.99	0.98133	0.003495	0.97313	0.98756
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**11.799**	11.382	12.231	0.007919	1.0718
20	9.3979	8.9922	9.8218	0.009688	0.97303
10	8.3798	7.9543	8.8279	0.0114	0.92323
5	**7.7271**	7.2862	8.1947	0.012812	0.88802
0	6.3534	5.8808	6.864	0.016671	0.80301

LC50:LC5 = 1.527

Notes: Acceptable model fit. Acceptable noise at low level effects.

Anderson and Buckley 1998	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Am-Acute-49	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.03	1.00
9.31	0.92
16.91	0.77
27.42	0.29
35.48	0.07
43.55	0.01



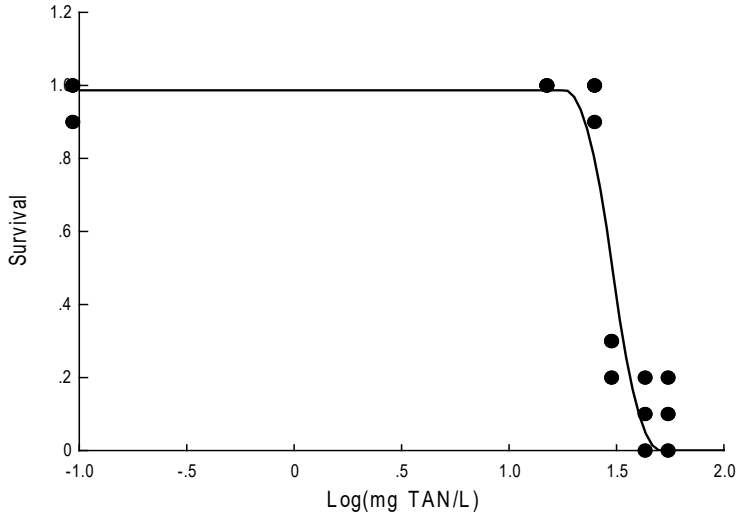
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.3	1.299	0.013526	1.2724	1.3257
StDev	0.19	0.18561	0.010662	0.16686	0.20915
Y0	1	0.9999	0.0010204	0.96358	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**19.909**	18.722	21.17	0.013526	1.299
20	13.55	12.454	14.742	0.018504	1.1319
10	11.161	10.082	12.356	0.022222	1.0477
5	**9.7311**	8.6721	10.919	0.025079	0.98816
0	6.9886	6.0123	8.1234	0.032328	0.84439

LC50:LC5 = 2.046

Notes: Acceptable model fit.

Sarda 1994	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Am-Acute-50	
Test: 2/22/93 Recon hard water	
TAN, mg/L	**Proportion surviving**
low	1.00
low	0.90
low	1.00
13.5	1.00
13.5	1.00
13.5	1.00
20.4	1.00
20.4	0.90
20.4	1.00
28	0.30
28	0.20
28	0.30
40	0.20
40	0.10
40	0
52	0.20
52	0
52	0.10



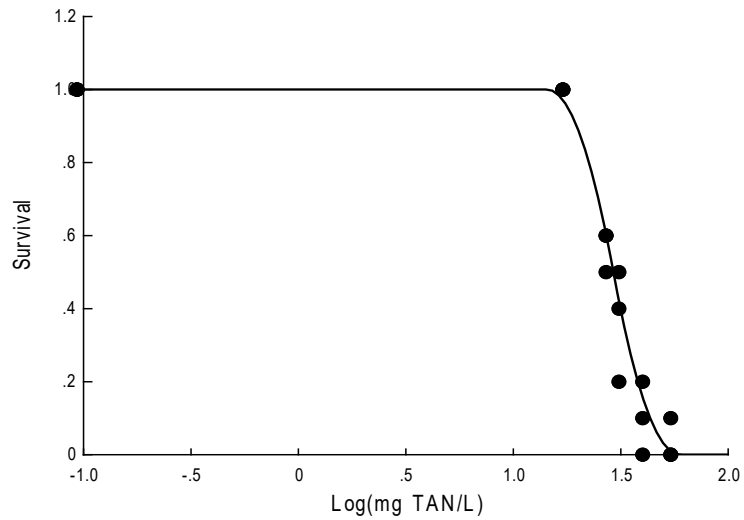
LC50:LC5 = 1.419

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.4825	0.014583	1.453	1.512
StDev	0.075	0.090662	0.014742	0.068909	0.13256
Y0	1	0.9865	0.014882	0.91597	0.99984

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**30.373**	28.378	32.508	0.014583	1.4825
20	25.169	22.745	27.851	0.021153	1.4009
10	22.894	20.069	26.116	0.026561	1.3597
5	**21.411**	18.042	25.408	0.033364	1.3306
0	18.214	14.357	23.107	0.041142	1.2604

Notes: Acceptable model fit.

Sarda 1994	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Am-Acute-51	
Test: 2/25/93 Recon hard water	
TAN, mg/L	**Proportion surviving**
low	1.00
low	1.00
low	1.00
15.2	1.00
15.2	1.00
15.2	1.00
25.3	0.60
25.3	0.60
25.3	0.50
29.6	0.50
29.6	0.40
29.6	0.20
39	0.20
39	0.10
39	0
50.2	0.10
50.2	0
50.2	0



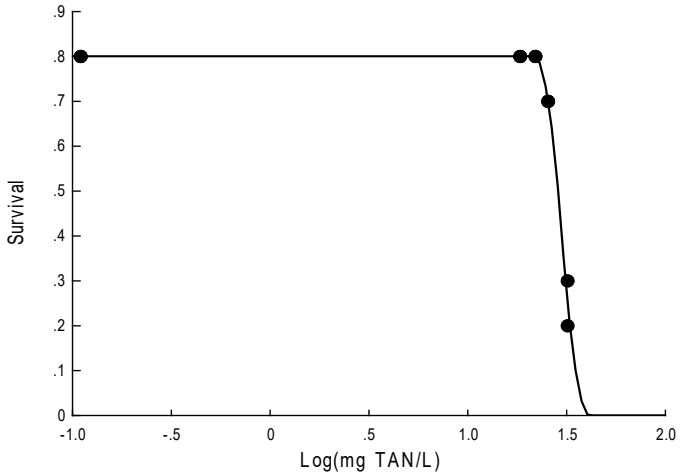
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.4658	0.015815	1.4342	1.4974
StDev	0.125	0.12632	0.013111	0.10504	0.15847
Y0	1	0.9999	0.001825	0.88418	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**29.23**	27.179	31.436	0.015815	1.4658
20	22.496	20.35	24.869	0.021558	1.3521
10	19.715	17.434	22.295	0.026081	1.2948
5	**17.958**	15.594	20.681	0.029546	1.2543
0	14.336	11.839	17.359	0.038297	1.1564

LC50:LC5 = 1.628

Notes: Acceptable model fit.

Hazel et al. 1979	
Species: *Stenelmis sexlineata*	
Test Endpoint: 4 day Survival	
C-R Curve Label: Am-Acute-53	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.11	0.8
0.11	0.8
18.4	0.8
18.4	0.8
22	0.8
22	0.8
25.5	0.7
25.5	0.7
32	0.3
32	0.2



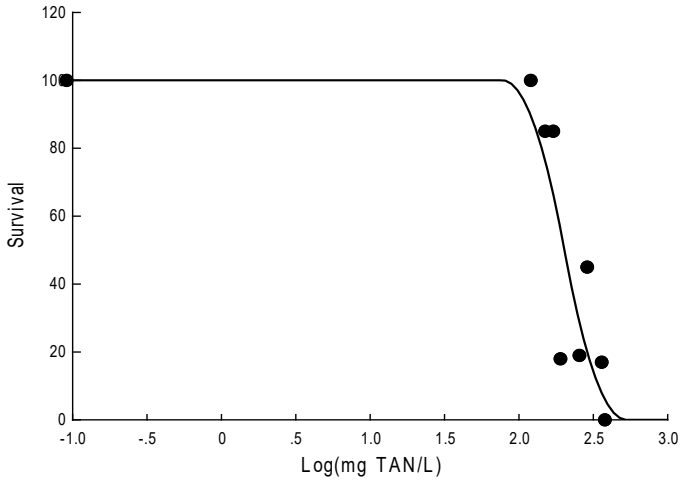
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.476	0.019937	1.4316	1.5204
StDev	0.05	0.05675	0.025296	0.039652	0.099593
Y0	0.8	0.80019	0.053584	0.67142	0.89534

LC50:LC5 = 1.245

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**29.923**	27.014	33.146	0.019937	1.476
20	26.602	22.229	31.835	0.03309	1.4249
10	25.071	19.503	32.228	0.042963	1.3992
5	**24.041**	17.491	33.045	0.050525	1.381
0	21.727	12.195	38.709	0.070165	1.337

Notes: Acceptable model fit.

Wicks et al. 2002	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 4 day Survival	
C-R Curve Label: Am-Acute-56	
Test: Resting Fish	
TAN, mg/L	**% Survival**
0.05	100
120	100
150	85
170	85
190	18
255	19
287.5	45
360	17
378	0



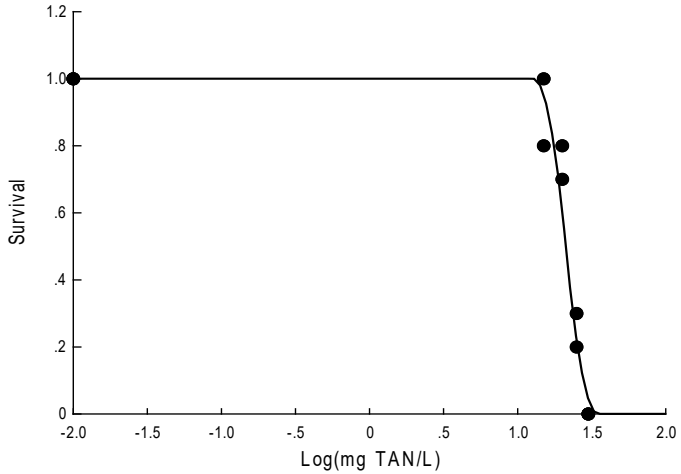
LC50:LC5 = 1.925

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.75	2.3058	0.044845	2.1998	2.4119
S	5	2.4047	0.84223	0.41319	4.3963
Y0	100	100			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**202.23**	158.41	258.16	0.044845	2.3058
20	142.23	96.037	210.65	0.072129	2.153
10	119.11	67.103	211.44	0.1054	2.076
5	**105.07**	47.994	230.04	0.14391	2.0215
0	77.624	23.97	251.37	0.21581	1.89

Notes: Acceptable model fit.

Hazel et al. 1979	
Species: *Cyprinella lutrensis*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-58	
Test: #2	
TAN, mg/L	**Proportion surviving**
0.01	1.0
0.01	1.0
15	1.0
15	0.8
20	0.7
20	0.8
25	0.3
25	0.2
30	0.0
30	0.0



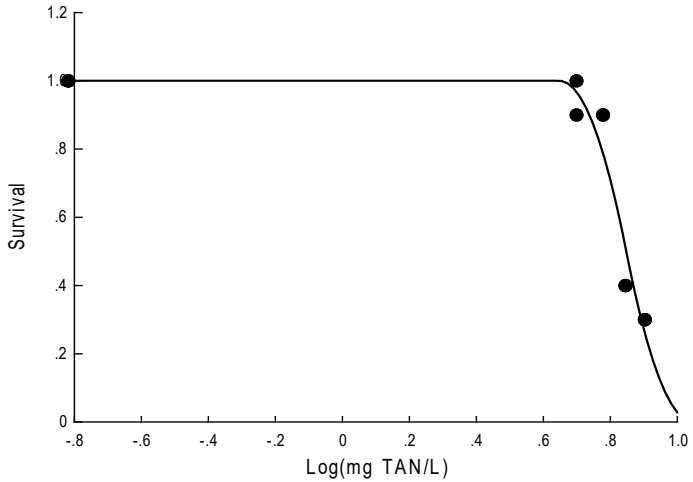
LC50:LC5 = 1.406

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.3167	1.325	0.01535	1.2938	1.3563
StDev	0.090628	0.088289	0.012934	0.068716	0.12353
Y0	1	0.9999	0.002236	0.83142	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**21.136**	19.67	22.712	0.01535	1.325
20	17.601	15.973	19.395	0.020269	1.2455
10	16.05	14.222	18.113	0.024542	1.2055
5	**15.037**	12.972	17.43	0.029161	1.1772
0	12.846	10.471	15.76	0.036691	1.1088

Notes: Acceptable model fit.

Hazel et al. 1979	
Species: *Cyprinella lutrensis*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-59	
Test: #1	
TAN, mg/L	**Proportion surviving**
0.14	1.0
0.15	1.0
5	0.9
5	1.0
6	0.9
6	0.9
7	0.4
7	0.4
8	0.3
8	0.3



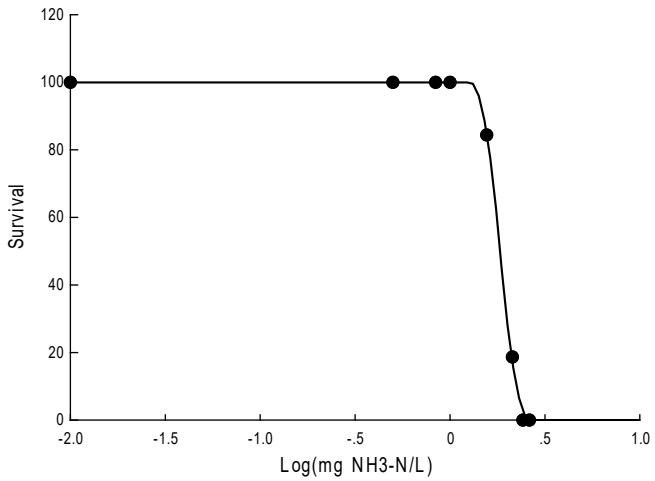
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.95	0.84759	0.014521	0.81799	0.87719
StDev	0.1	0.081393	0.015394	0.059578	0.12842
Y0	1	0.9999	0.002236	0.83143	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**7.0403**	6.5765	7.5369	0.014521	0.84759
20	5.9472	5.5119	6.417	0.015609	0.77431
10	5.4624	4.9274	6.0554	0.020159	0.73738
5	**5.1436**	4.5177	5.8562	0.024192	0.71127
0	4.4486	3.5537	5.5687	0.035327	0.64822

LC50:LC5 = 1.369

Notes: Acceptable model fit.

Hasan and MacIntosh 1986	
Species: *Cyprinus carpio*	
Test Endpoint: 168 and 96 hr Survival	
C-R Curve Label: Am-Acute-62	
Test: Trial 2	
NH3-N, mg/L	**% Survival**
0	100
0.5	100
0.84	100
1	100
1.56	84.4
2.13	18.7
2.42	0
2.62	0



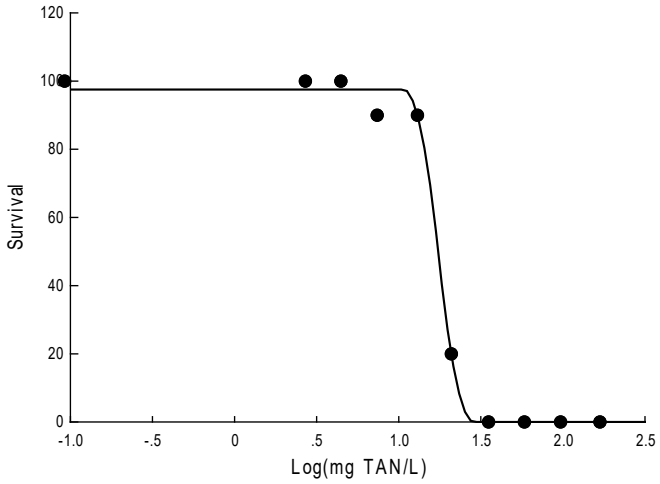
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.22915	0.26367	0.002829	0.25639	0.27094
S	4.8541	6.389	0.23968	5.7729	7.0051
Y0	100	99.947	0.69899	98.15	101.74

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.8351**	1.8046	1.8661	0.002829	0.26367
20	1.6075	1.5704	1.6453	0.003935	0.20614
10	1.5036	1.4624	1.5461	0.0047	0.17714
5	**1.4343**	1.391	1.4789	0.005175	0.15664
0	1.2798	1.2336	1.3277	0.006207	0.10715

LC50:LC5 = 1.279

Notes: Acceptable model fit.

Buhl 2002	
Species: *Hybognathus amarus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-63	
Test: Single	
TAN, mg/L	**% Survival**
<0.10	100
2.7	100
4.44	100
7.38	90
13	90
20.9	20
35.2	0
58.2	0
96.7	0
168	0



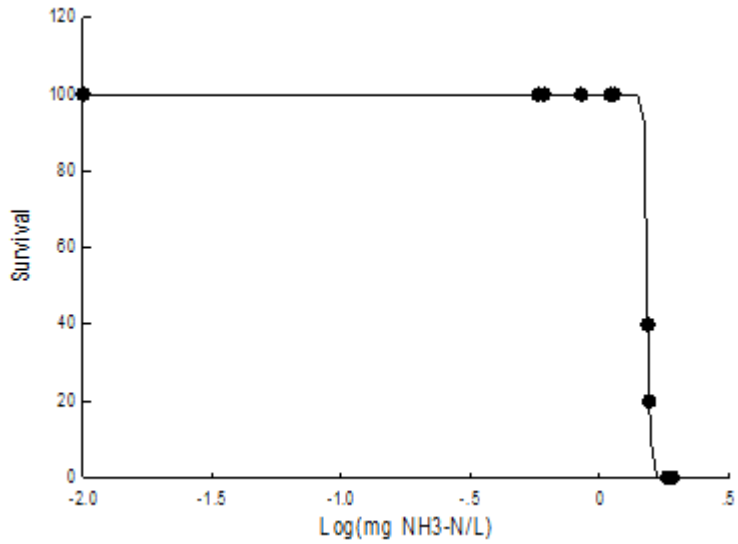
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.25	1.2435	0.010493	1.2187	1.2683
S	4.75	4.6908	0.5141	3.4751	5.9064
Y0	100	97.5	1.6366	93.63	101.37

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**17.519**	16.546	18.549	0.010493	1.2435
20	14.627	13.439	15.92	0.015562	1.1652
10	13.356	12.043	14.811	0.018996	1.1257
5	**12.524**	11.127	14.096	0.021721	1.0977
0	10.723	7.7315	14.873	0.060077	1.0303

LC50:LC5 = 1.399

Notes: Acceptable model fit. Acceptable noise at low level effects.

Swigert and Spacie 1983	
Species: *Pimephales promelas*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-69	
Test: 0.2 g fish	
NH3-N, mg/L	**% Survival**
Control (0.01)	100
Control (0.01)	100
0.58	100
0.61	100
0.85	100
0.85	100
1.1	100
1.14	100
1.54	40
1.56	20
1.83	0
1.91	0



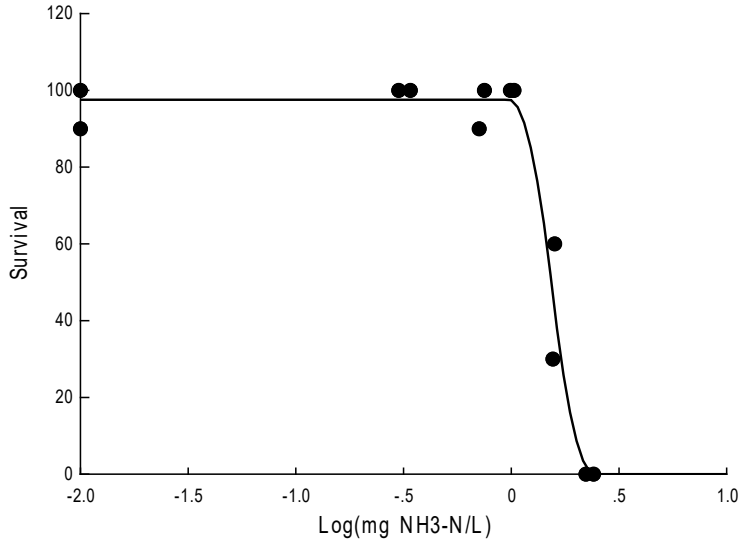
LC50:LC5 = 1.034

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.14	0.18526	0	0.18526	0.18526
S	20	46.748	0	46.748	46.748
Y0	100	100	0	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.532**	1.532	1.532	0	0.18526
20	1.5045	1.5045	1.5045	0	0.1774
10	1.4909	1.4909	1.4909	0	0.17344
5	**1.4813**	1.4813	1.4813	0	0.17064
0	1.4584	1.4584	1.4584	0	0.16387

Notes: Representative curve slope due to model steepness. Acceptable.

Swigert and Spacie 1983	
Species: *Pimephales promelas*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-70	
Test: 0.5 g fish	
NH3-N, mg/L	**% Survival**
Control (0.01)	90
Control (0.01)	100
0.3	100
0.34	100
0.71	90
0.75	100
0.99	100
1.03	100
1.56	30
1.59	60
2.22	0
2.41	0



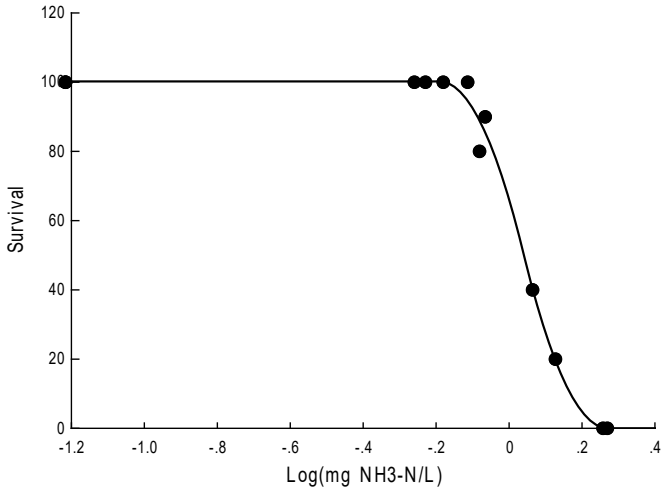
LC50:LC5 = 1.365

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.18	0.18865	1.51E-02	0.15445	0.22284
S	5	5.0605	2.5711	-0.75577	10.877
Y0	98	97.528	3.3256	90.005	105.05

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.544**	1.4271	1.6705	1.51E-02	0.18865
20	1.3062	0.98116	1.739	5.49E-02	0.11602
10	1.2006	0.88198	1.6344	5.92E-02	7.94E-02
5	**1.1312**	0.84558	1.5132	5.59E-02	5.35E-02
0	0.97957	0.66052	1.4527	7.57E-02	-8.96E-03

Notes: Large SE for steepness (S), but acceptable model fit.

Reinbold and Pescitelli 1982c	
Species: *Catostomus commersonii*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-71	
Test: #2	
NH3-N, mg/L	**% Survival**
Control (0.05)	100
Control (0.05)	100
0.55	100
0.59	100
0.66	100
0.77	100
0.83	80
0.86	90
1.16	40
1.34	20
1.81	0
1.86	0

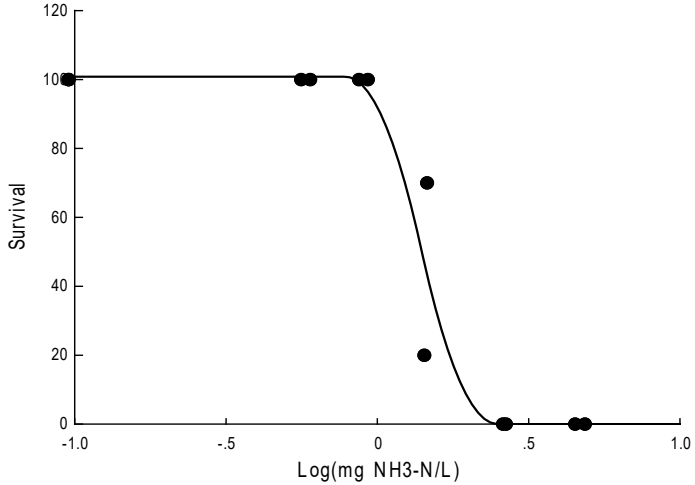


LC50:LC5 = 1.439

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.05	0.040488	0.0072965	0.023983	0.056994
S	4.2	4.3295	0.37218	3.4876	5.1714
Y0	100	100.21	1.7137	96.329	104.08
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.0977**	1.0568	1.1402	0.007297	0.040488
20	0.90281	0.85363	0.95482	0.010753	-0.0444
10	0.81811	0.76368	0.87641	0.013217	-0.08719
5	**0.76305**	0.70701	0.82355	0.014647	-0.11744
0	0.64493	0.58706	0.70852	0.018052	-0.19048

Notes: Acceptable model fit.

Reinbold and Pescitelli 1982d	
Species: *Ictalurus punctatus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-74	
Test: #1	
NH3-N, mg/L	**% Survival**
Control (0.05)	100
Control (0.05)	100
0.56	100
0.6	100
0.87	100
0.93	100
1.43	20
1.46	70
2.6	0
2.66	0
4.5	0
4.85	0



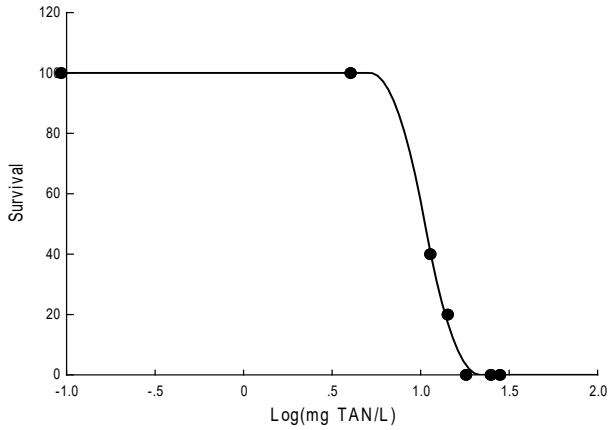
LC50:LC5 = 1.485

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.15	0.14627	0.025362	0.088898	0.20365
S	4	3.9804	2.1789	-0.94846	8.9094
Y0	100	100.79	6.2664	86.61	114.96

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.4005**	1.2272	1.5983	0.025362	0.14627
20	1.1322	0.82097	1.5615	0.061713	0.053935
10	1.0172	0.65115	1.5889	0.085632	0.007397
5	**0.94295**	0.551	1.6137	0.10315	-0.02551
0	0.78532	0.36279	1.6999	0.14826	-0.10496

Notes: Large SE for steepness, but acceptable model fit.

Jude 1973	
Species: *Lepomis gibbosus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-77	
Test: Single	
TAN, mg/L	**% Survival**
0.08	100
4.02	100
11.34	40
14.23	20
18.07	0
24.95	0
28.1	0



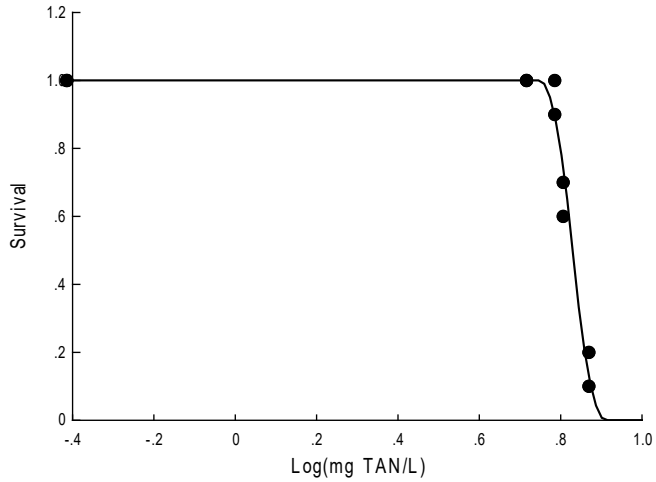
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	1.0251	0.0095797	0.9985	1.0517
S	3.2	3.2268	0.33642	2.2927	4.1608
Y0	100	100	1.5299	95.752	104.25

LC50:LC5 = 1.629

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**10.595**	9.9655	11.264	0.00958	1.0251
20	8.1506	6.9328	9.5823	0.025313	0.91119
10	7.1414	5.327	9.5737	0.045848	0.85378
5	**6.5041**	4.2757	9.8939	0.065615	0.81319
0	5.1902	3.4107	7.8983	0.065676	0.71519

Notes: Acceptable model fit.

Hazel et al. 1979	
Species: *Lepomis macrochirus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-80	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.3	1.0
0.3	1.0
5.2	1.0
5.2	1.0
6.1	0.9
6.1	0.6
6.4	0.7
6.4	0.1
7.4	0.2
7.4	1.0



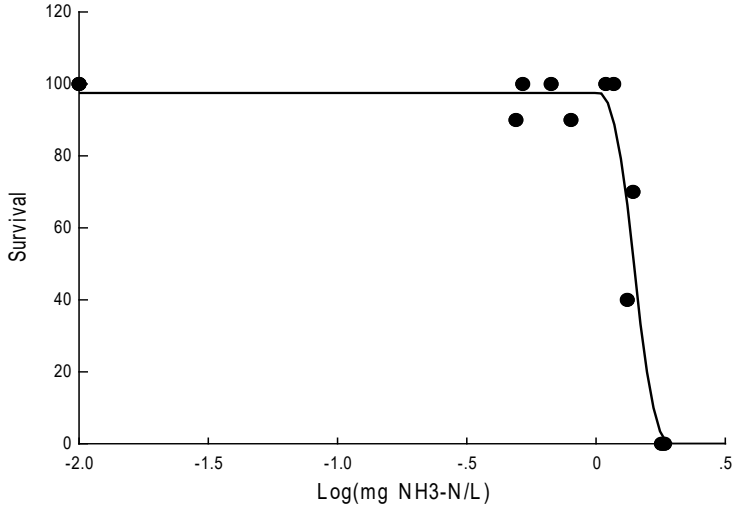
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.9	0.82941	0.007024	0.81486	0.84397
StDev	0.05	0.033202	0.00645	0.024131	0.053194
Y0	1	0.9999	0.001581	0.91171	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**6.7517**	6.5292	6.9818	0.007024	0.82941
20	6.3026	6.0621	6.5527	0.007839	0.79952
10	6.0878	5.7878	6.4032	0.009662	0.78446
5	**5.9403**	5.5826	6.3208	0.011279	0.7738
0	5.5987	5.0429	6.2158	0.015811	0.74809

LC50:LC5 = 1.137

Notes: Acceptable model fit.

Swigert and Spacie 1983	
Species: *Lepomis macrochirus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-83	
Test: July 20, 1982 test	
NH3-N, mg/L	**% Survival**
Control (0.01)	100
Control (0.01)	100
0.49	90
0.52	100
0.67	100
0.8	90
1.09	100
1.17	100
1.32	40
1.39	70
1.79	0
1.84	0



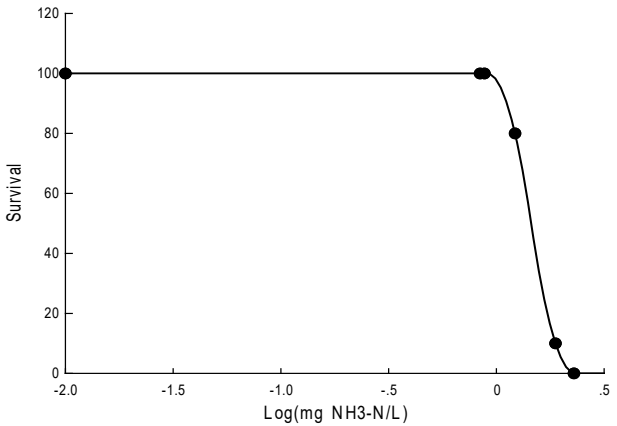
LC50:LC5 = 1.237

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.15	0.14828	0.01426	0.11602	0.18053
S	12	7.4072	2.7369	1.2158	13.599
Y0	100	97.474	4.711	86.817	108.13

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.4069**	1.3062	1.5154	0.01426	0.14828
20	1.255	1.1261	1.3988	0.020815	0.098656
10	1.1848	1.0021	1.4008	0.032144	0.073648
5	**1.1375**	0.94655	1.367	0.035285	0.055964
0	1.031	0.86267	1.2323	0.034228	0.013272

Notes: No errors. Good interpolation through pre-threshold values. Falling limb well characterized. Acceptable.

Swigert and Spacie 1983	
Species: *Lepomis macrochirus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-84	
Test: Sept 28,1982 test	
TAN, mg/L	**% Survival**
Control (0.01)	100
0.84	100
0.88	100
1.22	80
1.88	10
2.29	0



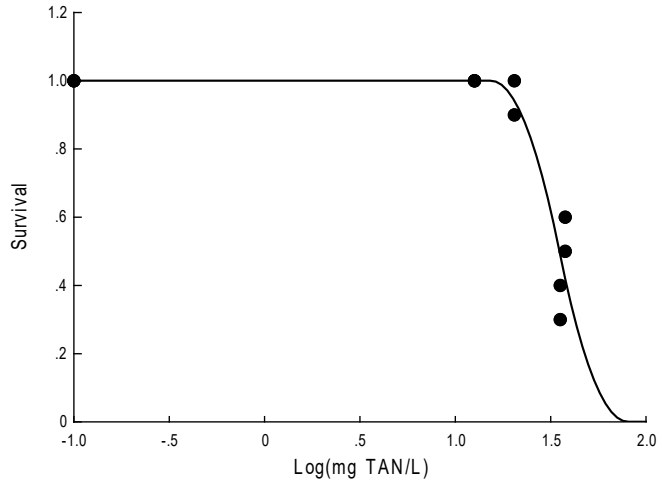
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.16	0.16135	6.1007E-05	0.16116	0.16155
S	4.5	4.9011	0.0031973	4.8909	4.9113
Y0	100	100	0.012405	99.96	100.04

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.450**	1.4493	1.4506	0.000061007	0.16135
20	1.22	1.2193	1.2207	0.00007625	0.086362
10	1.1183	1.1176	1.1191	0.000092008	0.048566
5	**1.0516**	1.0508	1.0524	0.00010159	0.021841
0	0.9064	0.9056	0.90719	0.00011968	-0.042681

LC50:LC5 = 1.379

Notes: Acceptable model fit.

Hazel et al. 1979	
Species: *Etheostoma spectabile*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-85	
Test: Single	
TAN, mg/L	**Proportion surviving**
0	1.0
0	1.0
12.6	1.0
12.6	1.0
20.4	0.9
20.4	1.0
35.5	0.3
35.5	0.4
37.7	0.5
37.7	0.6



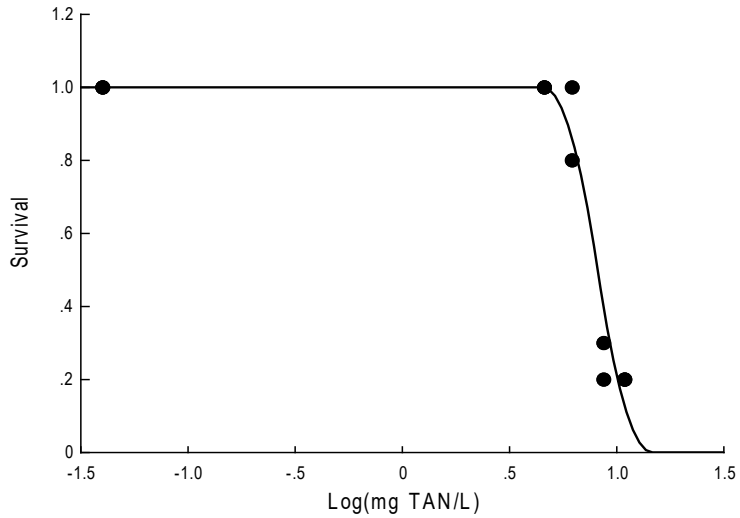
LC50:LC5 = 1.760

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.5459	0.027914	1.4887	1.6032
StDev	0.15	0.14665	0.036114	0.10247	0.25736
Y0	1	0.9999	0.001581	0.91171	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**35.151**	30.812	40.101	0.027914	1.5459
20	25.936	21.797	30.862	0.034964	1.4139
10	22.252	17.311	28.603	0.047094	1.3474
5	**19.967**	14.412	27.664	0.057041	1.3003
0	15.372	8.2939	28.489	0.083786	1.1867

Notes: Acceptable model fit.

Hazel et al. 1979	
Species: *Etheostoma spectabile*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-86	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.04	1.0
0.04	1.0
4.6	1.0
4.6	1.0
6.2	0.8
6.2	1.0
8.7	0.2
8.7	0.3
10.9	0.2
10.9	0.2



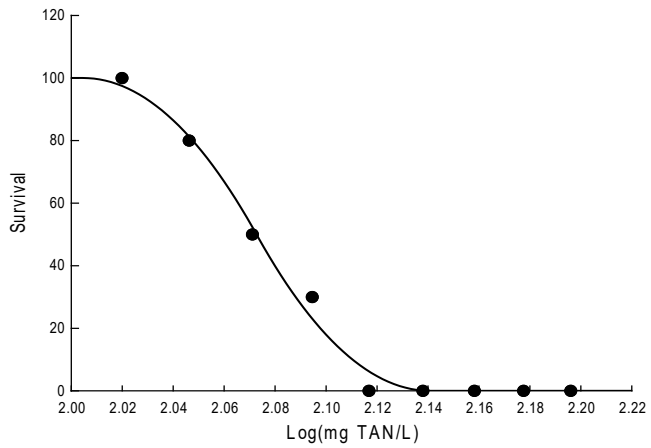
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.9	0.9112	0.01918	0.87198	0.95042
StDev	0.1	0.10365	0.016034	0.0797	0.14828
Y0	1	0.9999	0.002124	0.84648	1

LC50:LC5 = 1.491

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**8.1508**	7.4471	8.921	0.01918	0.9112
20	6.5748	5.8953	7.3326	0.022607	0.81788
10	5.9	5.1534	6.7546	0.027153	0.77085
5	**5.465**	4.6601	6.409	0.030998	0.73759
0	4.5426	3.5794	5.7649	0.041609	0.6573

Notes: Acceptable model fit.

Rani et al. 1998	
Species: *Oreochromis mossambicus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-87	
Test: Single	
TAN, mg/L	**% Survival**
105	100
111	80
118	50
124	30
131	0
137	0
144	0
150	0
157	0



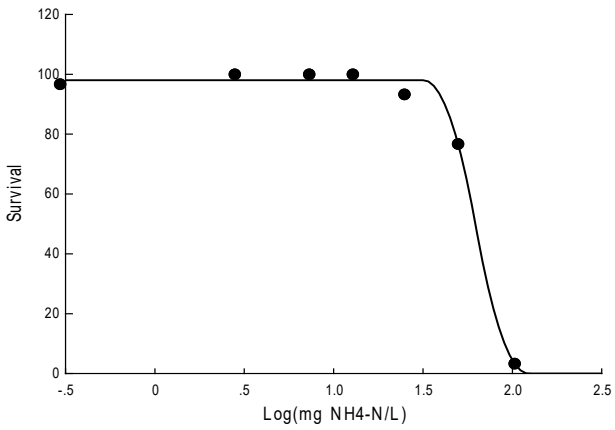
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2	2.0727	0.001841	2.0684	2.0771
S	15	14.672	1.2792	11.647	17.697
Y0	100	100			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**118.22**	117.04	119.41	0.0018408	2.0727
20	111.6	109.81	113.41	0.0029589	2.0477
10	108.4	106.08	110.76	0.0039639	2.035
5	**106.19**	103.62	108.83	0.0045037	2.0261
0	101.05	98.395	103.78	0.0048933	2.0045

LC50:LC5 = 1.113

Notes: Acceptable model fit despite no true control.

Schuytema and Nebeker 1999a	
Species: *Pseudacris regilla*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-89	
Test: ammonium chloride	
NH-4 N, mg/L	**% Survival**
0.2	97
2.8	100
7.3	100
12.8	100
24.9	93
49.7	77
102.9	3



	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.7	1.7959	0.014658	1.7553	1.8366
S	3	3.4208	0.40246	2.3034	4.5382
Y0	99	98	1.3375	94.286	101.71
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**62.51**	56.918	68.651	0.014658	1.7959
20	48.81	44.415	53.639	0.014758	1.6885
10	43.088	33.357	55.657	0.04004	1.6344
5	**39.451**	26.109	59.611	0.064566	1.5961
0	31.887	26.562	38.28	0.028581	1.5036

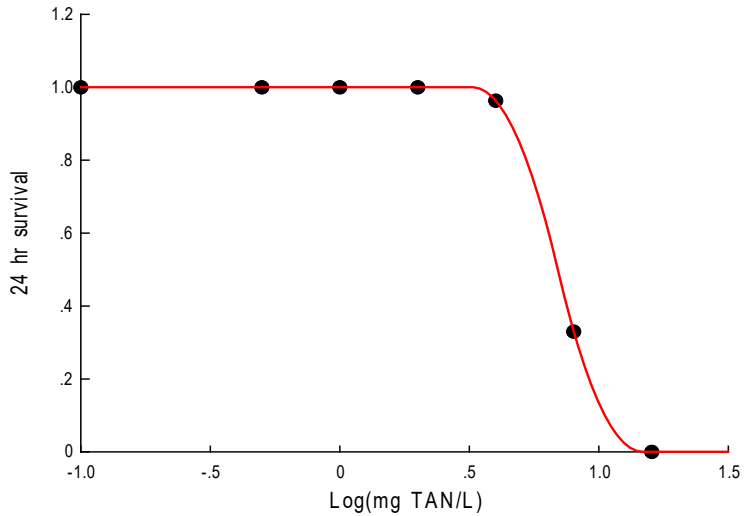
LC50:LC5 = 1.584

Notes: No TRAP flags or errors. Acceptable noise at low level effects.

Appendix A.2

Test Information, C-R Data and Resulting TRAP models for Acute Ammonia Toxicity Tests Considered Unacceptable for TAF and MAF Calculation

Wang et al. 2007b	
Species: *Actinonaias ligamentina* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-1	
Test: #1	
TAN, mg/L	**Proportion Surviving**
0.1	1.00
0.5	1.00
1	1.00
2	1.00
4	0.96
8	0.33
16	0



	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.84	0.8415	0.009133	0.8235	0.85951
StDev	0.14	0.13399	0.007631	0.12056	0.15082
Y0	0.99	0.9999	0.000289	0.99672	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**6.9423**	6.6604	7.2361	0.009133	0.8415
20	5.2586	5.043	5.4834	0.009195	0.72087
10	4.5717	4.3496	4.805	0.01089	0.66007
5	**4.1408**	3.9093	4.3859	0.012533	0.61708
0	3.2606	3.0058	3.5369	0.017502	0.51329

LC50:LC5 = 1.677

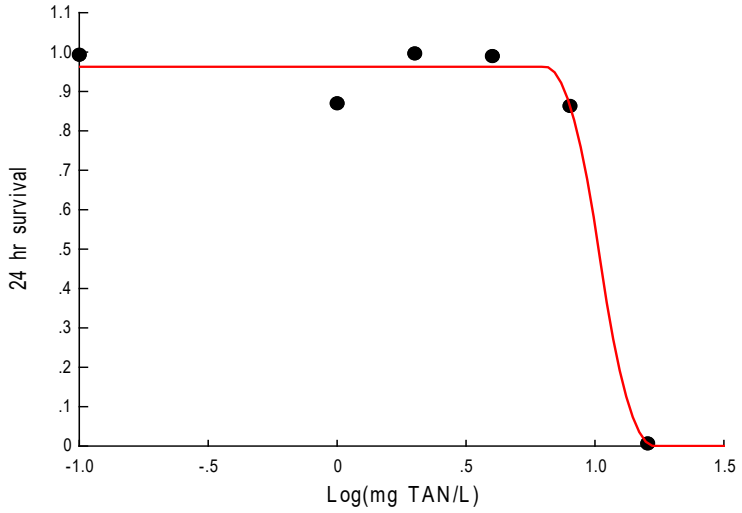
Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Actinonaias ligamentina* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-4	
Test: #3 (March 2004)	
TAN, mg/L	**Proportion Surviving**
0.1	0.99
1	0.87
2	1.00
4	0.99
8	0.86
16	0.01

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	1.0181	0.00696	1.0044	1.0319
StDev	0.086	0.085989	0.00377	0.079193	0.094072
Y0	0.97	0.9625	0.005484	0.95014	0.97252

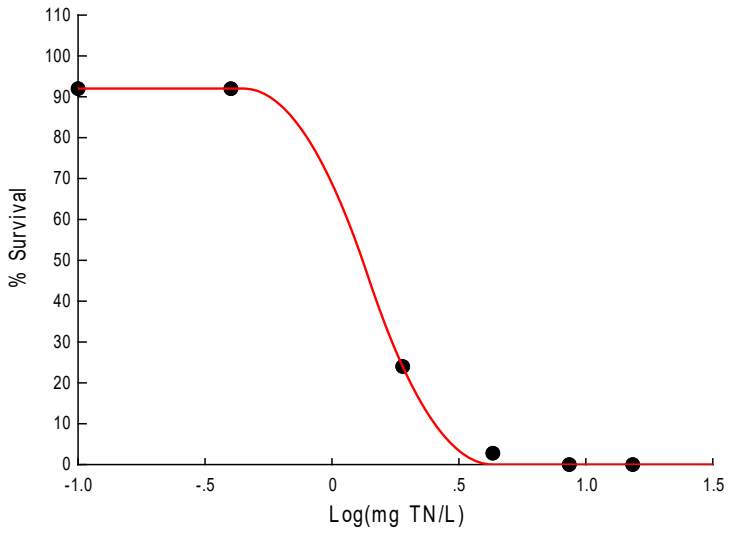
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**10.426**	10.101	10.761	0.00696	1.0181
20	8.7234	8.3821	9.0787	0.008758	0.94069
10	7.9739	7.6213	8.3427	0.009897	0.90167
5	**7.4831**	7.1208	7.8637	0.010835	0.87408
0	6.4191	6.038	6.8242	0.013266	0.80747

Notes: TRAP flagged for IP (No Unique Solution).



LC50:LC5 = 1.393

Wang et al. 2017	
Species: *Amblema plicata*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-5	
Test: Single	
TAN, mg/L	**% Survival**
0.1	92
0.4	92
1.9	24
4.3	2.8
8.6	0
15.3	0



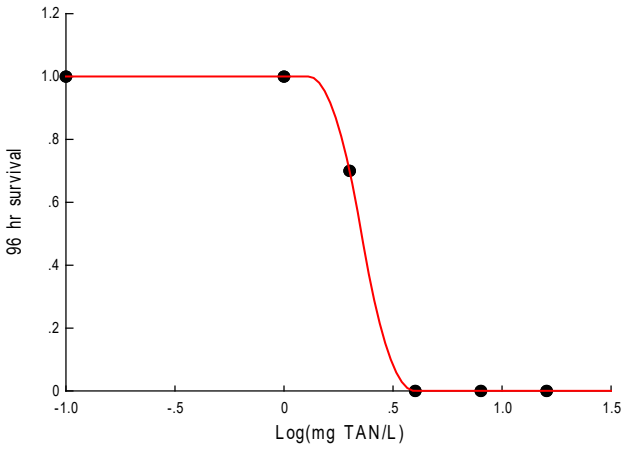
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.179	0.14245			
S	1.83	2.0373			
Y0	92	92			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.3882**				0.14245
20	0.9163				-0.03796
10	0.74321				-0.12889
5	**0.64094**				-0.19318
0	0.44832				-0.34841

Notes: TRAP flagged for IP (No Unique Solution).

LC50:LC5 = 2.166

Wang et al. 2007b	
Species: *Lampsilis abrupta* (2-mo old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-9	
Test: Single	
TAN, mg/L	**Proportion Surviving**
0.1	1.0
1	1.0
2	0.70
4	0.0
8	0.0
16	0.0

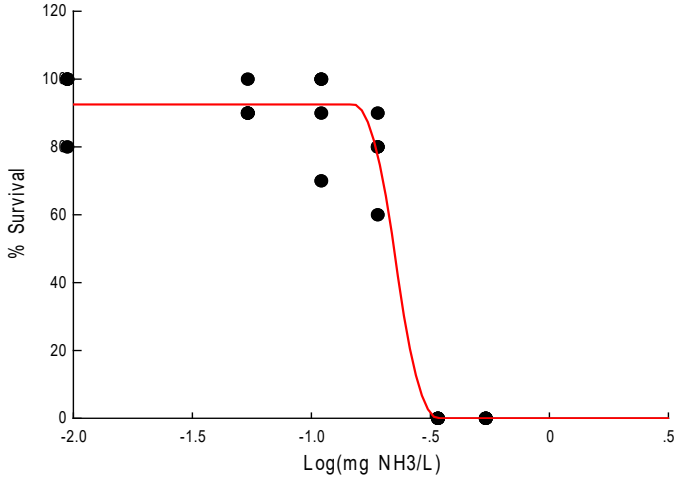


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.35	0.35571			
StDev	0.1	0.099014			
Y0	1	0.9999			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**2.2684**				0.35571
20	1.8474				0.26657
10	1.6659				0.22164
5	**1.5484**				0.18987
0	1.2977				0.11318

LC50:LC5 = 1.465

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

Mummert et al. 2003	
Species: *Lampsilis fasciola* (2-5 d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-11	
Test: Single	
NH3, mg/L	**% Survival**
0.01	100
0.01	100
0.01	100
0.01	80
0.054	100
0.054	90
0.054	90
0.054	90
0.11	100
0.11	100
0.11	90
0.11	70
0.19	90
0.19	80
0.19	80
0.19	60
0.34	0
0.34	0
0.34	0
0.34	0
0.54	0
0.54	0
0.54	0
0.54	0



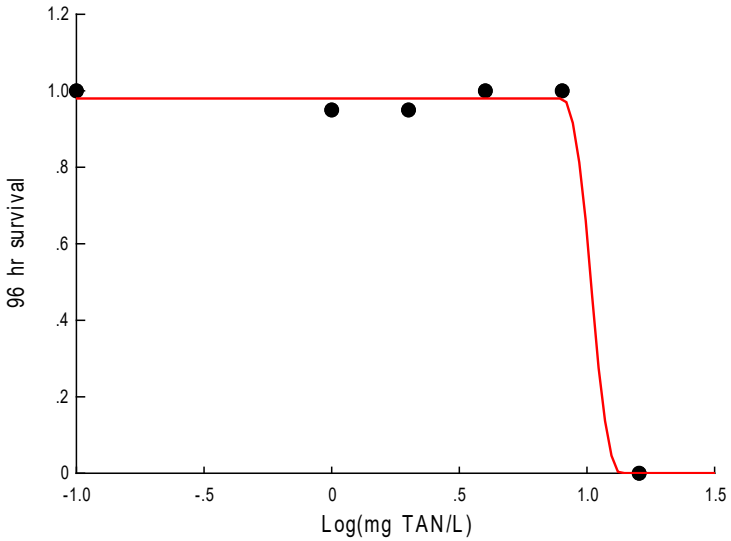
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.65	-0.64503	0.81873	-2.3477	1.0576
S	5	5.6485	60.674	-120.53	131.83
Y0	92.5	92.5	2.4398	87.426	97.574

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**0.22645**	0.0044907	11.419	0.81873	-0.64503
20	0.19494	0.181	0.20995	0.015495	-0.7101
10	0.18076	0.16626	0.19653	0.017466	-0.74289
5	**0.17136**	0.15629	0.18789	0.019225	-0.76608
0	0.15064	0.13494	0.16817	0.022988	-0.82207

LC50:LC5 = 1.321

Notes: TRAP flagged for IP (No Unique Solution).

Wang et 2007b	
Species: *Lampsilis rafinesqueana* (<5-d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-15	
Test: #1	
TAN, mg/L	**Proportion Surviving**
0.1	1.00
1	0.95
2	0.95
4	1.00
8	1.00
16	0

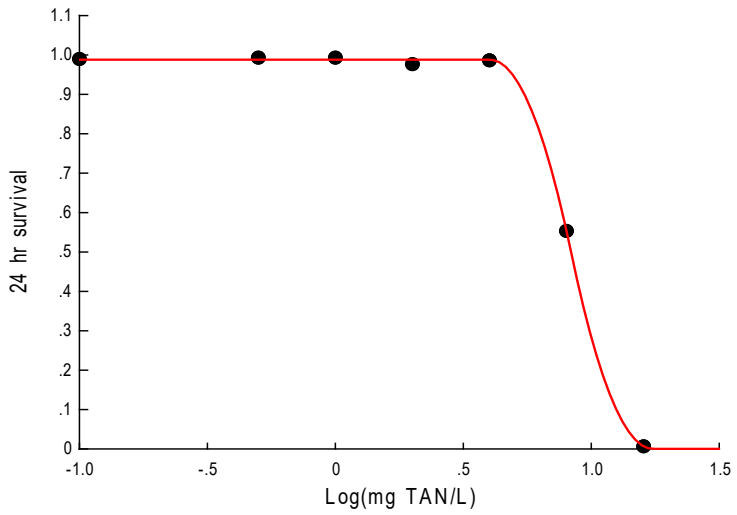


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	1.017			
StDev	0.07	0.046441			
Y0	0.98	0.9798			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**10.399**				1.017
20	9.4432				0.97512
10	8.9955				0.95402
5	**8.6917**				0.93911
0	8				0.90309

LC50:LC5 = 1.196

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Lampsilis rafinesqueana* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-17	
Test: NMAm1d	
TAN, mg/L	**Proportion Surviving**
0.1	0.99
0.5	0.99
1	0.99
2	0.98
4	0.99
8	0.55
16	0.01



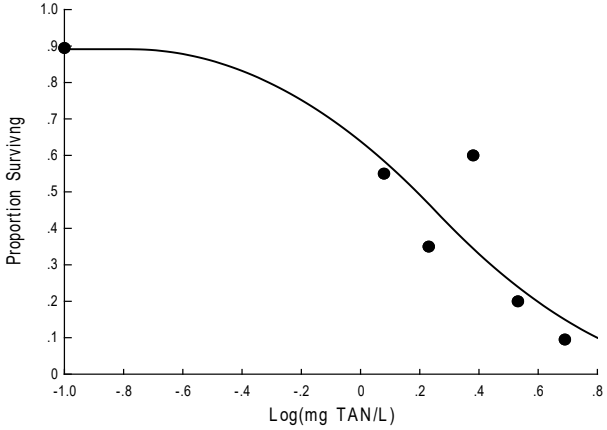
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.92	0.92278	9.26E-03	0.90452	0.94104
StDev	0.13	0.12983	7.08E-03	0.11731	0.14535
Y0	0.99	0.988	2.81E-03	0.9811	0.99287

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**8.3711**	8.0265	8.7306	0.0093	0.92278
20	6.3959	5.9872	6.8324	0.0145	0.8059
10	5.5846	5.1797	6.0212	0.0165	0.74699
5	**5.0739**	4.6624	5.5217	0.0184	0.70534
0	4.0251	3.6152	4.4815	0.0231	0.60478

LC50:LC5 = 1.650

Notes: TRAP flagged for IP (No Unique Solution).

Myers-Kinzie 1998	
Species: *Lampsilis siliquoidea* (juvenile)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-18	
Test: 5-d old	
TAN, mg/L	**Proportion Surviving**
0.1	0.895
1.2	0.55
1.7	0.35
2.4	0.60
3.4	0.20
4.9	0.10

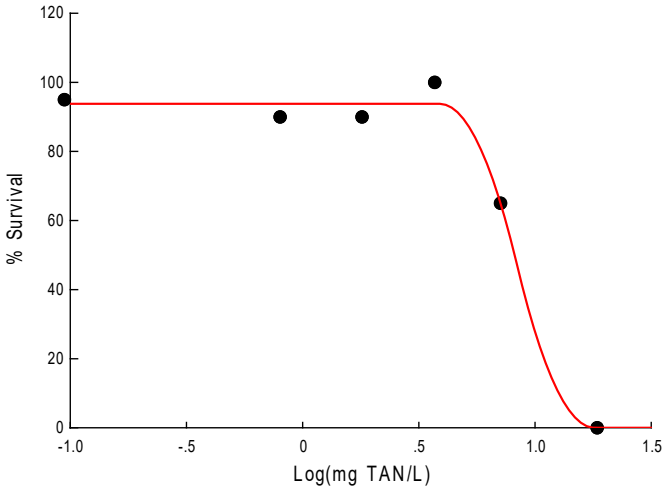


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.3	0.25554	0.088737	0.071783	0.4393
S	0.4	0.4216	0.13558	0.29458	0.73989
Y0	0.895	0.89106	0.071321	0.6646	0.98568
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.8011**	1.1797	2.7497	0.088735	0.25553
20	0.75155	0.29505	1.9143	0.186	-0.12404
10	0.48379	0.12728	1.8388	0.24763	-0.31534
5	**0.35431**	0.064686	1.9407	0.29402	-0.45062
0	0.16704	0.00388	7.1906	0.50392	-0.77719

LC50:LC5 = 5.083

Notes: Not core data. No effect within area of concern.

Miao et al. 2010	
Species: *Lampsilis siliquoidea* (3 mo old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-19	
Test: Single	
TAN, mg/L	**% Survival**
<0.1	95
0.8	90
1.8	90
3.7	100
7.1	65
18.5	0



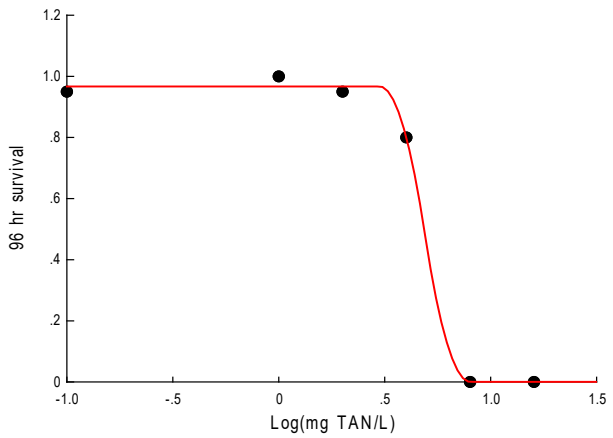
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	0.92541	5.962	-18.048	19.899
S	1.5	2.9245	235.14	-745.41	751.26
Y0	93.75	93.75	2.3936	86.133	101.37

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**8.4218**			5.962	0.92541
20	6.3056	4.9165	8.0872	3.40E-02	0.79973
10	5.4499	4.1284	7.1943	3.79E-02	0.73639
5	**4.9158**	3.6801	6.5665	3.95E-02	0.6916
0	3.8323	2.7802	5.2826	4.38E-02	0.58346

LC50:LC5 = 1.713

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Lampsilis siliquoidea* (2-mo old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-20	
Test: Single	
TAN, mg/L	**Proportion Surviving**
0.1	0.95
1	1.00
2	0.95
4	0.80
8	0.00
16	0.00

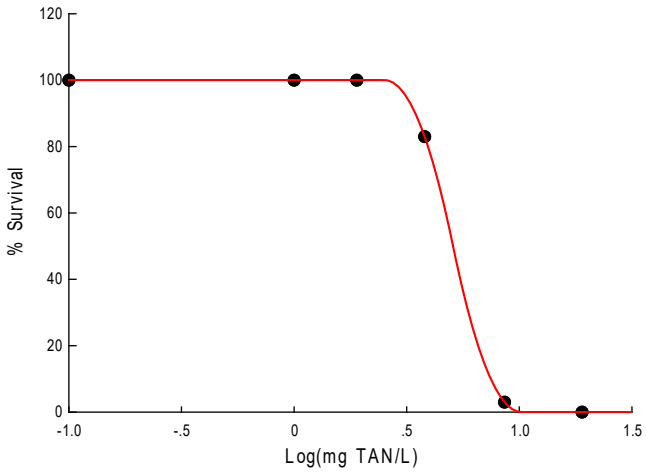


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.7	0.69001			
StDev	0.1	0.086988			
Y0	0.96667	0.96667			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**4.8979**				0.69001
20	4.0897				0.61169
10	3.7344				0.57222
5	**3.502**				0.54431
0	2.9987				0.47693

LC50:LC5 = 1.399

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

Wang et al. 2008	
Species: *Lampsilis siliquoidea* (7-d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-23	
Test: Experiment 1- pH=8.0	
TAN, mg/L	**% Survival**
Control (0.1)	100
1	100
1.9	100
3.8	83
8.6	3
19	0



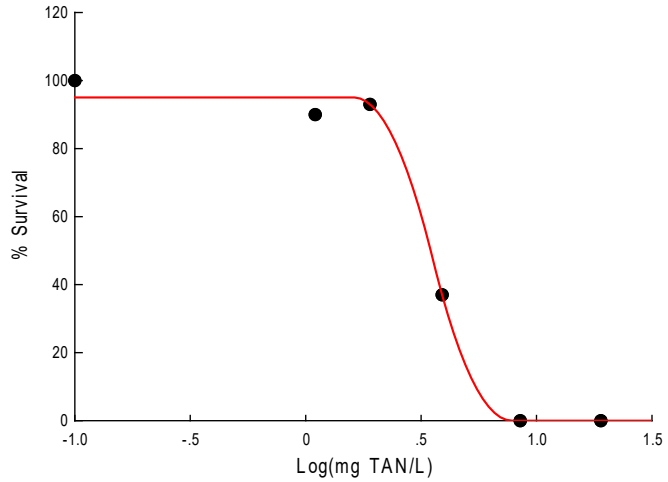
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.7	0.70597	0	0.70597	0.70597
S	3.3	3.3039	0	3.3039	3.3039
Y0	100	100	0	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**5.0812**	5.0812	5.0812	0	0.70597
20	3.933	3.933	3.933	0	0.59472
10	3.4567	3.4567	3.4567	0	0.53866
5	**3.1551**	3.1551	3.1551	0	0.49901
0	2.531	2.531	2.531	0	0.4033

LC50:LC5 = 1.610

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2008	
Species: *Lampsilis siliquoidea* (7-d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-24	
Test: Experiment 1- pH=8.5	
TAN, mg/L	**% Survival**
Control (0.1)	100
1.1	90
1.9	93
3.9	37
8.5	0
19	0



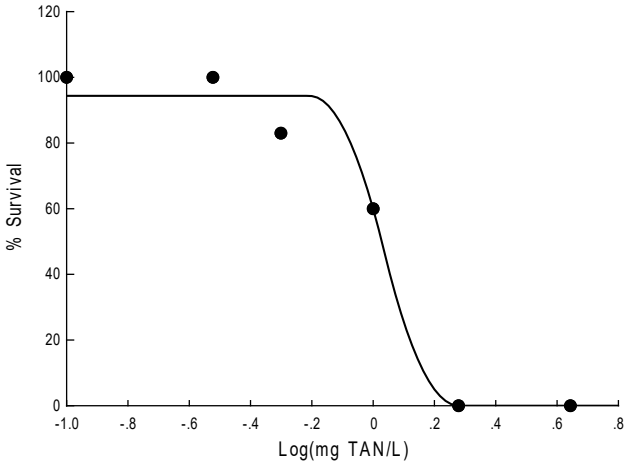
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.55	0.55086	0.020101	0.48689	0.61483
S	3	2.9209	0.80711	0.35231	5.4895
Y0	94.333	95	2.8868	85.813	104.19

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**3.5552**	3.0683	4.1194	0.020101	0.55086
20	2.6609	1.868	3.7904	0.048282	0.42503
10	2.2994	1.4295	3.6985	0.06486	0.36161
5	**2.0738**	1.1808	3.6422	0.076859	0.31677
0	1.6162	0.73678	3.5454	0.1072	0.2085

LC50:LC5 = 1.714

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2008	
Species: *Lampsilis siliquoidea* (7-d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-25	
Test: Experiment 1- pH=9.0	
TAN, mg/L	**% Survival**
Control (0.1)	100
0.3	100
0.5	83
1	60
1.9	0
4.4	0

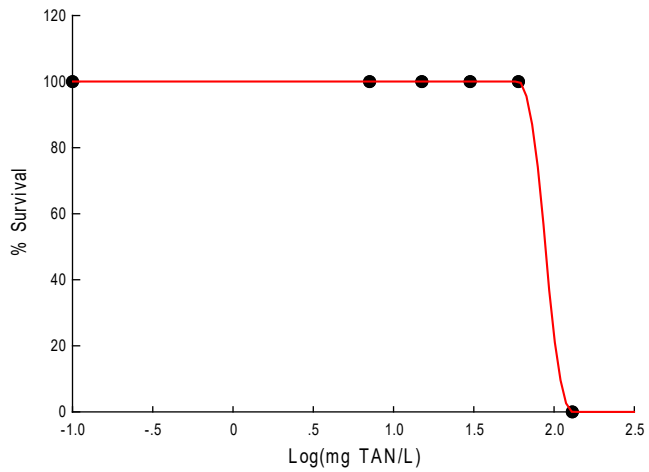


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.03	0.035716	2.8802	-9.1305	9.2019
S	2.5	4.1108	331.5	-1050.9	1059.1
Y0	100	94.333	4.6268	79.609	109.06
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.0857**			2.8802	0.035716
20	0.8837	0.61346	1.273	0.049811	-0.05369
10	0.79661	0.55448	1.1445	0.049446	-0.09876
5	**0.74025**	0.51427	1.0655	0.049706	-0.13062
0	0.62009	0.42061	0.91418	0.052971	-0.20755

LC50:LC5 = 1.467

Notes: Poor model fit.

Wang et al. 2008	
Species: *Lampsilis siliquoidea* (7-d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-26	
Test: Experiment 2- pH=6.6	
TAN, mg/L	**% Survival**
Control (0.1)	100
7.1	100
15	100
30	100
60	100
130	0



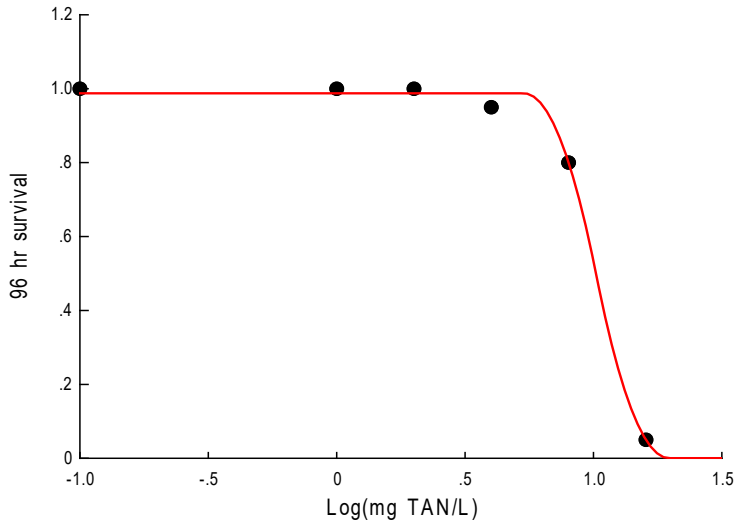
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.946	1.946	1.31E-07	1.946	1.946
S	5.795	5.9561	4.64E-06	5.956	5.9561
Y0	100	100	1.60E-11	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**88.318**				1.946
20	76.619				1.8843
10	71.324				1.8532
5	**67.802**				1.8312
0	60				1.7782

LC50:LC5 = 1.303

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Lampsilis siliquoidea* (<5 d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-28	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.1	1.00
1	1.00
2	1.00
4	0.95
8	0.80
16	0.05

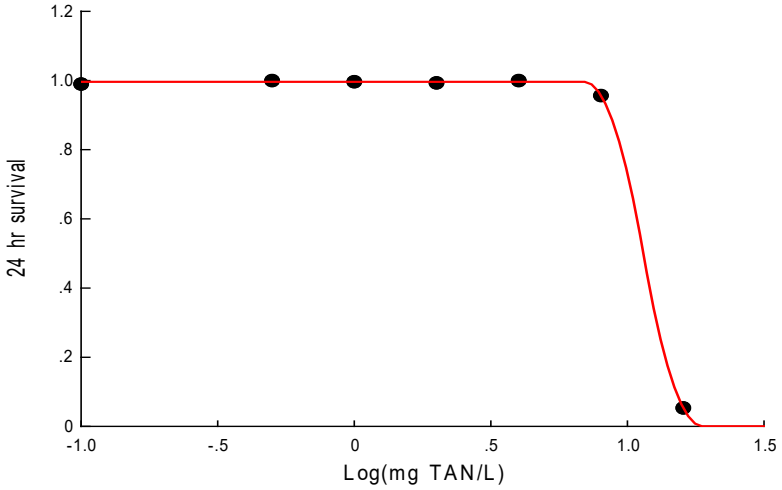


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	1.0115	0.031069	0.94473	1.0782
StDev	0.1	0.11531	0.023183	0.08303	0.18856
Y0	1	0.9875	0.012422	0.93231	0.99968
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**10.268**	8.8051	11.973	0.031069	1.0115
20	8.0847	6.5359	10	0.041149	0.90766
10	7.1671	5.4829	9.3687	0.048929	0.85534
5	**6.5818**	4.7347	9.1496	0.056827	0.81835
0	5.3583	3.2411	8.8587	0.070743	0.72903

LC50:LC5 = 1.560

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Lampsilis siliquoidea* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-29	
Test: #1	
TAN, mg/L	**Proportion surviving**
0.1	0.99
0.5	1.00
1	1.00
2	0.99
4	1.00
8	0.96
16	0.05



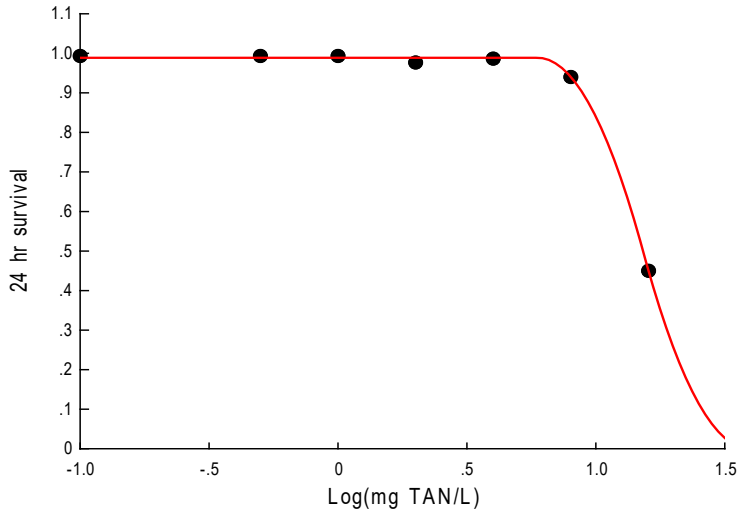
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.07	1.0586	6.28E-03	1.0462	1.071
StDev	8.80E-02	8.83E-02	3.69E-03	8.16E-02	9.62E-02
Y0	0.999	0.996	1.63E-03	0.99131	0.99853

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**11.444**	11.122	11.775	6.28E-03	1.0586
20	9.5298	9.2228	9.847	7.20E-03	0.97908
10	8.6901	8.3736	9.0185	8.14E-03	0.93902
5	**8.1414**	7.8158	8.4805	8.94E-03	0.9107
0	6.9552	6.6074	7.3213	1.12E-02	0.84231

LC50:LC5 = 1.406

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Lampsilis siliquoidea* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-30	
Test: #3	
TAN, mg/L	**Proportion surviving**
0.1	0.99
0.5	0.99
1	0.99
2	0.98
4	0.99
8	0.94
16	0.45



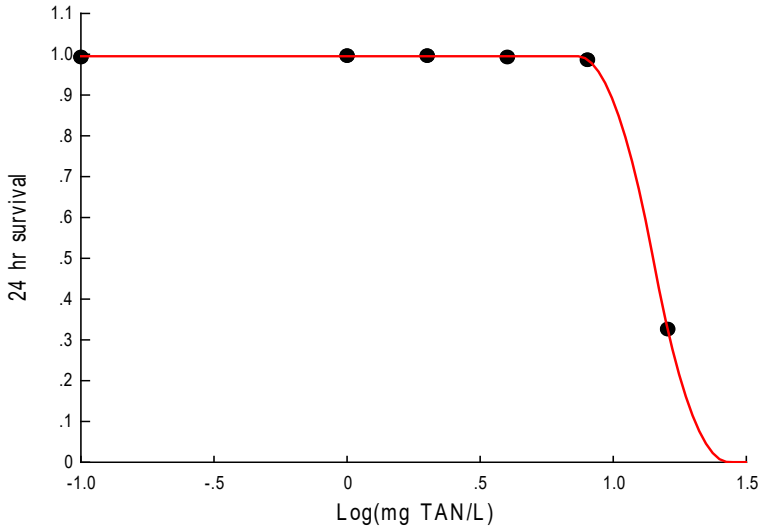
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.19	1.1852	0.011813	1.1619	1.2085
StDev	0.17	0.16785	0.012412	0.14665	0.19628
Y0	0.99	0.98867	0.002733	0.98192	0.99338

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**15.319**	14.519	16.163	0.011813	1.1852
20	10.817	10.239	11.428	0.012027	1.0341
10	9.0772	8.4582	9.7415	0.015366	0.95795
5	**8.0186**	7.363	8.7325	0.018436	0.9041
0	5.944	5.2237	6.7637	0.027318	0.77408

LC50:LC5 = 1.910

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Lampsilis siliquoidea* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-31	
Test: #4 (April 2004)	
TAN, mg/L	**Proportion surviving**
0.1	0.99
1	1.00
2	1.00
4	0.99
8	0.99
16	0.33

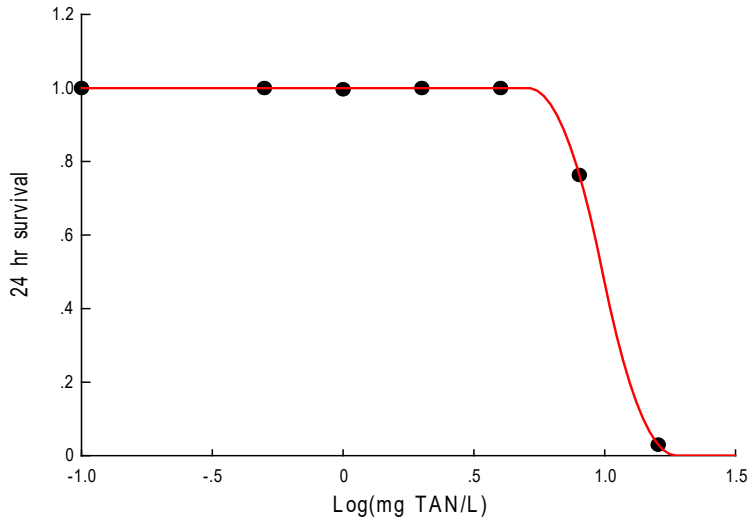


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.15	1.1502	0.008313	1.1339	1.1666
StDev	0.12	0.1159	0.006908	0.1038	0.13123
Y0	0.99	0.995	0.002036	0.98915	0.99816
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**14.133**	13.61	14.677	0.008313	1.1502
20	11.115	10.651	11.599	0.009362	1.0459
10	9.8471	9.3567	10.363	0.01116	0.99331
5	**9.039**	8.5254	9.5836	0.012727	0.95612
0	7.351	6.7851	7.964	0.017182	0.86634

LC50:LC5 = 1.564

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Lampsilis siliquoidea* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-33	
Test: #2 (repeat)	
TAN, mg/L	**Proportion surviving**
0.1	1.00
0.5	1.00
1	1.00
2	1.00
4	1.00
8	0.76
16	0.03



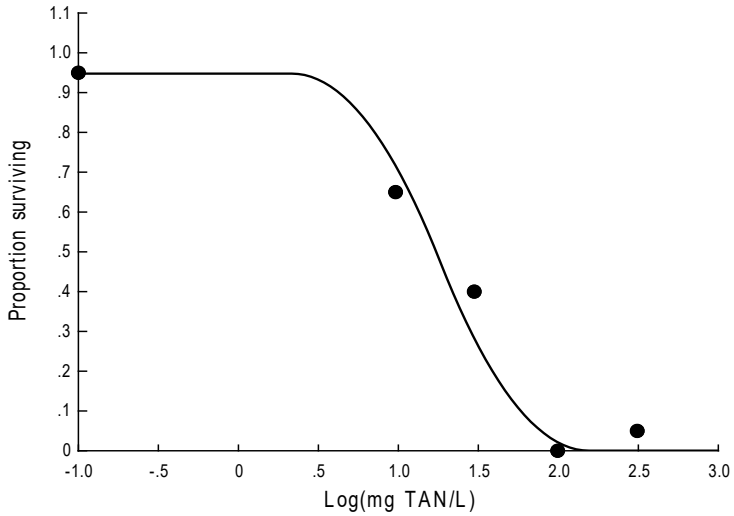
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.99	0.99123	0.007862	0.97573	1.0067
StDev	0.11	0.11506	0.005802	0.10473	0.12768
Y0	0.99	0.99933	0.000666	0.99629	0.99998

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**9.8**	9.4565	10.156	0.007862	0.99123
20	7.7203	7.3566	8.1021	0.010607	0.88764
10	6.8459	6.4617	7.2529	0.012653	0.83543
5	**6.288**	5.8927	6.7097	0.014179	0.79851
0	5.1213	4.7112	5.5672	0.018051	0.70938

LC50:LC5 = 1.559

Notes: TRAP flagged for IP (No Unique Solution).

Scheller et al 1997	
Species: *Pyganodon grandis* (adult)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-36	
Test: pH 7.71 test	
TAN, mg/L	**Proportion surviving**
0.1	0.95
9.6	0.65
29.8	0.4
99	0
311.1	0.05

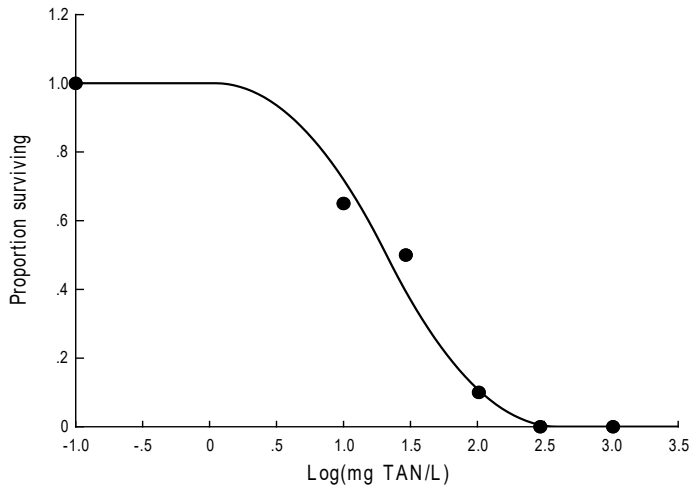


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.25	1.2628	0.096872	1.0568	1.4689
S	0.38	0.37956	0.079223	0.27049	0.6355
Y0	0.95	0.94769	0.049676	0.74857	0.99846
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**18.316**	11.396	29.437	0.096872	1.2628
20	8.3391	3.9215	17.733	0.14697	0.92112
10	5.6091	1.5992	19.674	0.22977	0.7489
5	**4.2376**	1.3118	13.689	0.20189	0.62712
0	2.1534	0.33035	14.037	0.25878	0.33311

LC50:LC5 = 4.322

Notes: No effect within area of concern.

Scheller et al 1997	
Species: *Pyganodon grandis* (adult)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-37	
Test: pH 7.5 test	
TAN, mg/L	**Proportion surviving**
0.1	1.00
10	0.65
29.2	0.50
102.5	0.10
294.7	0.00
1030	0.00

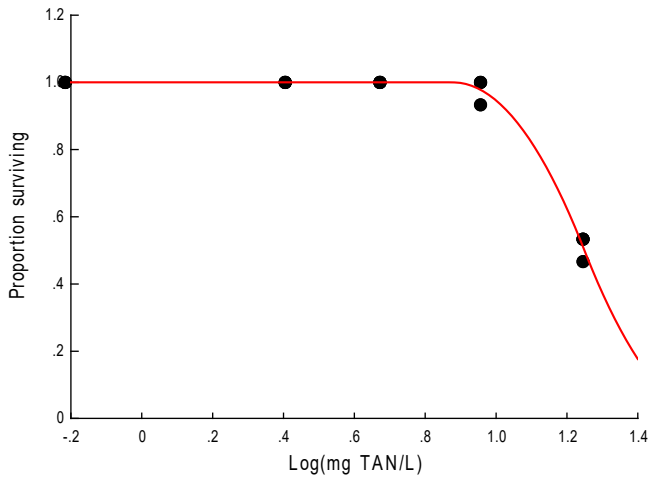


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.3	1.3218	0.10493	1.1055	1.538
S	0.5	0.52211	0.087665	0.39381	0.7748
Y0	1	0.9999	0.002236	0.83139	1
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**20.977**	12.751	34.511	0.10493	1.3218
20	7.1072	2.8819	17.528	0.18475	0.8517
10	4.119	1.4946	11.352	0.19972	0.61479
5	**2.8008**	0.85189	9.2081	0.22588	0.44727
0	1.1037	0.19577	6.2223	0.28801	4.29E-02

LC50:LC5 = 7.490

Notes: No effect within area of concern.

Wade 1992	
Species: *Utterbackia imbecillis*	
Test Endpoint: 9 day Survival	
C-R Curve Label: Am-Acute-38	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.52	1.00
0.52	1.00
0.52	1.00
2.54	1.00
2.54	1.00
2.54	1.00
4.7	1.00
4.7	1.00
4.7	1.00
9.04	1.00
9.04	0.933
9.04	1.00
17.59	0.533
17.59	0.467
17.59	0.533



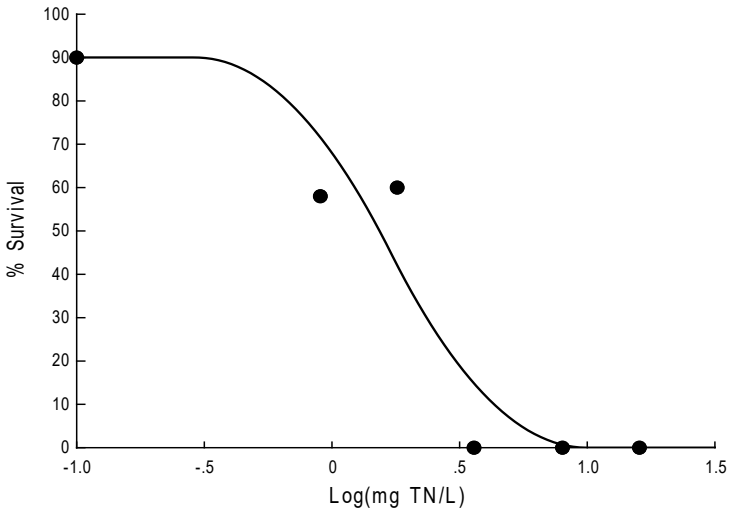
LC50:LC5 = 1.794

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.25	1.2494	2.84E-02	1.1913	1.3075
S	0.15	0.15161	2.51E-02	0.11474	0.22351
Y0	0.999	0.9999	8.68E-04	0.97244	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**17.759**	15.534	20.302	2.84E-02	1.2494
20	12.969	11.58	14.526	2.34E-02	1.1129
10	11.069	9.5994	12.765	2.83E-02	1.0441
5	**9.8965**	8.2987	11.802	3.38E-02	0.99548
0	7.5517	5.6218	10.144	4.99E-02	0.87805

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2017	
Species: *Utterbackia imbecilis* (glochidia)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-39	
Test: Single	
TAN, mg/L	**% Survival**
0.1	90
0.9	58
1.8	60
3.6	0
8	0
16	0



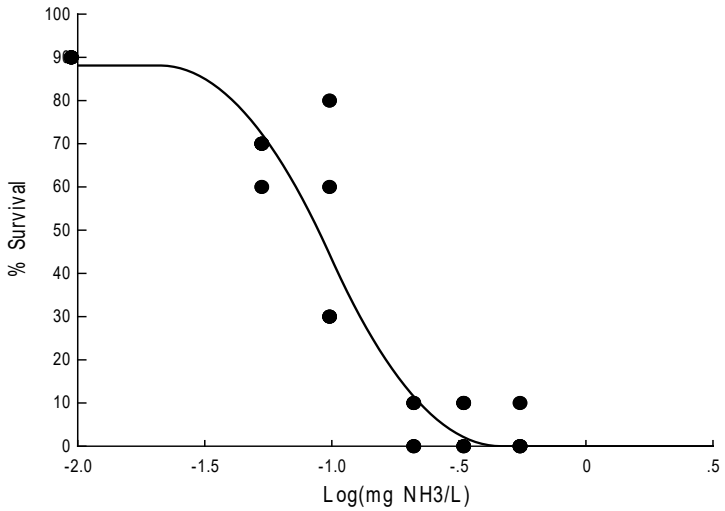
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.25	0.23034	0.088434	-0.015196	0.47587
S	1.5	1.306	0.55383	-0.2317	2.8437
Y0	90	90			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.6996**	0.96562	2.9914	0.088434	0.23034
20	0.889	0.31487	2.51	0.16236	-0.051097
10	0.6413	0.14971	2.7471	0.22756	-0.19294
5	**0.50905**	0.094623	2.7386	0.2632	-0.29324
0	0.29149	0.045132	1.8826	0.29179	-0.53538

LC50:LC5 = 3.339

Notes: No effect within area of concern.

Mummert et al. 2003	
Species: *Villosa iris* (2-5 d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-45	
Test: Single	
TAN, mg/L	**% Survival**
0.005	90
0.005	90
0.005	90
0.005	90
0.053	70
0.053	70
0.053	70
0.053	60
0.098	80
0.098	60
0.098	30
0.098	30
0.21	10
0.21	10
0.21	0
0.21	0
0.33	10
0.33	10
0.33	0
0.33	0
0.55	10
0.55	0
0.55	0
0.55	0

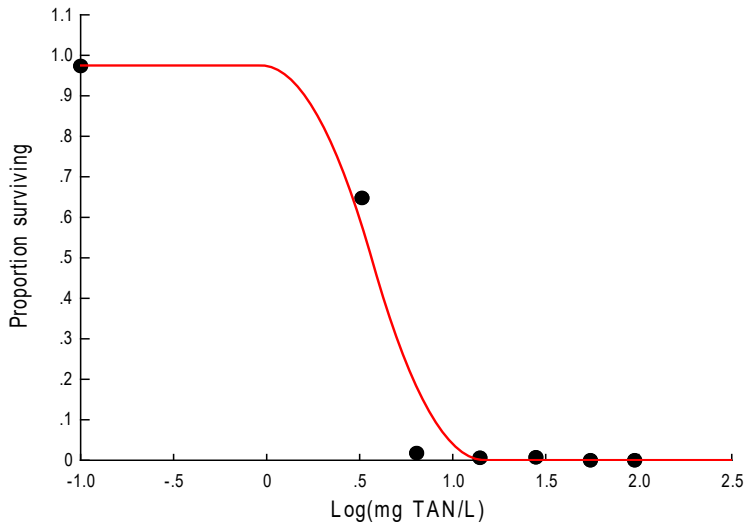


LC50:LC5 = 2.879

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-1	-1.0061	4.27E-02	-1.0948	-0.91735
S	1.5	1.4888	0.2661	0.93537	2.0421
Y0	90	88.091	5.4161	76.828	99.354
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**0.098613**	0.080392	0.12096	0.042662	-1.0061
20	0.055854	0.039399	0.079181	0.072883	-1.2529
10	0.04194	0.025352	0.069381	0.10512	-1.3774
5	**0.034248**	0.018233	0.064333	0.13165	-1.4654
0	0.021001	0.010613	0.041554	0.14252	-1.6778

Notes: No effect within area of concern.

Scheller et al 1997	
Species: *Villosa iris* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-47	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.01	0.97
3.25	0.65
6.4	0.02
14	0.01
28	0.01
55	0.00
95	0.00



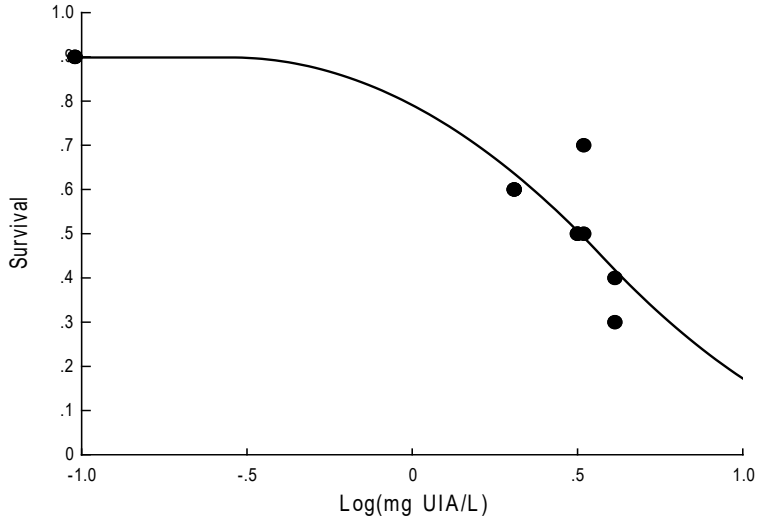
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.12112	0.57144	0.023246	0.52538	0.6175
S	0.61041	0.2455	0.017302	0.21577	0.28482
Y0	0.97368	0.97486	0.01466	0.92674	0.99504

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**3.7277**	3.3526	4.1448	0.023246	0.57144
20	2.2409	1.9111	2.6275	0.034715	0.35042
10	1.7339	1.4331	2.0978	0.041292	0.23902
5	**1.4463**	1.1676	1.7915	0.046118	0.16025
0	0.93344	0.71057	1.2262	0.057616	-0.02992

LC50:LC5 = 2.557

Notes: TRAP flagged for IP (No Unique Solution).

Evans 1979	
Species: *Orconectes nais* (2.78 cm)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-52	
Test: Single	
Unionized ammonia NH3, mg/L	**Proportion surviving**
0.04	0.9
0.04	0.9
2.035	0.6
2.035	0.6
3.16	0.5
3.16	0.5
3.3	0.7
3.3	0.5
4.1	0.3
4.1	0.4



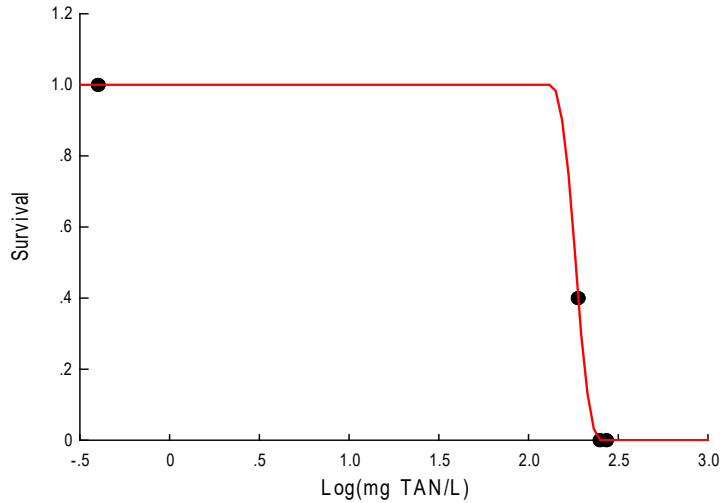
LC50:LC5 = 5.851

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.6	0.57308	0.1026	0.35902	0.78713
StDev	0.5	0.45808	0.34387	0.32007	0.8039
Y0	0.9	0.89842	0.067529	0.68107	0.98713

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**3.7418**	2.2857	6.1253	0.1026	0.57308
20	1.4477	0.34403	6.0917	0.28363	0.16067
10	0.89705	0.080005	10.058	0.44456	-0.047183
5	**0.6395**	0.02374	17.227	0.56446	-0.19416
0	0.2825	0.00040779	195.7	0.86727	-0.54898

Notes: No effect within area of concern.

Wicks and Randall 2002	
Species: *Oncorhynchus mykiss* (juvenile)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-54	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.4	1.00
0.4	1.00
189	0.40
189	0.40
250	0.00
250	0.00
272	0.00
272	0.00

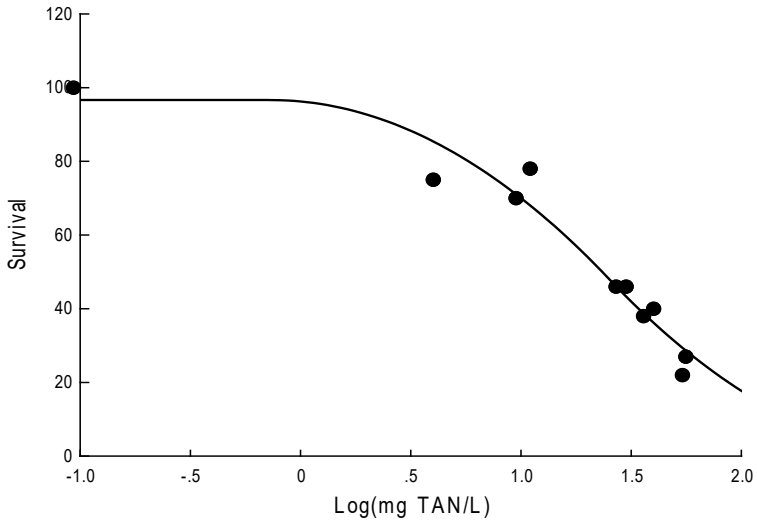


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.2623	2.2621			
StDev	0.062719	0.055447			
Y0	1	0.9999			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**182.86**				2.2621
20	163.01				2.2122
10	153.83				2.187
5	**147.66**				2.1693
0	133.75				2.1263

LC50:LC5 = 1.238

Notes: TRAP flagged for IP (No Unique Solution).

Wicks et al. 2002	
Species: *Oncorhynchus mykiss* (40 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-55	
Test: Swimming	
TAN, mg/L	**% Survival**
0.05	100
4	75
11	78
9.5	70
27	46
30	46
36	38
40	40
54	22
56	27



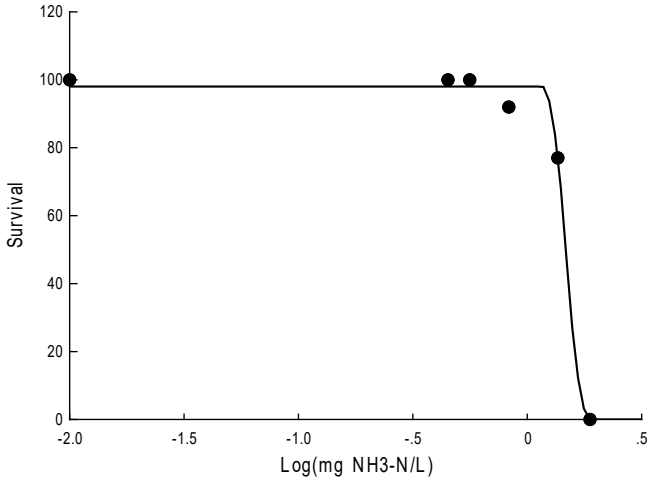
LC50:LC5 = 11.16

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.3955	0.076062	1.2157	1.5754
S	1	0.65278	0.11673	0.37674	0.92881
Y0	100	96.621	6.3199	81.677	111.57

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**24.86**	16.431	37.616	0.076062	1.3955
20	6.799	2.8895	16	0.15717	0.83247
10	3.538	1.111	11.263	0.2127	0.54869
5	**2.229**	0.54258	9.1539	0.25948	0.34803
0	0.73	0.067208	7.9391	0.4382	-0.1364

Notes: No effect within area of concern.

Swigert and Spacie 1983	
Species: *Campostoma anomalum* (2.1 g)	
Test Endpoint: 4 day Survival	
C-R Curve Label: Am-Acute-57	
Test: Single	
NH3-N, mg/L	**% Survival**
0.01	100
0.45	100
0.56	100
0.83	92
1.36	77
1.88	0



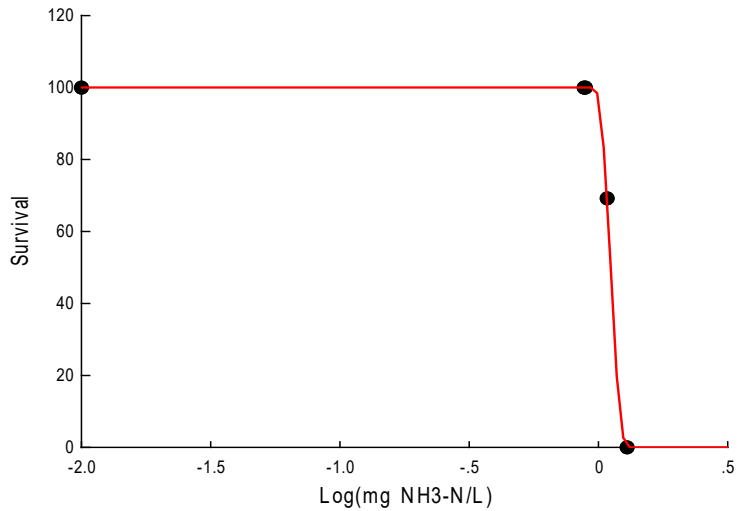
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.125	0.16964	3.0863	-9.6522	9.9915
S	6	9.5648	817.58	-2592.3	2611.5
Y0	100	98	2	91.635	104.36

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.4779**	2.2E-10	9806800000	3.0863	0.16964
20	1.3528	1.2837	1.4255	0.0071529	0.13122
10	1.2938	1.214	1.3787	0.0086776	0.11185
5	**1.2536**	1.1695	1.3437	0.0094742	0.098156
0	1.1617	1.0709	1.2602	0.011109	0.065095

LC50:LC5 = 1.179

Notes: Poor model fit. Large SE for X50, steepness (S).

Swigert and Spacie 1983	
Species: *Cyprinella spiloptera* (0.5 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-60	
Test: Single	
NH3-N, mg/L	**% Survival**
0.01	100
0.88	100
0.89	100
1.08	69.2
1.29	0

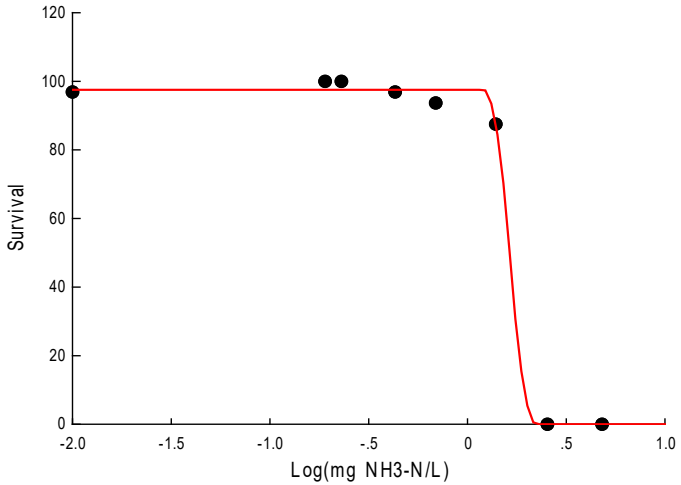


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.05	0.047086			
S	8	15.747			
Y0	100	100			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.1145**				0.047086
20	1.0562	1.0562	1.0562	5.8847E-14	0.023746
10	1.028	1.028	1.028	6.5628E-14	0.011982
5	**1.0085**	1.0085	1.0085	6.8491E-14	0.003664
0	0.9629	0.9629	0.9629	7.6208E-14	-0.01642

LC50:LC5 = 1.105

Notes: TRAP flagged for IP (No Unique Solution).

Hasan and MacIntosh 1986	
Species: *Cyprinus carpio*	
Test Endpoint: 168 and 96 hr Survival	
C-R Curve Label: Am-Acute-61	
Test: Trial 1	
NH3-N, mg/L	**% Survival**
0	96.9
0.19	100
0.23	100
0.43	96.9
0.69	93.7
1.39	87.5
2.54	0
4.8	0

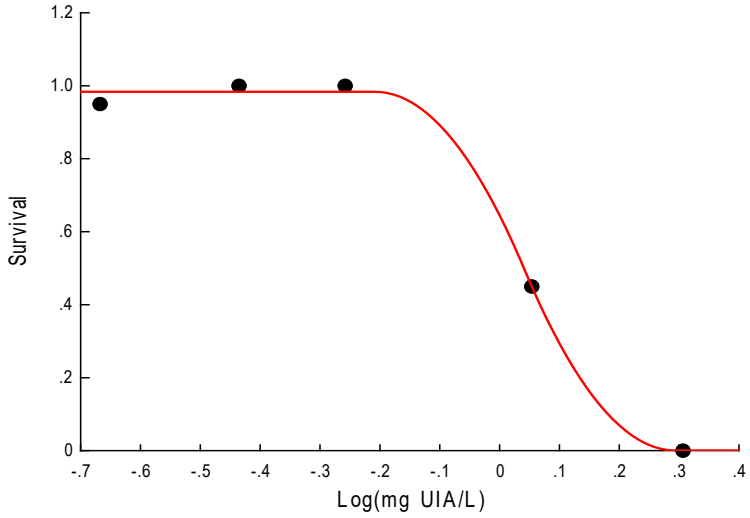


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.2	0.2151			
S	6	7.5897			
Y0	97.5	97.5			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.641**				0.2151
20	1.4678				0.16667
10	1.3876				0.14226
5	**1.3335**				0.12501
0	1.2115				8.33E-02

LC50:LC5 = 1.231

Notes: TRAP flagged for IP (No Unique Solution).

EA Engineering 1985	
Species: *Notemigonus crysoleucas*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-64	
Test: 254	
Unionized ammonia (NH3), mg/L	**Proportion surviving**
0.215	0.95
0.367	1.00
0.552	1.00
1.132	0.45
2.025	0.00



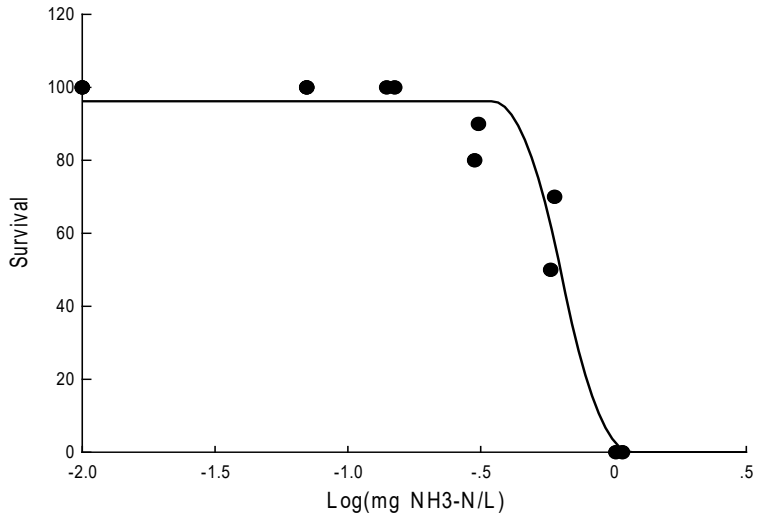
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0	4.30E-02			
StDev	0.29	0.10256			
Y0	0.98333	0.98333			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.104**				4.30E-02
20	0.89251				-4.94E-02
10	0.80182				-9.59E-02
5	**0.74331**				-0.12883
0	0.61905				-0.20828

LC50:LC5 = 1.485

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

Swigert and Spacie 1983	
Species: *Notemigonus crysoleucas* (8.7 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-65	
Test: Single	
Unionized ammonia nitrogen (NH3-N), mg/L	**Proportion surviving**
0.01	100
0.01	100
0.07	100
0.07	100
0.15	100
0.14	100
0.30	80
0.31	90
0.58	50
0.60	70
1.02	0
1.08	0



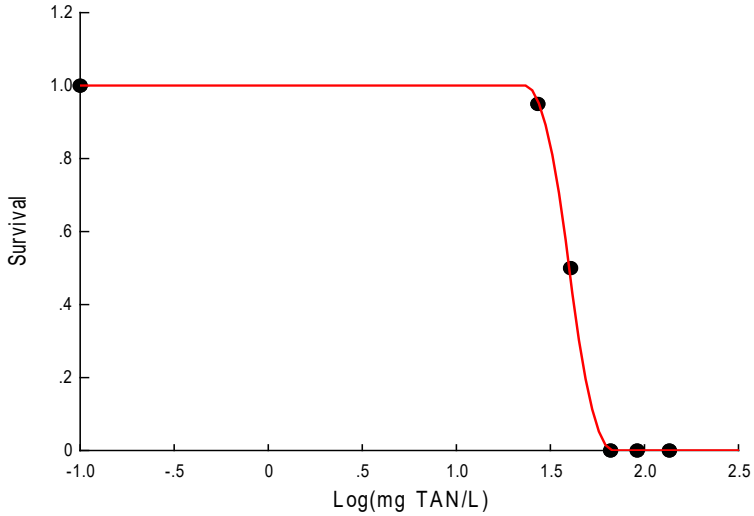
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.2	-0.19427	0.021893	-0.2438	-0.14475
S	2	3.8214	1.4672	0.50238	7.1404
Y0	100	96.162	3.1152	89.115	103.21

LC50:LC5 = 1.510

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**0.63933**	0.57043	0.71656	0.021893	-0.19427
20	0.51233	0.38705	0.67816	0.053835	-0.29045
10	0.45822	0.24963	0.84112	0.11661	-0.33893
5	**0.42344**	0.28585	0.62727	0.075441	-0.3732
0	0.34998	0.26422	0.46358	0.053968	-0.45596

Notes: Poor model fit.

EA Engineering 1985	
Species: *Pimephales promelas*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-66	
Test: 298	
TAN, mg/L	**Proportion surviving**
0.1	1.00
27.1	0.95
40.48	0.50
66.03	0.00
91.4	0.00
135.67	0.00



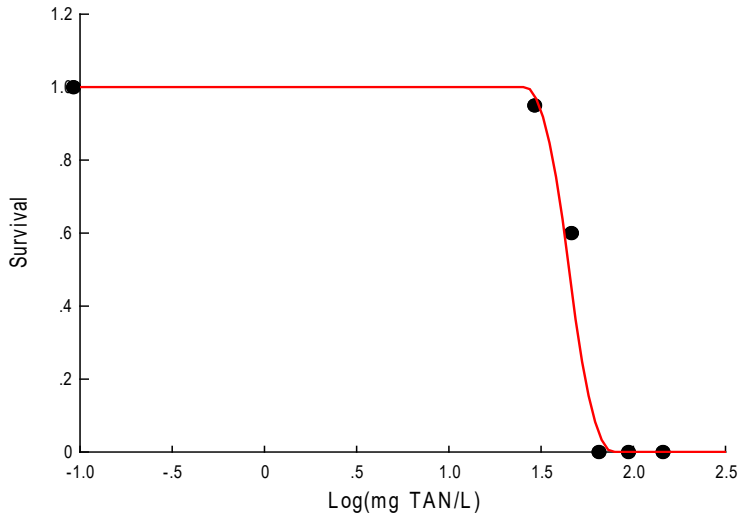
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.6	1.5997	0.018846	1.5609	1.6384
StDev	0.1	0.095159	0.012901	0.075293	0.12935
Y0	1	0.9999	0.0022356	0.83144	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**39.78**	36.382	43.496	0.018846	1.5997
20	32.659	29.135	36.608	0.023642	1.514
10	29.568	25.768	33.928	0.027798	1.4708
5	**27.56**	23.55	32.253	0.031032	1.4403
0	23.258	18.754	28.844	0.039159	1.3666

LC50:LC5 = 1.443

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

EA Engineering 1985	
Species: *Pimephales promelas*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-67	
Test: 299	
TAN, mg/L	**Proportion surviving**
0.09	1.00
29.2	0.95
46.2	0.60
65.16	0.00
94.1	0.00
144.9	0.00

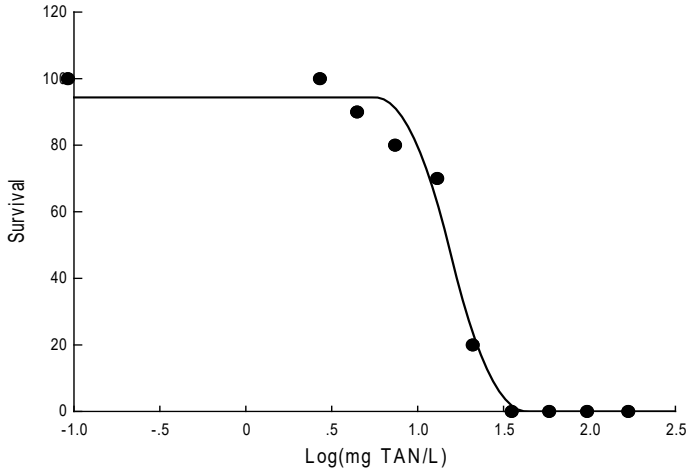


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.6517	0.019102	1.6124	1.691
StDev	0.15	0.097047	0.014506	0.075198	0.13688
Y0	1	0.9999	0.002235	0.83145	1
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**44.845**	40.967	49.091	0.019102	1.6517
20	36.673	32.689	41.142	0.023732	1.5643
10	33.137	28.782	38.151	0.02822	1.5203
5	**30.844**	26.146	36.387	0.03215	1.4892
0	25.942	20.519	32.799	0.041255	1.414

LC50:LC5 = 1.454

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

Buhl 2002	
Species: *Pimephales promelas* (4-6 d old)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-68	
Test:	
TAN, mg/L	**% Survival**
<0.10	100
2.7	100
4.44	90
7.38	80
13.00	70
20.9	20
35.2	0
58.2	0
96.7	0
168	0



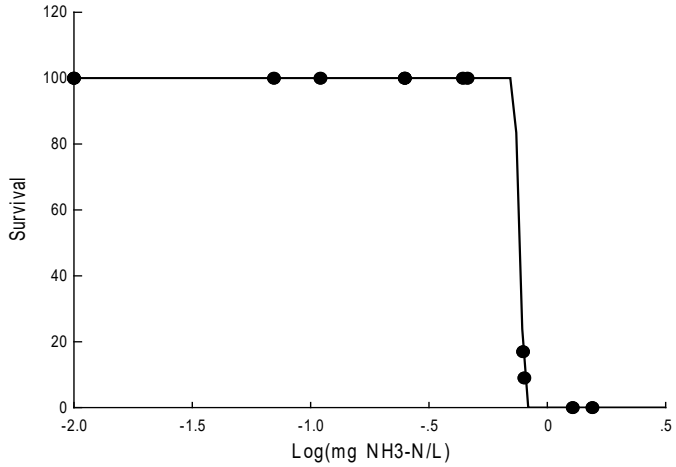
LC50:LC5 = 1.992

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.2	1.1935	0.028804	1.1254	1.2616
S	2	2.284	0.46024	1.1957	3.3723
Y0	100	94.327	3.4969	86.058	102.6

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**15.613**	13.347	18.264	0.028804	1.1935
20	10.779	8.2916	14.012	0.04818	1.0326
10	8.9426	6.2012	12.896	0.067237	0.95146
5	**7.8363**	5.0525	12.154	0.080606	0.89411
0	5.6972	3.5525	9.1366	0.086746	0.75566

Notes: Not core data. Poor model fit.

Swigert and Spacie 1983	
Species: *Catostomus commersonii*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-72	
Test: Single	
NH3-N, mg/L	**% Survival**
Control (0.01)	100
Control (0.01)	100
0.07	100
0.11	100
0.25	100
0.25	100
0.44	100
0.46	100
0.79	17
0.8	9
1.28	0
1.55	0



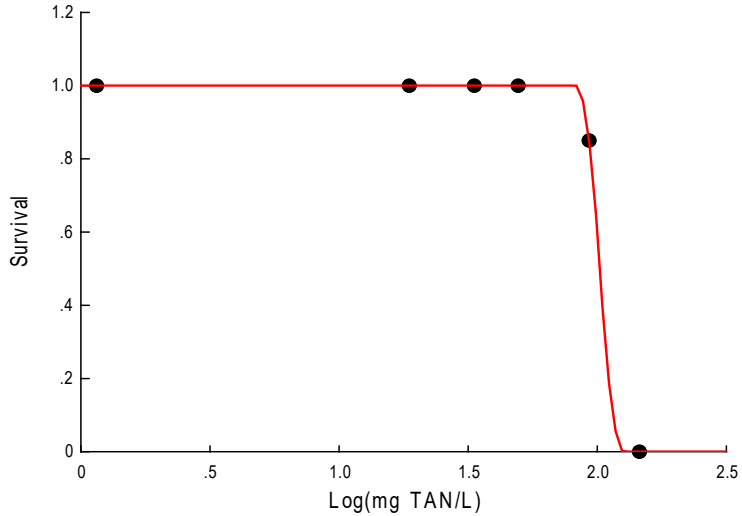
LC50:LC5 = 1.056

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.125	-0.1167	0	-0.11671	-0.11671
S	12	29.075	0	29.075	29.075
Y0	100	100	0	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**0.76434**	0.76434	0.76434	0	-0.11671
20	0.74241	0.74241	0.74241	0	-0.12935
10	0.7316	0.7316	0.7316	0	-0.13572
5	**0.72405**	0.72405	0.72405	0	-0.14023
0	0.70614	0.70614	0.70614	0	-0.15111

Notes: No TRAP flags for IP, but curve slope based on arbitrary breakpoint.

EA Engineering 1985	
Species: *Ictalurus punctatus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-73	
Test: 255	
TAN, mg/L	**Proportion surviving**
1.15	1.00
18.7	1.00
33.4	1.00
49.38	1.00
92.93	0.85
145.69	0.00

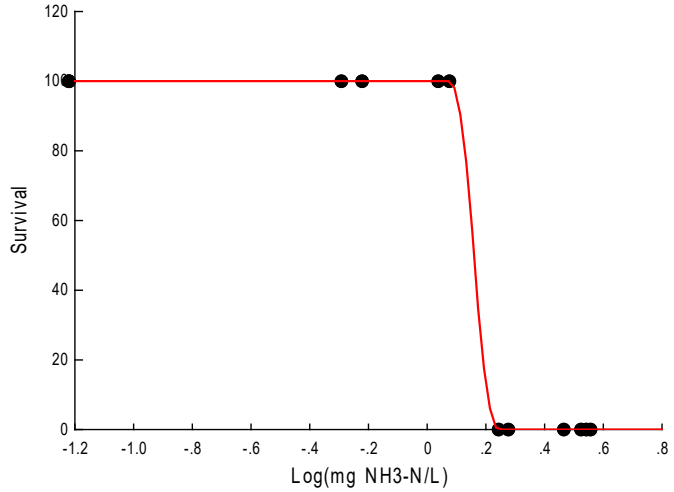


Log X50	2	2.0097			
StDev	0.05	3.75E-02			
Y0	1	0.9999			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**102.26**				2.0097
20	94.613				1.976
10	90.978				1.9589
5	**88.491**				1.9469
0	82.765				1.9178

LC50:LC5 = 1.156

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

Reinbold and Pescitelli1982d	
Species: *Ictalurus punctatus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-75	
Test: #2	
NH3-N, mg/L	**% Survival**
Control (0.05)	100
Control (0.05)	100
0.51	100
0.6	100
1.09	100
1.19	100
1.75	0
1.89	0
2.92	0
3.34	0
3.48	0
3.6	0

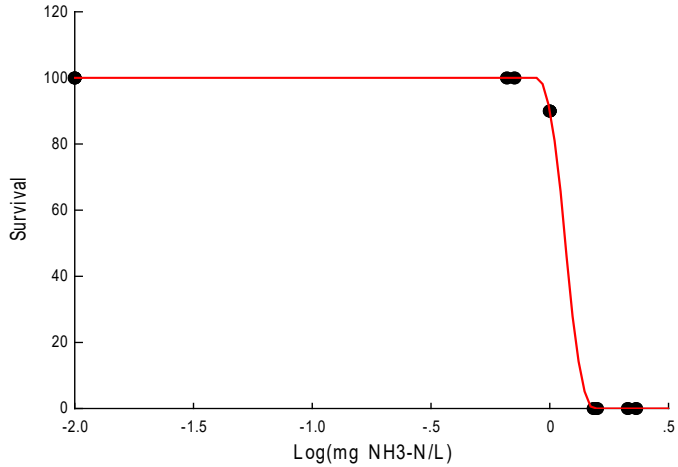


LC50:LC5 = 1.140

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.16	0.15985			
S	12	12.021			
Y0	100	100			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.4449**				0.15985
20	1.3467				0.12928
10	1.2998				0.11387
5	**1.2676**				0.10297
0	1.1931				0.076667

Notes: TRAP flagged for IP (No Unique Solution).

Swigert and Spacie 1983	
Species: *Ictalurus punctatus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-76	
Test: Single	
NH3-N, mg/L	**% Survival**
Control (0.01)	100
Control (0.01)	100
0.66	100
0.71	100
1	90
1	90
1.53	0
1.58	0
2.13	0
2.31	0



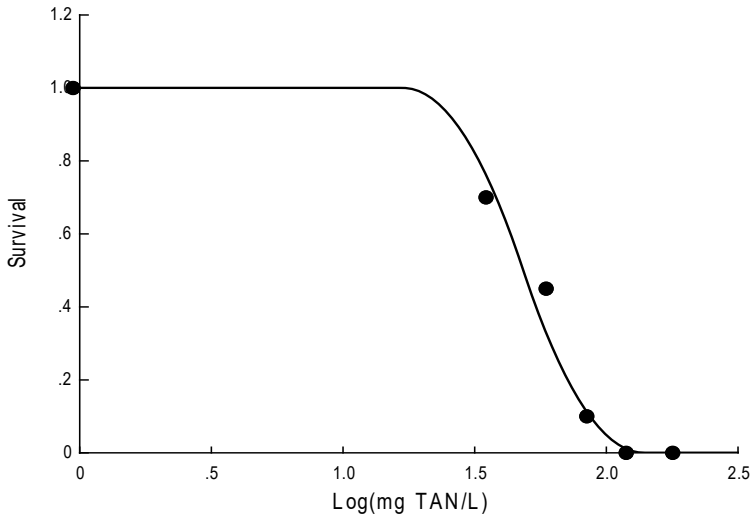
LC50:LC5 = 1.206

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.05	0.06575	7.27E-09	0.06575	0.06575
S	8	8.4075	9.3E-07	8.4075	8.4075
Y0	100	100	7.8E-12	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.1635**	1.1635	1.1635	7.2718E-09	0.06575
20	1.052	1.052	1.052	3.7449E-14	0.022033
10	1	1	1	3.479E-14	3.96E-10
5	**0.96476**	0.96476	0.96476	3.8135E-14	-0.01558
0	0.88472	0.88472	0.88472	4.6146E-14	-0.05319

Notes: TRAP flagged for IP (No Unique Solution).

EA Engineering 1985	
Species: *Lepomis macrochirus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-78	
Test: 186	
TAN, mg/L	**Proportion surviving**
0.46	1.00
34.9	0.70
59.02	0.45
84.25	0.10
118.88	0.00
178.6	0.00



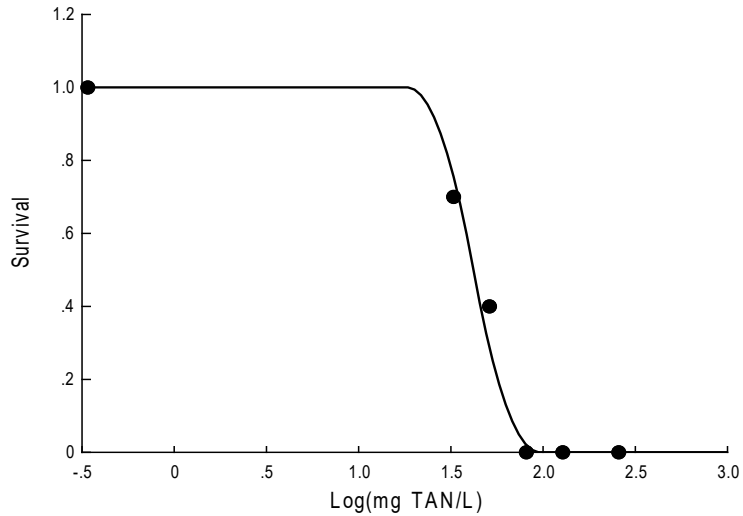
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.7	1.6848	0.038662	1.6049	1.7648
StDev	0.2	0.1867	0.031713	0.14042	0.27859
Y0	1	0.9999	0.0022359	0.83139	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**48.399**	40.264	58.178	0.038662	1.6848
20	32.867	24.505	44.081	0.059847	1.5168
10	27.042	18.671	39.166	0.072609	1.432
5	**23.558**	15.269	36.346	0.081799	1.3721
0	16.886	8.9782	31.758	0.10416	1.2275

LC50:LC5 = 2.054

Notes: Not core data. No effect within area of concern.

EA Engineering 1985	
Species: *Lepomis macrochirus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-79	
Test: 187	
TAN, mg/L	**Proportion surviving**
0.34	1.00
32.72	0.70
51.24	0.40
81.04	0.00
127.75	0.00
257	0.00



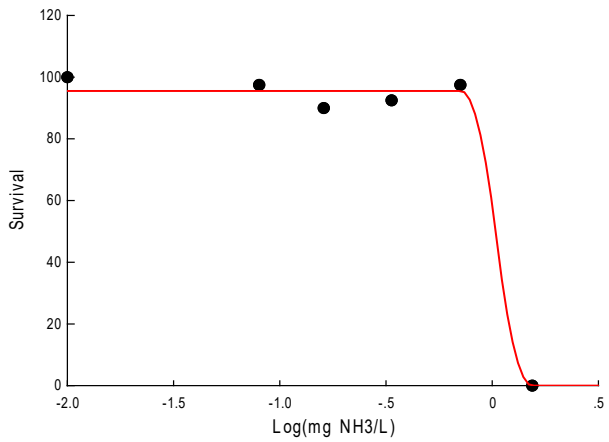
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.6	1.6228	0.03233	1.5554	1.6901
StDev	0.15	0.14634	0.027707	0.10709	0.23104
Y0	1	0.9999	0.002236	0.83139	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**41.954**	35.929	48.991	0.03233	1.6228
20	30.976	24.299	39.488	0.048746	1.491
10	26.584	18.885	37.422	0.065337	1.4246
5	**23.86**	16.481	34.543	0.067327	1.3777
0	18.379	10.453	32.316	0.08635	1.2643

LC50:LC5 = 1.758

Notes: Not core data. No effect within area of concern.

Smith et al. 1984	
Species: *Lepomis macrochirus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-81	
Test: Single	
NH3, mg/L	**% Survival**
Control (0.01)	100
0.08	97.5
0.161	90
0.336	92.5
0.708	97.5
1.543	0

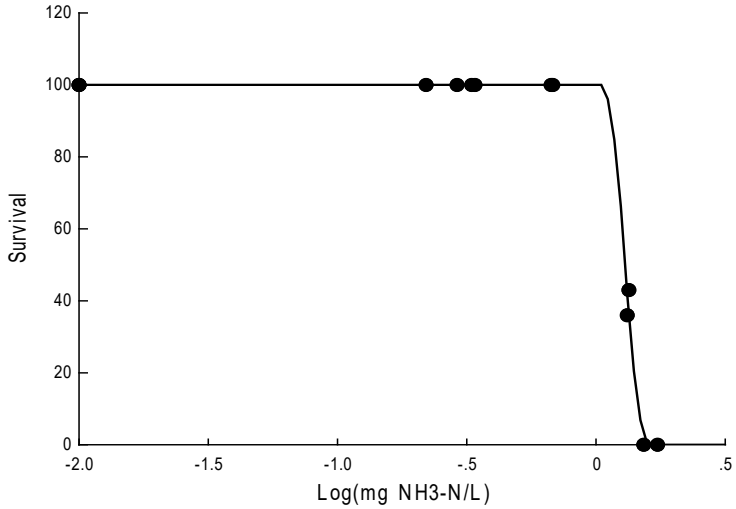


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.02	0.02			
S	6	6			
Y0	95.5	95.5			
p	Xp	95% LCI	95% UCL	Log Xp SE	Log Xp
50	**1.0471**				0.02
20	0.90937				-0.041257
10	0.84697				-0.072131
5	**0.80545**				-0.093962
0	0.7134				-0.14667

LC50:LC5 = 1.300

Notes: TRAP flagged for IP (No Unique Solution).

Swigert and Spacie 1983	
Species: *Lepomis macrochirus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-82	
Test: Jan 22, 1981 test	
NH3-N, mg/L	**% Survival**
Control (0.01)	100
Control (0.01)	100
0.22	100
0.29	100
0.33	100
0.34	100
0.67	100
0.68	100
1.32	36
1.34	43
1.53	0
1.73	0



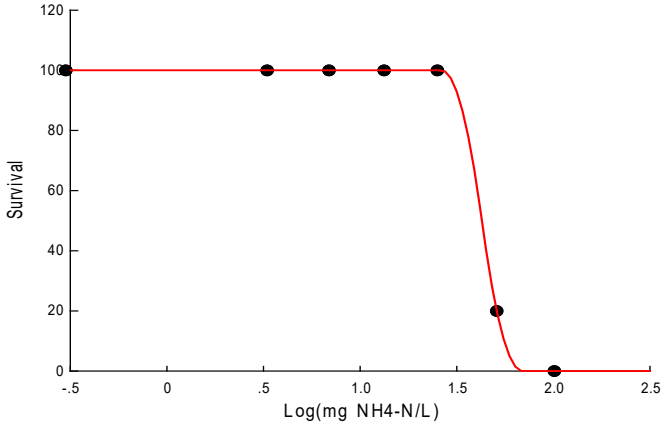
LC50:LC5 = 1.159

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.1	0.11272	0.003645	0.10447	0.12096
S	10	10.679	2.2361	5.6207	15.737
Y0	100	100	1.1446	97.411	102.59

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.2963**	1.272	1.3212	0.003645	0.11272
20	1.1976	1.0991	1.3049	0.016479	0.0783
10	1.1507	0.85415	1.5501	0.05721	0.060953
5	**1.1186**	0.89055	1.4051	0.043777	0.048688
0	1.0449	0.92165	1.1846	0.024097	0.019076

Notes: No TRAP flags for IP, but curve slope based on arbitrary breakpoint.

Schuytema and Nebeker 1999a	
Species: *Pseudacris regilla*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-88	
Test: ammonium nitrate	
NH4-N, mg/L	**% Survival**
0.3	100
3.3	100
6.9	100
13.3	100
25.1	100
50.9	20
101.2	0



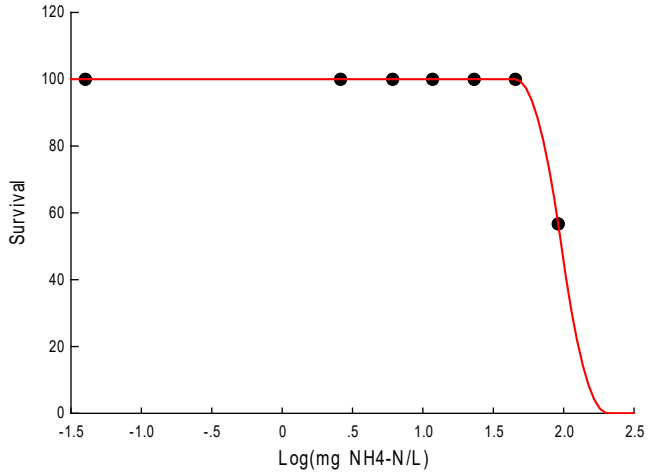
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.6	1.6301			
S	4.8	4.7993			
Y0	100	100			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**42.671**				1.6301
20	35.773				1.5536
10	32.731				1.515
5	**30.737**				1.4877
0	26.41				1.4218

LC50:LC5 = 1.388

Notes: TRAP flagged for IP (No Unique Solution).

Schuytema and Nebeker 1999a	
Species: *Pseudacris regilla*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-90	
Test: ammonium sulfate	
NH4-N, mg/L	**% Survival**
0.04	100
2.6	100
6.1	100
11.7	100
23.1	100
45.4	100
91.5	56.7



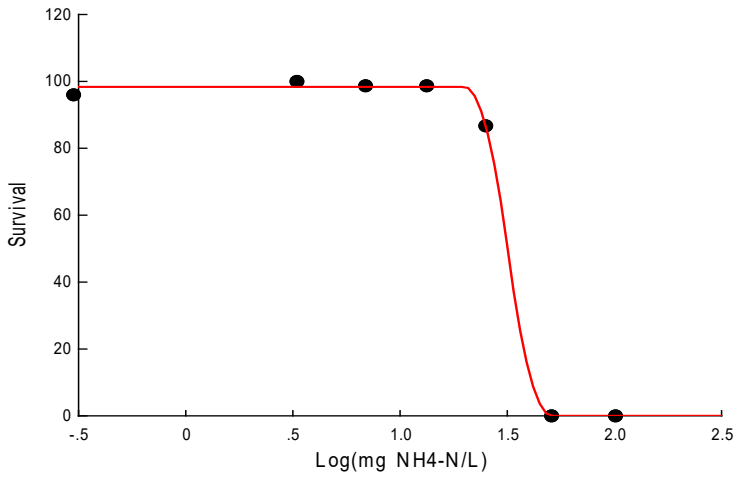
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2	1.9841	0	1.9841	1.9841
S	3	3.0575	0	3.0575	3.0575
Y0	100	100	0	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**96.41**	96.41	96.41	0	1.9841
20	73.099	73.099	73.099	0	1.8639
10	63.581	63.581	63.581	0	1.8033
5	**57.608**	57.608	57.608	0	1.7605
0	45.4	45.4	45.4	0	1.6571

LC50:LC5 = 1.674

Notes: TRAP flagged for IP (No Unique Solution).

Schuytema and Nebeker 1999a	
Species: *Xenopus laevis*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-91	
Test: ammonium nitrate	
NH4-N, mg/L	**% Survival**
0.3	96
3.3	100
6.9	99
13.3	99
25.1	87
50.9	0
101.2	0



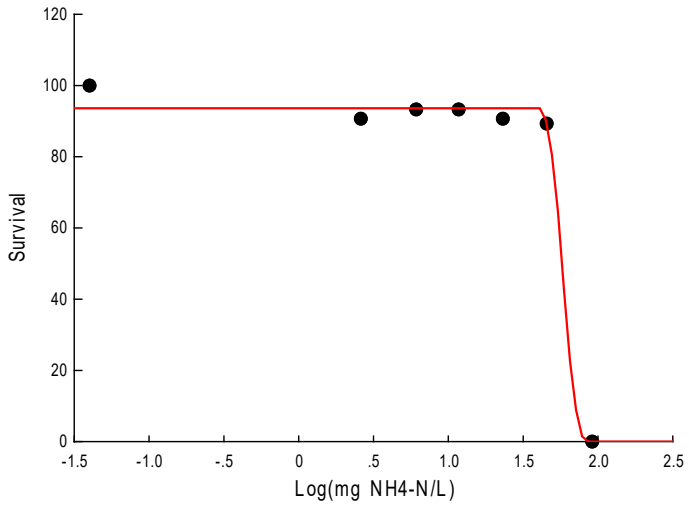
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.5038			
S	5	4.9303			
Y0	98.35	98.35			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**31.899**				1.5038
20	26.868				1.4292
10	24.641				1.3917
5	**23.179**				1.3651
0	19.996				1.301

LC50:LC5 = 1.376

Notes: TRAP flagged for IP (No Unique Solution).

Schuytema and Nebeker 1999a	
Species: *Xenopus laevis*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-92	
Test: ammonium sulfate	
NH4-N, mg/L	**% Survival**
0.04	100
2.6	91
6.1	93
11.7	93
23.1	91
45.4	89
91.5	0



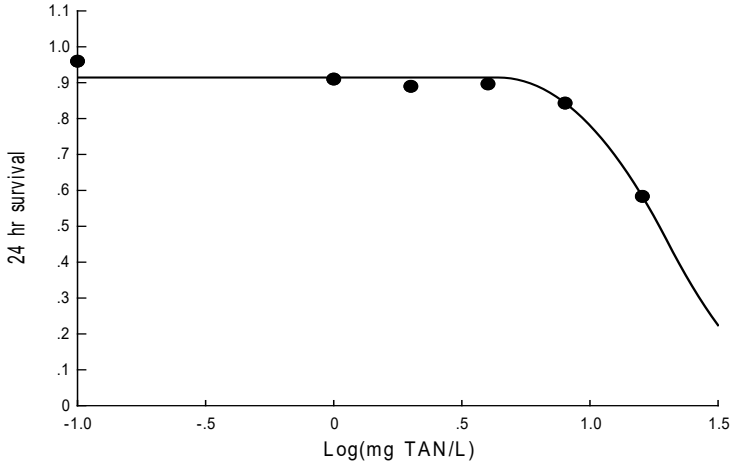
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.75	1.7656			
S	5.5	6.4217			
Y0	100	93.6			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**58.288**				1.7656
20	51.091				1.7083
10	47.807				1.6795
5	**45.614**				1.6591
0	40.724				1.6099

LC50:LC5 = 1.278

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Alasmidonta heterodon*	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-93	
Test: glochidia	
TAN, mg/L	**Proportion surviving**
0.1	0.96
1	0.91
2	0.89
4	0.90
8	0.84
16	0.58



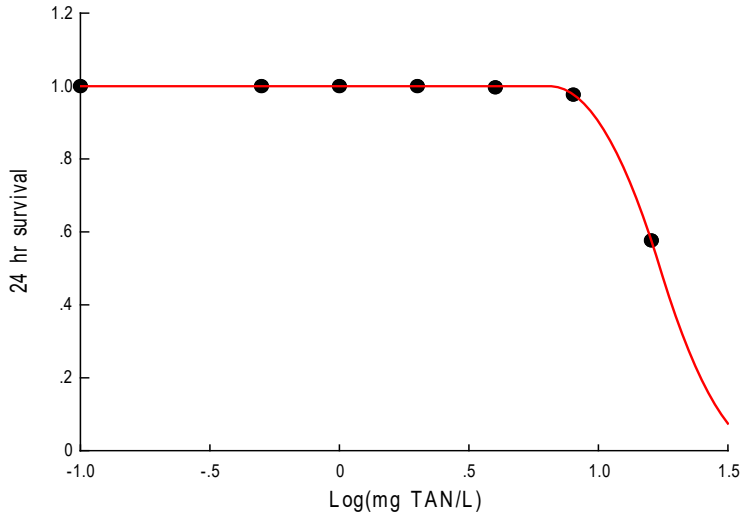
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.3	1.3024	0.034365	1.2337	1.3711
StDev	0.27	0.26884	0.041333	0.20701	0.38361
Y0	0.96	0.91417	0.008086	0.89687	0.9294

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**20.062**	17.126	23.501	0.034365	1.3024
20	11.49	10.264	12.863	0.023927	1.0603
10	8.6765	7.2734	10.35	0.03627	0.93834
5	**7.1135**	5.6037	9.0302	0.047597	0.85209
0	4.4039	2.8608	6.7794	0.077515	0.64384

LC50:LC5 = 2.820

Notes: No TRAP flags, but lack of partials greater than 50% to define tail end of curve.

Wang et al. 2007b	
Species: *Potamilus ohiensis*	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-94	
Test: glochidia	
TAN, mg/L	**Proportion surviving**
0.1	1.00
0.5	1.00
1	1.00
2	1.00
4	1.00
8	0.98
16	0.58



	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.2311	1.2383	1.49E-02	1.2089	1.2677
StDev	0.15169	0.17388	1.27E-02	0.15222	0.2028
Y0	0.99556	0.99933	6.66E-04	0.99629	0.99998

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**3.2149**	2.9613	3.4902	0.018114	0.50716
20	1.7994	1.5815	2.0474	0.028359	0.25513
10	1.3431	1.1433	1.5778	0.035207	0.12811
5	**1.0922**	0.90698	1.3152	0.040435	0.038292
0	0.6629	0.51582	0.85193	0.053785	-0.17855

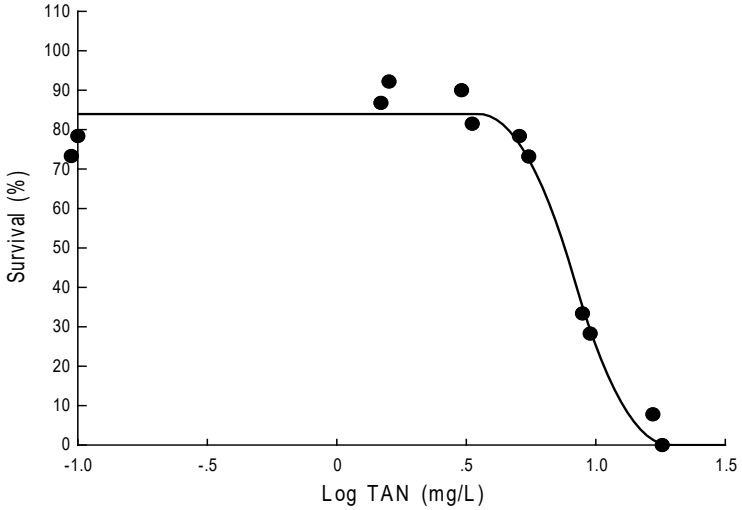
LC50:LC5 = 2.944

Notes: TRAP flagged for IP (No Unique Solution). Lack of partials greater than 50% to define tail end of curve.

Appendix A.3

Test Information, C-R Data and Resulting TRAP models for Chronic Ammonia Toxicity Tests Acceptable for TAF and MAF Calculation

Anderson et al. 1978	
Species: *Musculium transversum*	
Test Endpoint: 42-d Juvenile Survival	
C-R Curve Label: Am-Chronic-4	
Test: Chronic bioassays 2 and 3 combined	
TAN, mg/L	**% Survival**
0.08	73.3
0.1	78.4
1.48	86.8
1.59	92.2
3.03	90
3.33	81.5
5.07	78.4
5.51	73.2
8.88	33.4
9.51	28.3
16.6	7.8
18.04	0



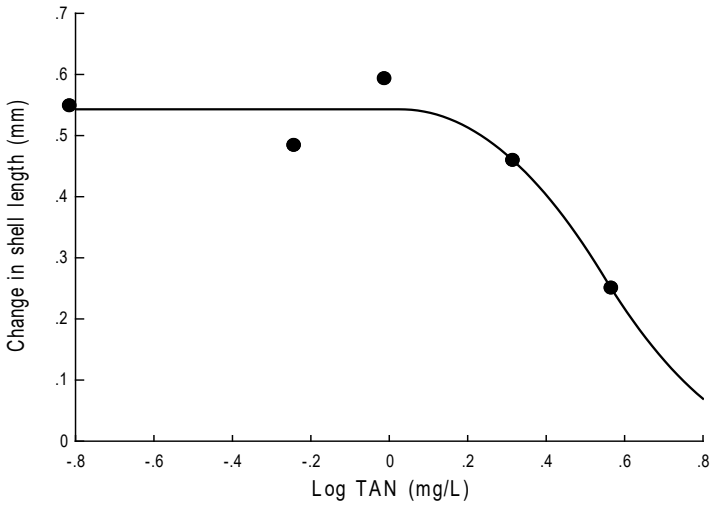
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.9	0.91709	0.019772	0.87236	0.96182
S	2.5	2.7149	0.48295	1.6224	3.8074
Y0	83.7	83.948	2.3969	78.526	89.371

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	8.2621	7.4536	9.1584	0.019772	0.91709
20	**6.0493**	5.0777	7.207	0.033617	0.78171
10	5.1698	4.1139	6.4967	0.04386	0.71348
5	**4.6262**	3.589	5.9633	0.048739	0.66523
0	3.5379	2.6158	4.7851	0.057972	0.54875

EC20:EC5 = 1.308

Notes: Acceptable model fit.

Besser 2011	
Species: *Fluminicola sp.*(juvenile)	
Test Endpoint: Change in shell length (0 – 28 days)	
C-R Curve Label: Am-Chronic-6	
Test: Single	
TAN, mg/L	**Change in shell length (mm)**
0.12	0.5497
0.57	0.4848
0.97	0.5939
2.06	0.4604
3.67	0.2513

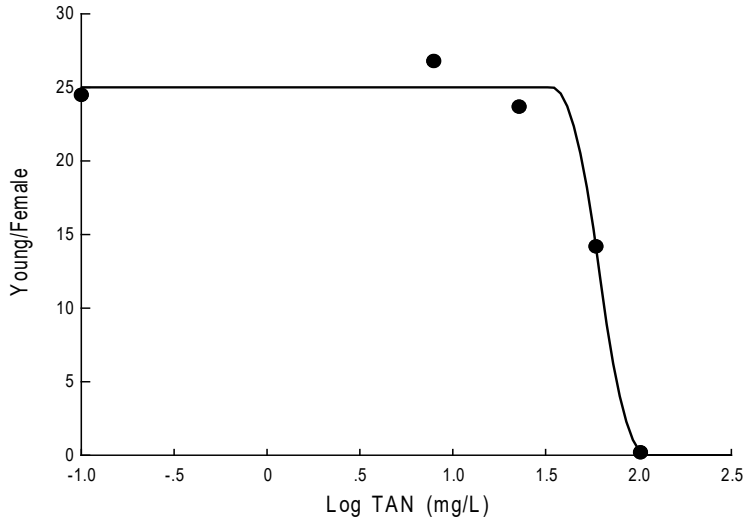


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.5496	0.54522	5.32E-02	0.31615	0.77429
StDev	1.7434	1.9407	0.87827	-1.8381	5.7196
Y0	0.5428	0.5428	3.17E-02	0.40648	0.67912
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	3.5093	2.0708	5.9469	5.32E-02	0.54522
20	**2.269**	0.9376	5.491	8.92E-02	0.35583
10	1.8213	0.5148	6.4436	0.12754	0.26038
5	**1.5592**	0.32367	7.5106	0.15869	0.19289
0	1.0714	7.28E-02	15.773	0.27145	2.99E-02

EC20:EC5 = 1.455

Notes: Acceptable model fit. Acceptable noise at low level effects.

Mount 1982	
Species: *Ceriodaphnia acanthina*	
Test Endpoint: 7-d LC Reproduction	
C-R Curve Label: Am-Chronic-7	
Test: Single	
TAN, mg/L	**Avg. young/female**
0.1	24.5
7.9	26.8
22.75	23.7
59	14.2
102.5	0.2



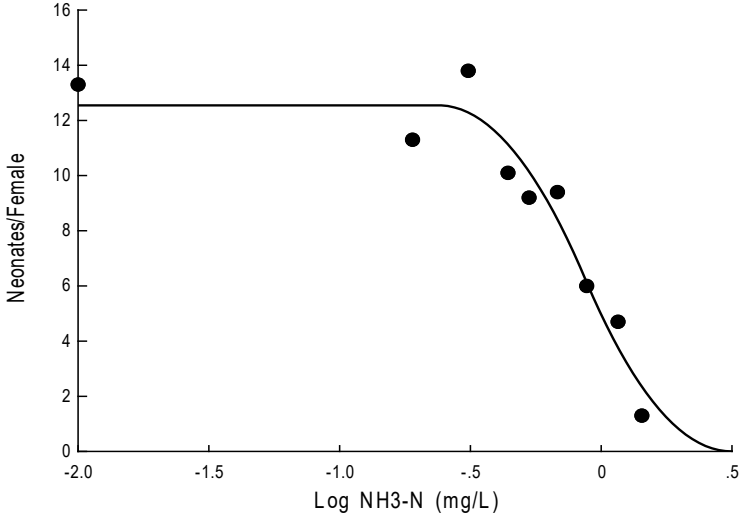
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.6135	1.7888	1.97E-02	1.7041	1.8734
S	1.6228	3.9354	2.1429	-5.2846	13.155
Y0	25.65	25	0.92916	21.002	28.998

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	61.484	50.591	74.722	1.97E-02	1.7888
20	**49.587**	5.7696	426.17	0.21713	1.6954
10	44.494	16.096	122.99	0.10263	1.6483
5	**41.211**	21.243	79.947	6.69E-02	1.615
0	34.25	20.598	56.95	5.13E-02	1.5347

EC20:EC5 = 1.203

Notes: Large SE for steepness. Acceptable model fit. Acceptable noise at low level effects.

Nimmo et al. 1989	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 7-d LC Reproduction	
C-R Curve Label: Am-Chronic-8	
Test: Single	
NH3-N (mg/L)	**Avg. # neonates/female**
Not detectable (0.01)	13.3
0.19	11.3
0.31	13.8
0.44	10.1
0.53	9.2
0.68	9.4
0.88	6.0
1.16	4.7
1.43	1.3



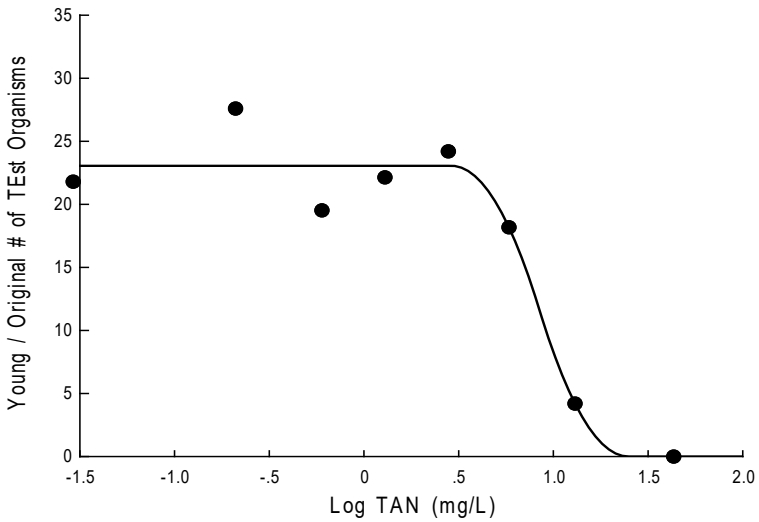
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.1	-0.0621	0.039824	-0.15955	0.035343
S	1.9	1.7858	0.41651	0.76665	2.805
Y0	12.8	12.544	0.80344	10.578	14.51

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.86676	0.69255	1.0848	0.039824	-0.0621
20	**0.53961**	0.36358	0.80087	0.07008	-0.26792
10	0.42497	0.24782	0.72873	0.095718	-0.37165
5	**0.35893**	0.18299	0.70401	0.11957	-0.44499
0	0.23874	0.066831	0.85285	0.22598	-0.62207

EC20:EC5 = 1.503

Notes: Acceptable model fit. Acceptable noise at low level effects.

Willingham 1987	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 7-d LC Reproduction	
C-R Curve Label: Am-Chronic-9	
Test: Single	
TAN, mg/L	**Young/original test animal (Brood 3)**
0.02	21.8
0.21	27.6
0.60	19.52
1.29	22.14
2.79	24.2
5.83	18.18
13.0	4.2
43.2	0

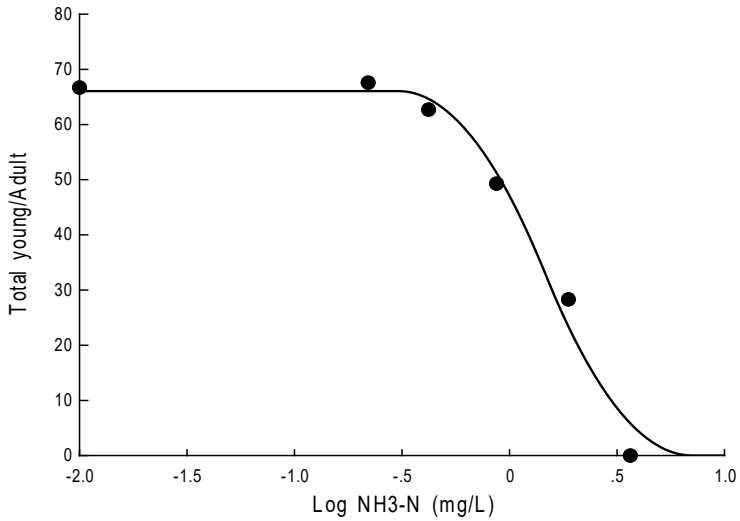


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	0.92895	0.064925	0.76206	1.0958
S	2	2.1425	0.77699	0.14523	4.1399
Y0	23.052	23.052	1.2145	19.93	26.174
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	8.4909	5.7818	12.469	0.064925	0.92895
20	**5.7202**	3.3223	9.8486	0.091795	0.75741
10	4.6876	2.3059	9.5291	0.11986	0.67095
5	**4.0721**	1.6429	10.093	0.15335	0.60981
0	2.8988			2.6871	0.46222

EC20:EC5 = 1.405

Notes: Acceptable model fit. Acceptable noise at low level effects.

Gersich et al. 1985	
Species: *Daphnia magna*	
Test Endpoint: 21-d LC Reproduction	
C-R Curve Label: Am-Chronic-10	
Test: Single	
NH3-N (mg/L)	**Total young/adult**
0.01	66.7
0.22	67.6
0.42	62.7
0.87	49.3
1.88	28.3
3.65	0

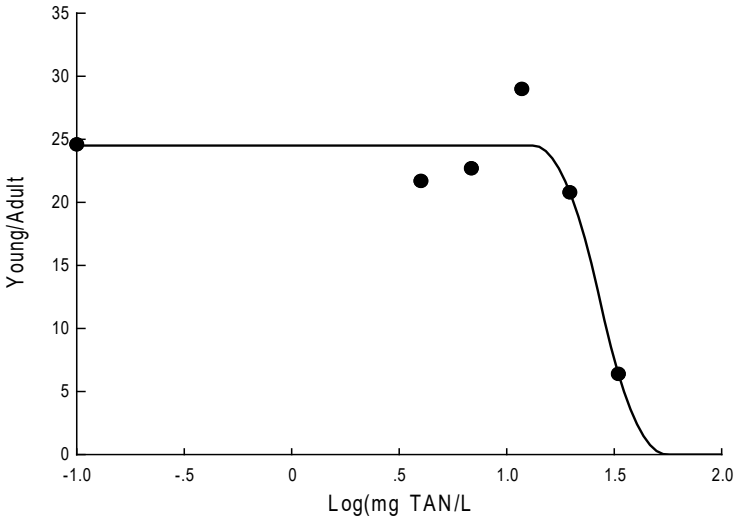


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.12	0.16559	0.049825	0.007022	0.32415
S	1.5	1.4637	0.30171	0.50356	2.4239
Y0	67.15	66.052	3.1285	56.095	76.008
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.4642	1.0163	2.1094	0.049825	0.16559
20	**0.82127**	0.44661	1.5102	0.083131	-0.08551
10	0.61367	0.2701	1.3943	0.11199	-0.21207
5	**0.4994**	0.1777	1.4035	0.14101	-0.30155
0	0.30367	0.062573	1.4737	0.21556	-0.5176

EC20:EC5 = 1.645

Notes: Acceptable model fit.

Reinbold and Pescitelli 1982a	
Species: *Daphnia magna*	
Test Endpoint: 21-d LC Reproduction	
C-R Curve Label: Am-Chronic-11	
Test: Single	
TAN, mg/L	**Mean # young produced/adult**
Control (0.1)	24.6
3.99	21.7
6.85	22.7
11.75	29
19.66	20.8
33.07	6.4



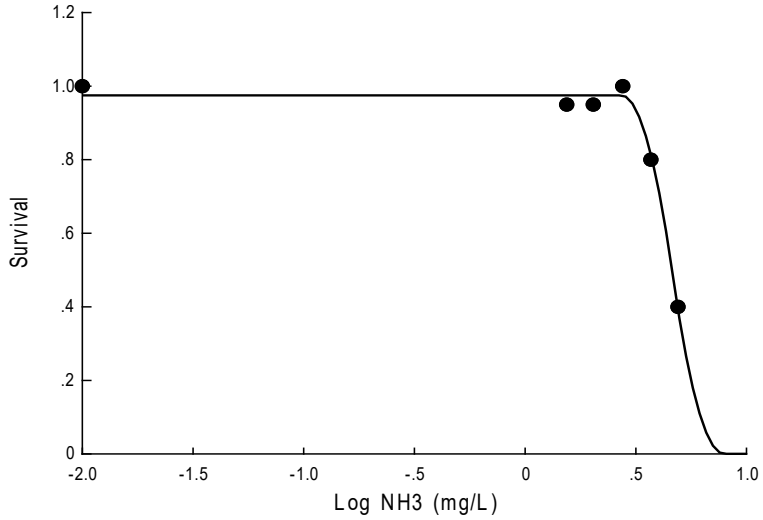
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.4334	1.4334	4.81E-02	1.2804	1.5864
S	2.7439	3.2216	1.3792	-1.1675	7.6108
Y0	24.5	24.5	1.6161	19.357	29.643

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	27.126	1.91E+01	38.585	4.81E-02	1.4334
20	**20.86**	12.271	35.459	7.24E-02	1.3193
10	18.273	9.2616	36.052	9.27E-02	1.2618
5	**16.64**	7.381	37.513	1.11E-01	1.2212
0	13.274	1.883	93.571	2.67E-01	1.123

EC20:EC5 = 1.254

Notes: Acceptable model fit. Acceptable noise at low level effects.

Thurston et al. 1984b	
Species: *Pteronarcella badia*	
Test Endpoint: 30-d Juvenile Survival	
C-R Curve Label: Am-Chronic-13	
Test: 293	
Mean NH3, mg/L	**Proportion Surviving**
0.01	1.0
1.54	1.0
2.03	1.0
2.76	1.0
3.7	0.8
4.9	0.4

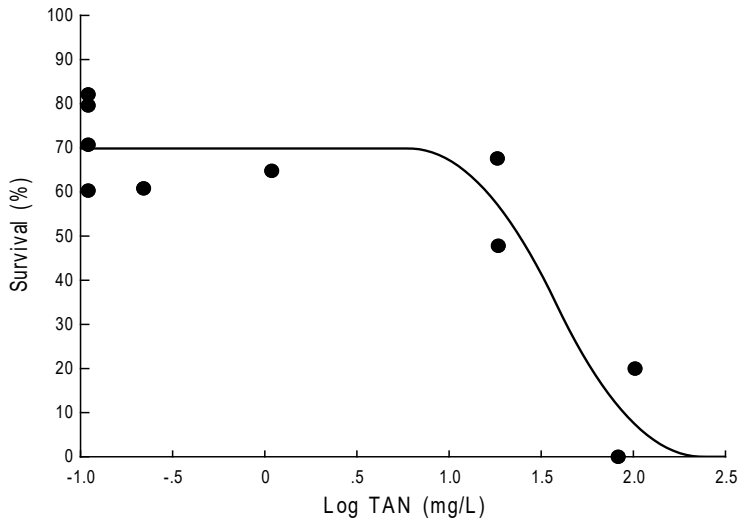


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.7	0.66659	0.024428	0.61451	0.71867
StDev	0.1	0.09446	0.035541	0.066001	0.16577
Y0	0.975	0.97461	0.017985	0.90987	0.99705
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	4.6407	4.1163	5.232	0.024428	0.66659
20	**3.8154**	3.22	4.521	0.032739	0.58155
10	3.4569	2.6783	4.4617	0.045824	0.53868
5	**3.2239**	2.2989	4.521	0.056517	0.50838
0	2.724	1.4051	5.2808	0.085269	0.43521

EC20:EC5 = 1.183

Notes: Acceptable model fit.

Koch et al. 1980	
Species: *Oncorhynchus clarkii* henshawi (fertilized eggs)	
Test Endpoint: 103-d ELS Survival	
C-R Curve Label: Am-Chronic-15	
Test: Single	
TAN, mg/L	**% Survival**
0.11	60.3
0.11	82.1
0.22	60.8
0.11	79.6
0.11	No data
0.11	70.7
1.09	64.8
1.09	Excluded
18.5	47.8
18.29	67.6
102.16	20
82.67	0



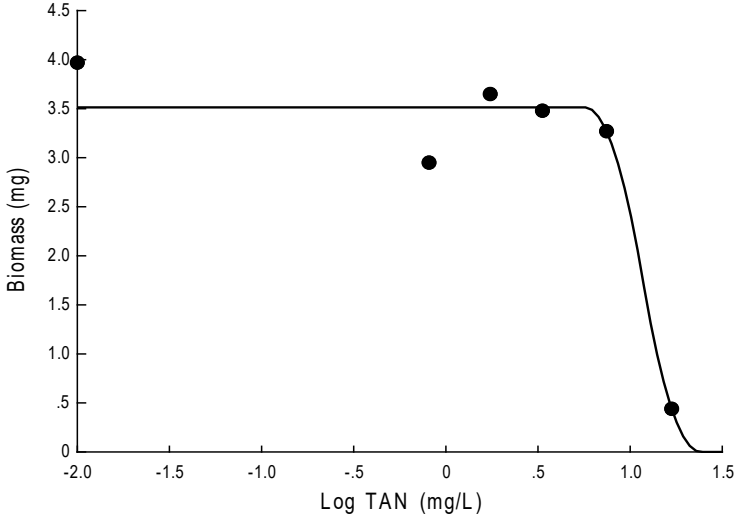
EC20:EC5 = 1.784

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.5782	0.12521	1.2821	1.8743
S	1.3	1.2579	0.44137	0.21424	2.3016
Y0	70	69.817	4.7023	58.698	80.936

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	37.86	19.147	74.86	0.12521	1.5782
20	**19.319**	7.9019	47.234	0.1642	1.286
10	13.764	4.4551	42.521	0.20717	1.1387
5	**10.829**	2.5134	46.659	0.26826	1.0346
0	6.0703	0.12263	300.48	0.71665	0.78321

Notes: Acceptable model fit. Acceptable noise at low level effects.

Brinkman et al. 2009	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 90-d ELS Biomass	
C-R Curve Label: Am-Chronic-16	
Test: Single	
TAN, mg/L	**Final Biomass (g)**
<0.02	3.97
0.81	2.95
1.74	3.65
3.34	3.48
7.44	3.27
16.8	0.44

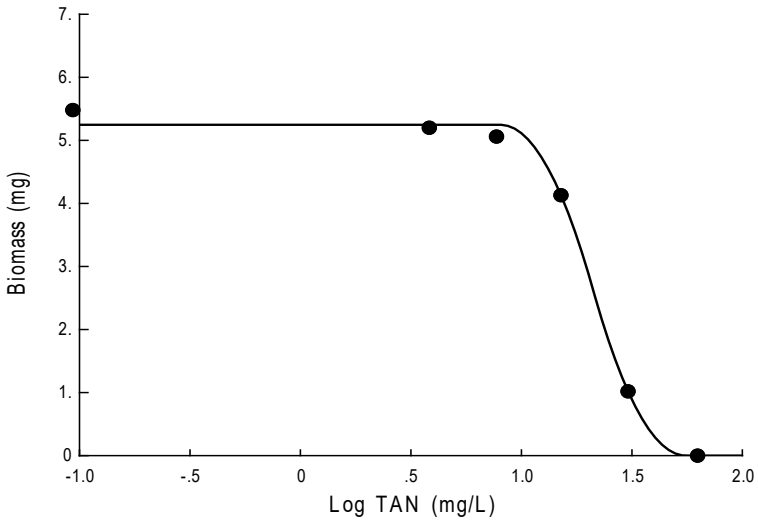


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	1.0687	0.066497	0.85704	1.2803
S	3	3.1884	1.2138	-0.67441	7.0513
Y0	3.52	3.5125	0.21324	2.8339	4.1911
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	11.713	7.1951	19.067	0.066497	1.0687
20	**8.9823**	4.6437	17.374	0.090031	0.95339
10	7.8576	3.6162	17.074	0.10591	0.89529
5	**7.1484**	2.9902	17.089	0.11894	0.85421
0	5.6889	1.2172	26.588	0.21042	0.75503

EC20:EC5 = 1.257

Notes: Acceptable model fit. Acceptable noise at low level effects.

Harrahy et al. 2004	
Species: *Esox lucius* (fertilized eggs)	
Test Endpoint: 52-d ELS Biomass	
C-R Curve Label: Am-Chronic-17	
Test: Single	
TAN, mg/L	**Mean Biomass(mg)**
0.05	5.48
3.83	5.2
7.71	5.06
15.1	4.13
30.38	1.02
62.67	0



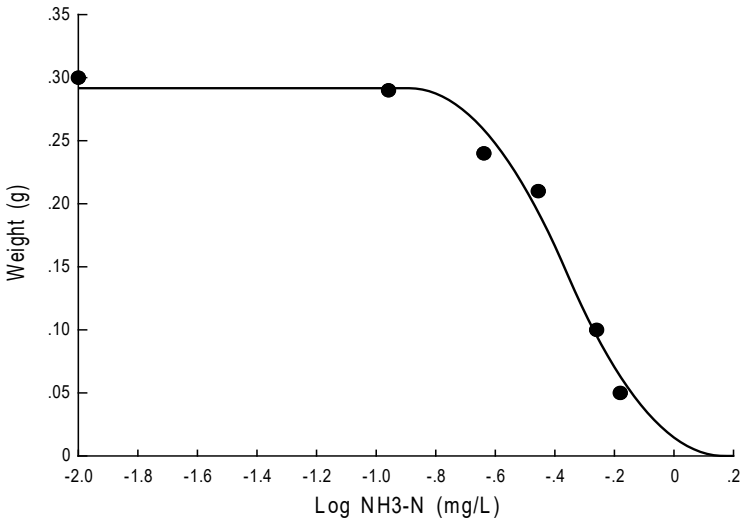
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.3	1.3247	0.016683	1.2716	1.3778
S	2.3	2.3847	0.24967	1.5901	3.1793
Y0	5.48	5.2467	0.10081	4.9258	5.5675

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	21.122	18.691	23.868	0.016683	1.3247
20	**14.812**	12.411	17.677	0.024132	1.1706
10	12.386	9.8355	15.597	0.031462	1.0929
5	**10.914**	8.1548	14.607	0.039775	1.038
0	8.0424	0.68577	94.317	0.33597	0.90538

EC20:EC5 = 1.357

Notes: Acceptable model fit.

Mallet and Sims 1994	
Species: *Cyprinus carpio*	
Test Endpoint: 28-d ELS Weight	
C-R Curve Label: Am-Chronic-18	
Test: Single	
Un-ionized ammonia NH3-N (mg/L)	**Weight (g)**
0.01	0.30
0.11	0.29
0.23	0.24
0.35	0.21
0.55	0.1
0.66	0.05



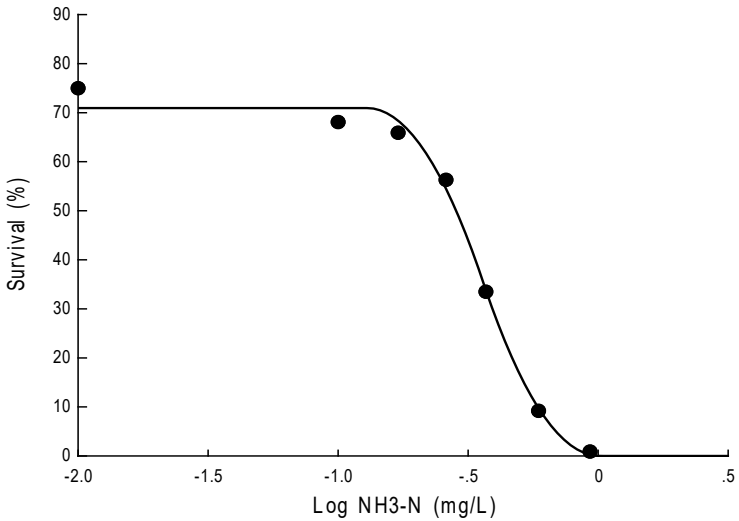
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.37886	-0.36113	0.027151	-0.44754	-0.27473
S	1.6758	1.8925	0.30589	0.91904	2.866
Y0	0.295	0.2916	0.012014	0.25337	0.32984

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.43538	0.35683	0.53122	0.027151	-0.36113
20	**0.27839**	0.19724	0.39294	0.047029	-0.55534
10	0.22222	0.14014	0.35236	0.062911	-0.65322
5	**0.18948**	0.10727	0.3347	0.077642	-0.72244
0	0.12896	0.042073	0.39531	0.15286	-0.88953

EC20:EC5 = 1.469

Notes: Acceptable model fit.

Mayes et al. 1986	
Species: *Pimephales promelas* (embryo-larvae)	
Test Endpoint: 28-d ELS Survival	
C-R Curve Label: Am-Chronic-19	
Test: Single	
NH3-N (mg/L)	**% Survival**
Control (0.01)	75
0.1	68.1
0.17	65.9
0.26	56.3
0.37	33.5
0.59	9.2
0.93	0.9

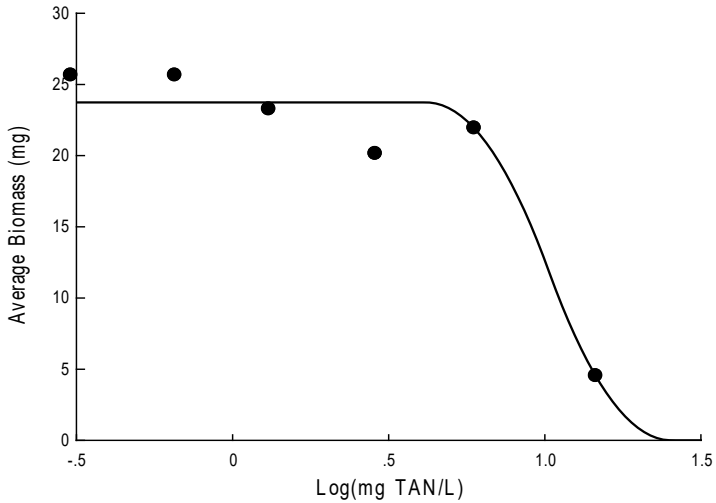


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.5	-0.44216	0.016496	-0.48796	-0.39636
S	2	2.234	0.2626	1.5049	2.9631
Y0	75	70.934	1.9575	65.499	76.368
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.36127	0.32512	0.40145	0.016496	-0.44216
20	**0.24735**	0.20628	0.2966	0.028403	-0.60669
10	0.20436	0.16035	0.26044	0.037931	-0.68961
5	**0.17855**	0.13573	0.23488	0.04289	-0.74824
0	0.12888	0.093959	0.17679	0.049439	-0.8898

EC20:EC5 = 1.385

Notes: Acceptable model fit.

Adelman et al. 2009	
Species: *Pimephales promelas* (embryo-larvae)	
Test Endpoint: 32-d ELS Biomass	
C-R Curve Label: Am-Chronic-20	
Test: Single	
TAN, mg/L	**Biomass(mg)**
0.13	25.704
0.65	25.704
1.3	23.325
2.85	20.194
5.91	21.984
14.49	4.592

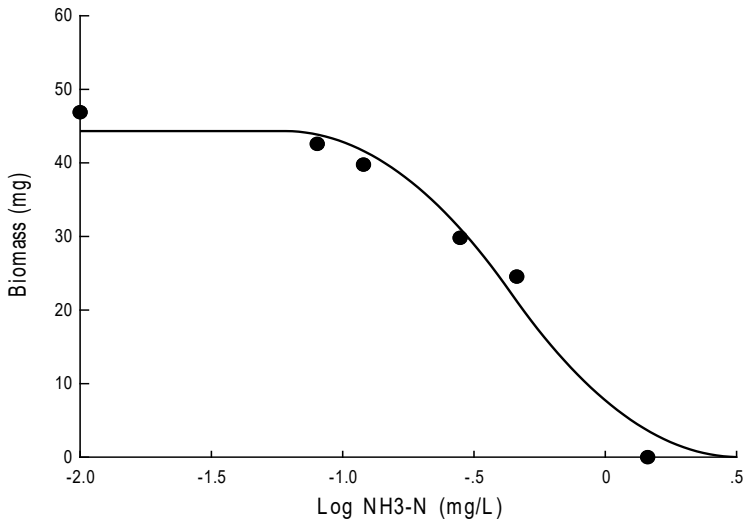


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	1.013	0.065131	0.80573	1.2203
S	2.5	2.5524	0.91461	-0.35825	5.4631
Y0	25.704	23.732	1.3058	19.576	27.887
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	10.304	6.3934	16.607	0.065131	1.013
20	**7.3962**	3.6679	14.914	0.095711	0.86901
10	6.258	2.6705	14.665	0.11622	0.79644
5	**5.5606**	2.1068	14.676	0.13244	0.74512
0	4.1805	0.11568	151.07	0.48955	0.62123

EC20:EC5 = 1.330

Notes: Large SE for steepness (S). Acceptable model fit. Acceptable noise at low level effects.

Swigert and Spacie 1983	
Species: *Pimephales promelas*	
Test Endpoint: 30-d ELS Biomass	
C-R Curve Label: Am-Chronic-21	
Test: Single	
Mean NH3-N (mg/L)	**Biomass(mg)**
Control (0.01)	46.895
0.08	42.585
0.12	39.77
0.28	29.82
0.46	24.552
1.45	0



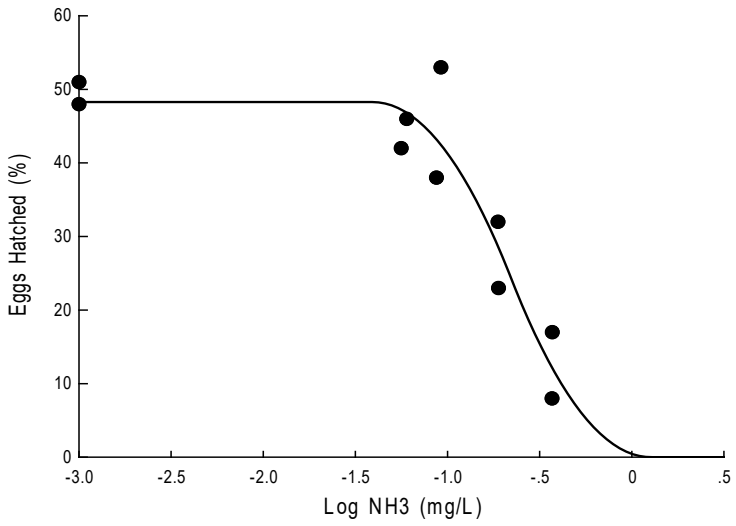
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.4	-0.35593	0.063673	-0.55857	-0.1533
S	1.15	1.1525	0.28868	0.23381	2.0712
Y0	46.895	44.322	2.7949	35.428	53.217

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.44062	0.27633	0.70259	0.063673	-0.35593
20	**0.21143**	0.089742	0.49811	0.11694	-0.67484
10	0.14603	0.040764	0.52311	0.17413	-0.83557
5	**0.1124**	0.02008	0.6292	0.23504	-0.94922
0	0.059759	0.0055898	0.63886	0.32334	-1.2236

EC20:EC5 = 1.881

Notes: Acceptable model fit.

Thurston et al. 1986	
Species: *Pimephales promelas*	
Test Endpoint: LC Reproduction	
C-R Curve Label: Am-Chronic-22	
Test: Single	
NH3 (mg/L)	**% eggs hatched**
0	48
0.001	51
0.056	42
0.060	46
0.087	38
0.092	53
0.188	32
0.189	23
0.369	8
0.370	17



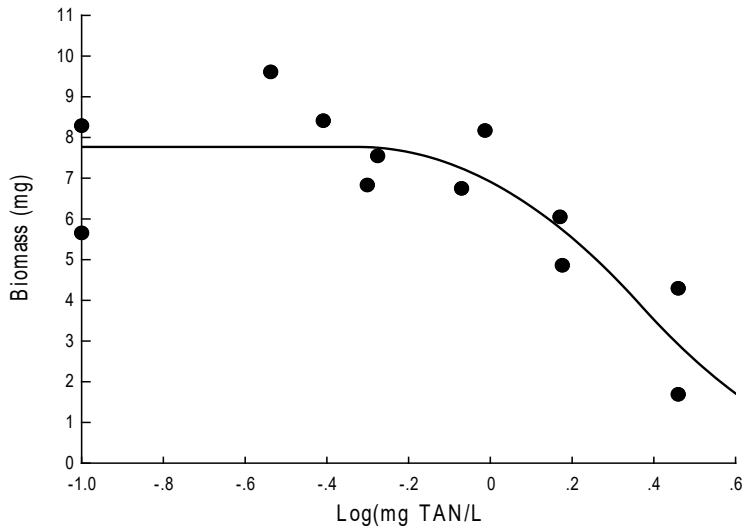
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.6	-0.65142	0.068628	-0.8137	-0.48914
S	2	1.3263	0.39632	0.38917	2.2635
Y0	52	48.262	3.7719	39.343	57.181

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.22314	0.15357	0.32423	0.068628	-0.65142
20	**0.11789**	0.060843	0.22841	0.12148	-0.92854
10	0.085467	0.03467	0.21069	0.16571	-1.0682
5	**0.068083**	0.022176	0.20902	0.20602	-1.167
0	0.03932	0.005894	0.26231	0.34855	-1.4054

EC20:EC5 = 1.732

Notes: Acceptable model fit.

Reinbold and Pescitelli 1982a	
Species: *Catostomus commersonii*	
Test Endpoint: 30-d Biomass	
C-R Curve Label: Am-Chronic-23	
Test: Single	
TAN, mg/L	**Biomass (mg)**
Control (0.1)	5.655
Control (0.1)	8.2925
0.39	8.415
0.29	9.6125
0.53	7.5488
0.50	6.8338
0.97	8.1732
0.85	6.7496
1.5	4.86
1.48	6.05
2.88	4.2945
2.88	1.6906



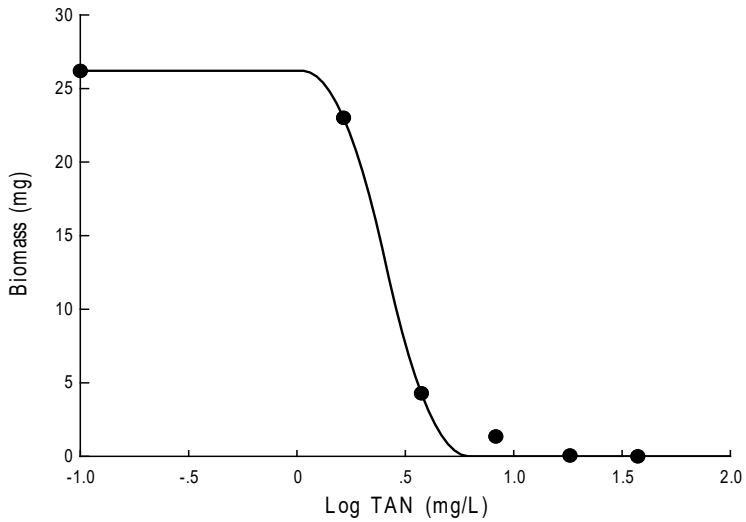
EC20:EC5 = 1.656

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.36	0.3672	0.080105	0.18599	0.54841
S	2	1.444	0.6006	0.085326	2.8026
Y0	7.7581	7.7683	0.55466	6.5136	9.023

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.3292	1.5346	3.5352	0.080105	0.3672
20	**1.2962**	0.67956	2.4723	0.12397	0.11266
10	0.96467	0.3944	2.3595	0.17171	-0.01562
5	**0.78283**	0.25625	2.3915	0.2144	-0.10633
0	0.47279	0.059615	3.7496	0.39755	-0.32533

Notes: Acceptable model fit. Acceptable noise at low level effects.

Smith et al. 1984	
Species: *Lepomis macrochirus*	
Test Endpoint: 30-d ELS Biomass	
C-R Curve Label: Am-Chronic-27	
Test: Single	
TAN, mg/L	**Biomass (mg)**
0.1	26.2
1.64	23.01
3.75	4.29
8.27	1.35
18.18	0.0625
37.38	0



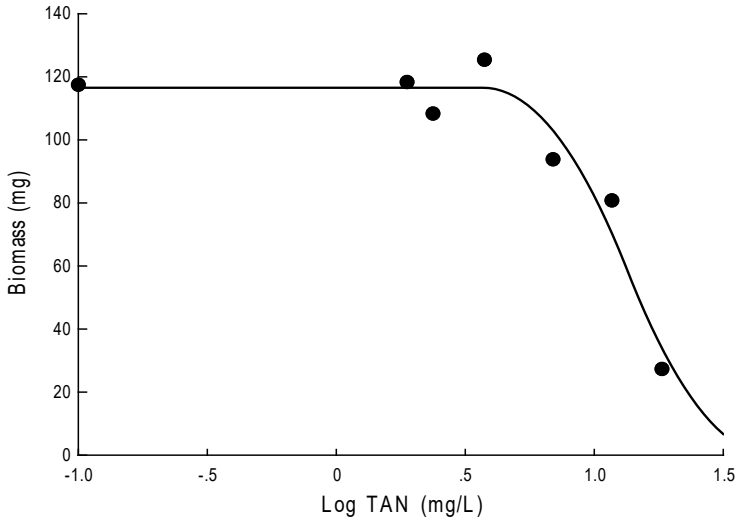
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.40961	0.40958	1.88E-02	0.34972	0.46945
S	1.039	2.6011	0.25408	1.7925	3.4097
Y0	26.2	26.2	0.78026	23.717	28.683

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.5679	2.24E+00	2.9475	1.88E-02	0.40958
20	**1.8547**	1.524	2.2572	2.68E-02	0.26828
10	1.5742	1.2417	1.9957	3.24E-02	0.19706
5	**1.4019**	1.0655	1.8444	3.74E-02	0.1467
0	1.0596	3.93E-02	28.563	4.50E-01	2.51E-02

EC20:EC5 = 1.323

Notes: Acceptable model fit.

Broderius et al. 1985	
Species: *Micropterus dolomieu*	
Test Endpoint: 32-d ELS Biomass	
C-R Curve Label: Am-Chronic-30	
Test: pH 7.83	
TAN, mg/L	**Biomass (mg)**
0.05	118
1.88	118
2.37	108
3.75	125
6.92	94
11.7	81
18.3	27



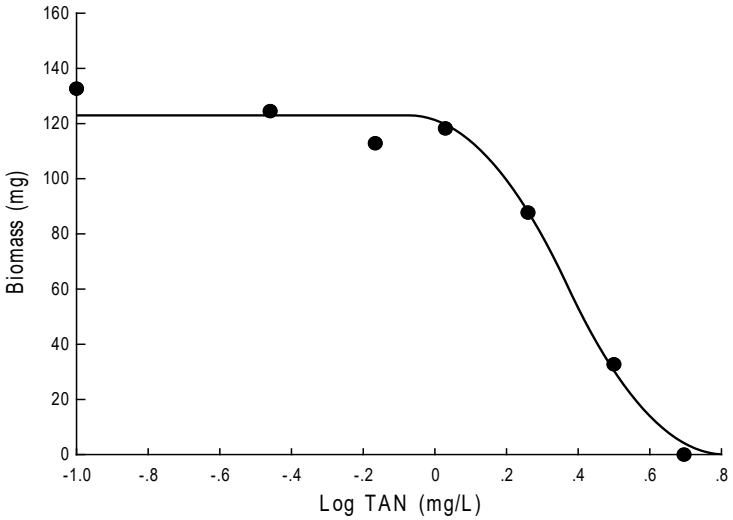
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.1	1.1297	4.09E-02	1.0162	1.2432
S	1.7	1.7867	0.49131	0.4226	3.1508
Y0	117.93	116.51	4.9015	102.9	130.12

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	13.481	10.38	17.508	4.09E-02	1.1297
20	**8.3946**	5.4119	13.021	6.87E-02	0.924
10	6.6118	3.5582	12.286	9.69E-02	0.82032
5	**5.5848**	2.5468	12.247	0.12283	0.74701
0	3.7155	0.90484	15.257	0.22095	0.57002

EC20:EC5 = 1.503

Notes: Acceptable model fit. Acceptable noise at low level effects.

Broderius et al. 1985	
Species: *Micropterus dolomieu*	
Test Endpoint: 32-d ELS Biomass	
C-R Curve Label: Am-Chronic-31	
Test: pH 8.68	
TAN, mg/L	**Biomass (mg)**
0.05	133
0.347	124
0.682	113
1.07	118
1.82	88
3.16	33
4.96	0



	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.4	0.36892	2.75E-02	0.29265	0.44519
S	2.5	2.2667	0.38425	1.1998	3.3335
Y0	132.63	122.94	4.1069	111.53	134.34

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.3384	1.9618	2.7874	2.75E-02	0.36892
20	**1.6098**	1.2216	2.1214	4.32E-02	0.20677
10	1.3337	0.91474	1.9445	5.90E-02	0.12505
5	**1.1675**	0.72729	1.8742	7.40E-02	6.73E-02
0	0.84674	0.48918	1.4656	8.58E-02	-7.23E-02

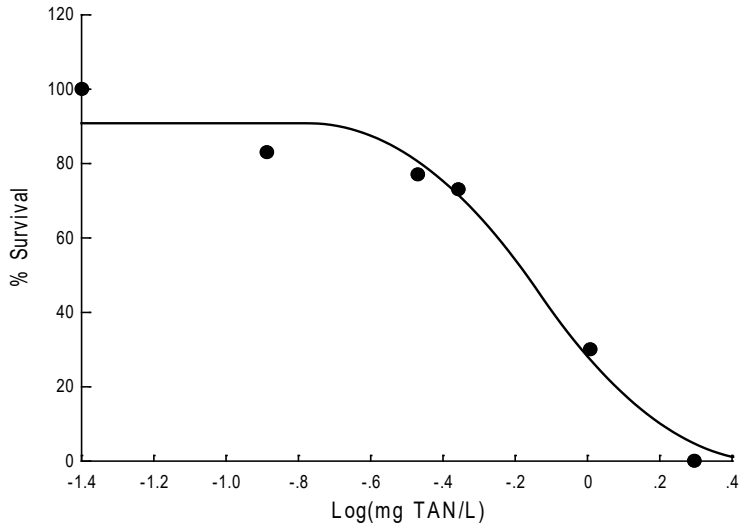
EC20:EC5 = 1.379

Notes: Acceptable model fit. Acceptable noise at low level effects.

Appendix A.4

Test Information, C-R Data and Resulting TRAP models for Chronic Ammonia Toxicity Tests Considered Unacceptable for TAF and MAF Calculation

Wang et al. 2007a	
Species: *Lampsilis fasciola* (2 month old juveniles)	
Test Endpoint: 28-d Juvenile Survival	
C-R Curve Label: Am-Chronic-1	
Test: Single	
TAN, mg/L	**% Survival**
0.04	100
0.13	83
0.34	77
0.44	73
1.02	30
1.98	0



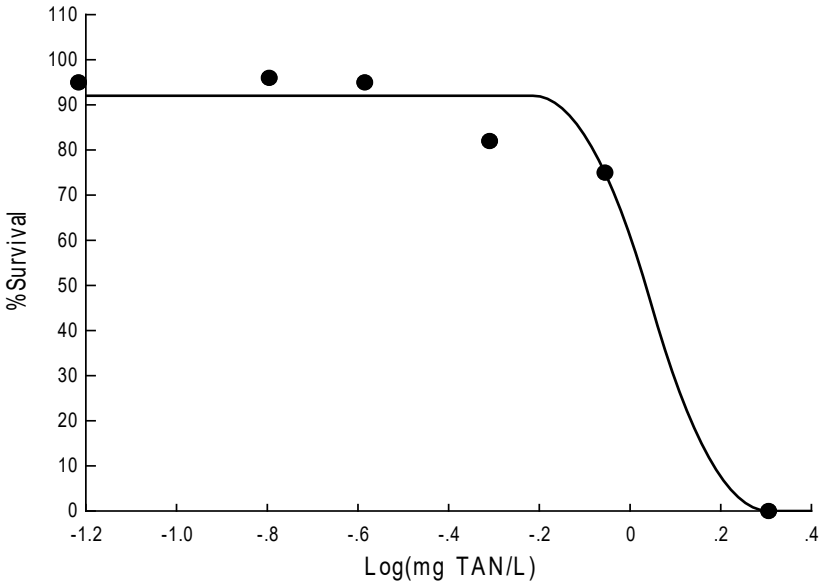
	Initial	Final	SE	95%LCL	95%UCL
LogX50	-0.15214	-0.13544	0.057599	-0.31875	0.047864
S	0.86383	1.5709	0.34755	0.46482	2.6769
Y0	100	90.838	5.5688	73.116	108.56

p	Xp	95%LCL	95%UCL	logXp SE	log Xp
50	0.73208	0.48001	1.1165	0.057599	-0.13544
20	**0.42715**	0.23211	0.78608	0.083233	-0.36942
10	0.32558	0.14709	0.72067	0.10843	-0.48734
5	**0.26871**	0.10041	0.71904	0.13432	-0.57072
0	0.16903	0.046296	0.61715	0.17673	-0.77203

EC20:EC5 = 1.590

Notes: Poor model fit.

Wang et al. 2007a	
Species: *Lampsilis siliquoidea* (2 month old juveniles)	
Test Endpoint: 28-d Juvenile Survival	
C-R Curve Label: Am-Chronic-2	
Test: with substrate test	
TAN, mg/L	**% Survival**
0.06	95
0.16	96
0.26	95
0.49	82
0.88	75
2.02	0



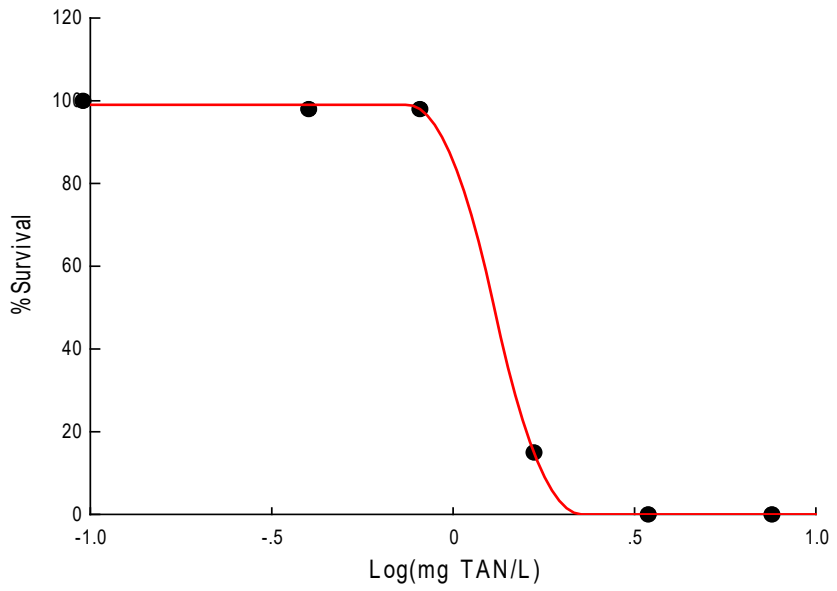
	Initial	Final	SE	95%LCL	95%UCL
LogX50	0.05828	0.046167	8.5591	-27.193	27.285
S	3.288	3.8559	324.56	-1029	1036.7
Y0	91.43	92	3.3417	81.365	102.63

p	Xp	95%LCL	95%UCL	logXp SE	log Xp
50	1.1122			8.5591	0.0462
20	0.8930	0.7010	1.1376	0.0330	-0.0492
10	0.7995	0.6017	1.0622	0.0388	-0.0972
5	0.7393	0.5410	1.0103	0.0426	-0.1312
0	0.6121	0.4226	0.8865	0.0506	-0.2132

EC20:EC5 = 1.208

Notes: Large SE for steepness (S) and X50. Poor model fit.

Wang et al. 2007a	
Species: *Villosa iris* (2 month old juveniles)	
Test Endpoint: 28-d Juvenile Survival	
C-R Curve Label: Am-Chronic-3	
Test: Single	
TAN, mg/L	**% Survival**
0.08	100
0.4	98
0.81	98
1.67	15
3.45	0
7.56	0



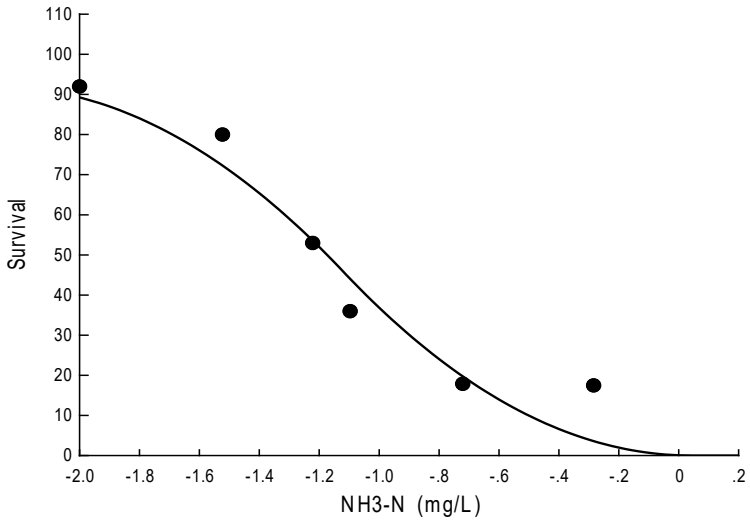
	Initial	Final	SE	95%LCL	95%UCL
LogX50	0.125	0.11467	6.45E-03	9.41E-02	1.35E-01
S	4.5	4.1606	2.28E-01	3.4364	4.8848
Y0	98.667	99	0.57735	97.163	100.84

p	Xp	95%LCL	95%UCL	logXp SE	log Xp
50	1.3022	1.2421	1.3652	0.0065	0.1147
20	1.0625	0.9814	1.1503	0.0108	0.0263
10	0.9590	0.8709	1.0560	0.0132	-0.0182
5	0.8919	0.8002	0.9942	0.0148	-0.0497
0	0.7487	0.6474	0.8659	0.0198	-0.1257

EC20:EC5 = 1.191

Notes: TRAP flagged for IP (No Unique Solution).

Sparks and Sandusky 1981	
Species: *Musculium transversum*	
Test Endpoint: 42-d Juvenile Survival	
C-R Curve Label: Am-Chronic-5	
Test: Single	
NH3-N (mg/L)	**% Survival**
0.01	92
0.03	80
0.06	53
0.08	36
0.19	17.9
0.52	17.5

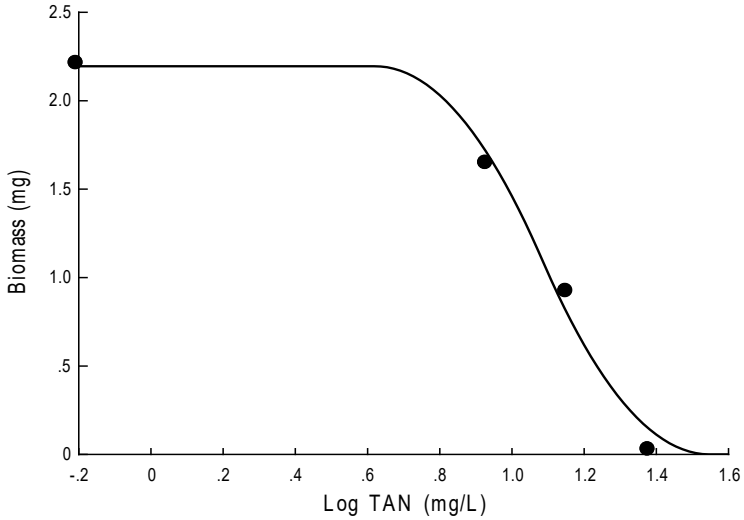


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-1	-1.1218	0.068782	-1.3128	-0.93084
S	1	0.86019	0.19851	0.30904	1.4113
Y0	92	92			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.075543	0.048666	0.11726	0.068782	-1.1218
20	**0.028243**	0.012899	0.06184	0.12259	-1.5491
10	0.017201	0.005259	0.056267	0.18538	-1.7644
5	**0.012114**	0.002566	0.057193	0.24278	-1.9167
0	0.005196	0.000726	0.037184	0.30784	-2.2843

EC20:EC5 = 2.331

Notes: Poor model fit due to no pre-threshold value.

Borgmann 1994	
Species: *Hyalella azteca*	
Test Endpoint: 28-d Biomass	
C-R Curve Label: Am-Chronic-12	
Test: Single	
TAN, mg/L	**Avg. Biomass (mg)**
0.616	2.21884
8.4	1.6543
14	0.93
23.66	0.034

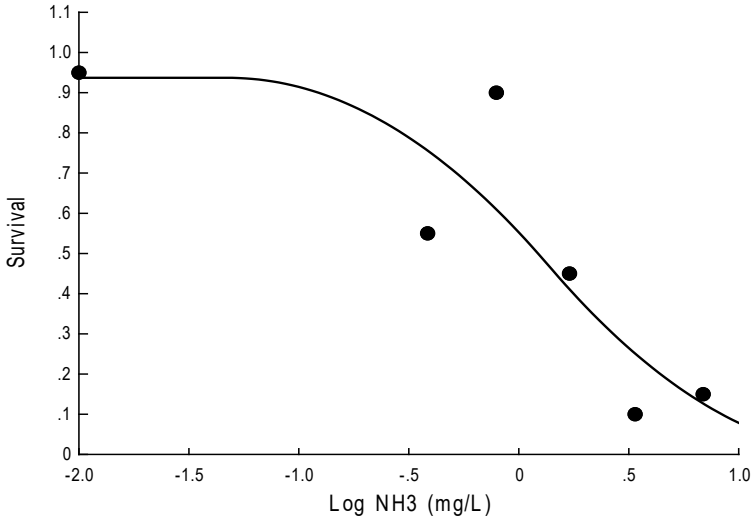


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.1	1.0845			
S	2.2	2.1593			
Y0	2.22	2.1944			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	12.148	3.6157	40.817	0.041423	1.0845
20	**8.2092**	1.0397	64.819	0.070627	0.9143
10	6.7377	0.38723	117.23	0.097632	0.82851
5	**5.8594**	0.14879	230.74	0.12555	0.76785
0	4.1822	0.032161	543.84	0.16638	0.6214

EC20:EC5 = 1.401

Notes: No effect within area of concern.

Thurston et al. 1984b	
Species: *Pteronarcella badia*	
Test Endpoint: 24-d Survival	
C-R Curve Label: Am-Chronic-14	
Test: 501	
Unionized ammonia (NH3) (mg/L)	**Proportion Surviving**
0.01	0.95
0.385	0.55
0.791	0.90
1.7	0.45
3.38	0.10
6.89	0.15

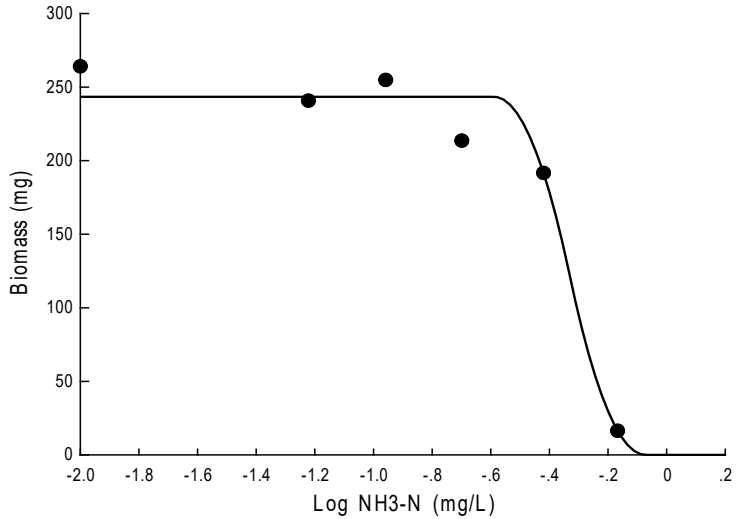


0	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.1	0.13766	0.11117	-0.08981	0.36514
StDev	0.4	0.59554	0.14071	0.41612	1.0451
Y0	0.95	0.93685	0.054061	0.73428	0.99682
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.373	0.81319	2.3181	0.11117	0.13766
20	**0.39948**	0.15171	1.0519	0.19504	-0.3985
10	0.21442	0.055545	0.82776	0.25386	-0.66873
5	**0.1381**	0.025132	0.75886	0.2987	-0.85981
0	0.04774	0.002253	1.0116	0.41563	-1.3211

EC20:EC5 = 2.893

Notes: Poor model fit and no effect within area of concern.

Swigert and Spacie 1983	
Species: *Ictalurus punctatus*	
Test Endpoint: 30-d Biomass	
C-R Curve Label: Am-Chronic-24	
Test: Single	
Mean NH3-N (mg/L)	**Biomass(mg)**
Control (0.01)	264.11
0.06	240.8
0.11	254.91
0.2	213.6
0.38	191.7
0.68	16.49



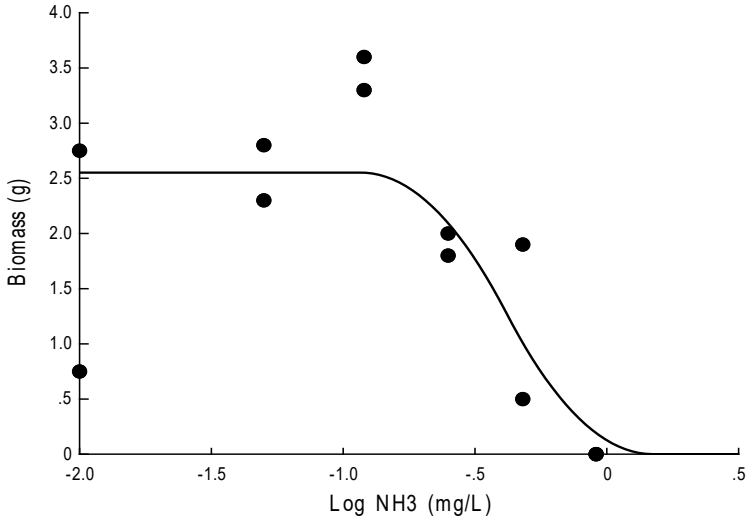
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.4	-0.33039	0.033735	-0.43775	-0.22303
S	3	3.8789	1.1326	0.27439	7.4835
Y0	253.3	243.35	11.016	208.3	278.41

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.46732	0.36497	0.59838	0.033735	-0.33039
20	**0.37572**	0.28175	0.50102	0.039276	-0.42514
10	0.33659	0.22356	0.50678	0.055843	-0.4729
5	**0.31141**	0.11389	0.8515	0.13727	-0.50666
0	0.25811	0.12768	0.52181	0.096059	-0.58819

EC20:EC5 = 1.207

Notes: Poor model fit.

McCormick et al. 1984	
Species: *Lepomis cyanellus*	
Test Endpoint: 30-d Biomass	
C-R Curve Label: Am-Chronic-25	
Test: Single	
NH3 (mg/L)	**Biomass(g)**
0.01	2.75
0.01	0.75
0.05	2.8
0.05	2.3
0.12	3.6
0.12	3.3
0.25	2
0.25	1.8
0.48	1.9
0.48	0.5
0.91	0
0.91	0



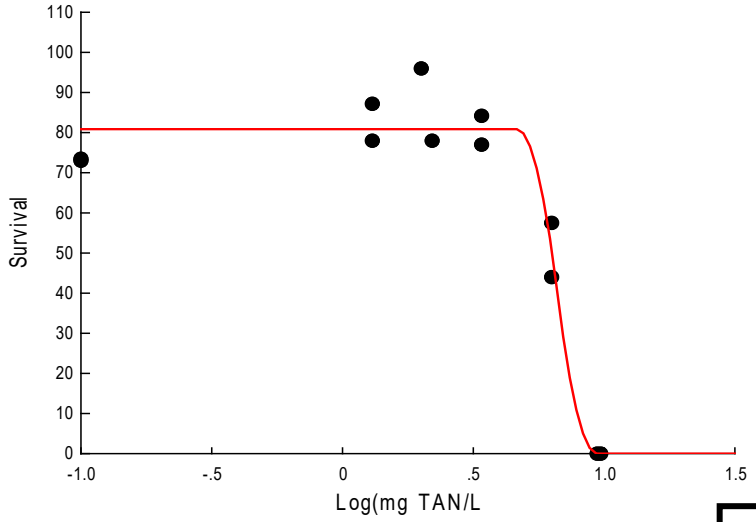
EC20:EC5 = 1.496

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.4	-0.37993	0.12544	-0.66369	-0.096171
S	2	1.807	1.2492	-1.0189	4.6329
Y0	2.58	2.5508	0.34506	1.7702	3.3314

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.41693	0.21692	0.80136	0.12544	-0.37993
20	**0.26102**	0.0858	0.79404	0.21359	-0.58333
10	0.20614	0.043865	0.96869	0.29708	-0.68585
5	**0.17445**	0.023988	1.2686	0.3809	-0.75833
0	0.11659	0.0076075	1.7868	0.52402	-0.93334

Notes: Large SE for steepness (S). Unacceptable noise at low level effects.

Reinbold and Pescitelli 1982a	
Species: *Lepomis cyanellus*	
Test Endpoint: 30-d Larval Survival	
C-R Curve Label: Am-Chronic-26	
Test: Single	
TAN, mg/L	**% Survival**
Control (0.1)	73
Control (0.1)	73.5
1.3	78
1.3	87.2
2	96
2.2	78
3.4	77
3.4	84.2
6.3	57.5
6.3	44
9.7	0
9.4	0



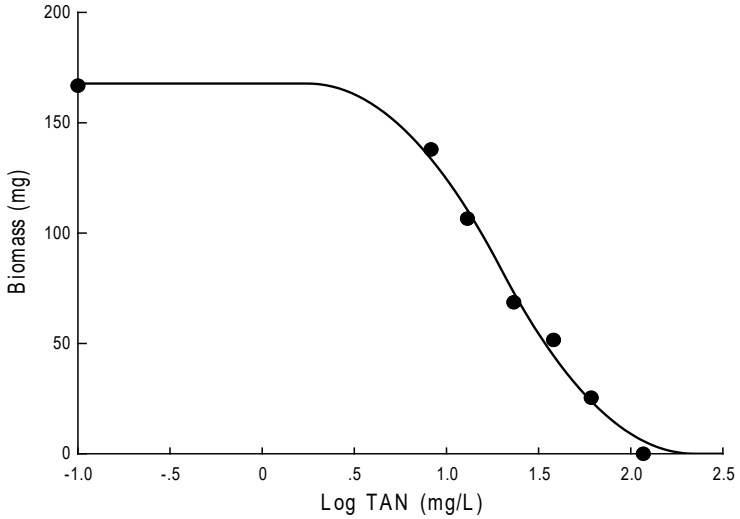
EC20:EC5 = 1.118

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.8	0.8203	1.7533	-3.146	4.7866
S	5	6.5367	546.87	-1230.6	1243.6
Y0	82.1	80.863	2.6846	74.79	86.935

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	6.6115	7.15E-04	61176	1.7533	0.8203
20	**5.8086**	4.9091	6.8729	3.23E-02	0.76407
10	5.4417	4.6496	6.3686	3.02E-02	0.73573
5	**5.1963**	4.4625	6.0507	2.92E-02	0.71569
0	4.6485	3.9988	5.4038	2.89E-02	0.66732

Notes: **Notes**: TRAP flagged for IP (No Unique Solution).

Broderius et al. 1985	
Species: *Micropterus dolomieu*	
Test Endpoint: 32-d ELS Biomass	
C-R Curve Label: Am-Chronic-28	
Test: pH 6.6	
TAN, mg/L	**Biomass (mg)**
0.05	167
8.24	138
13	107
23.2	69
38.1	52
61	25
117	0



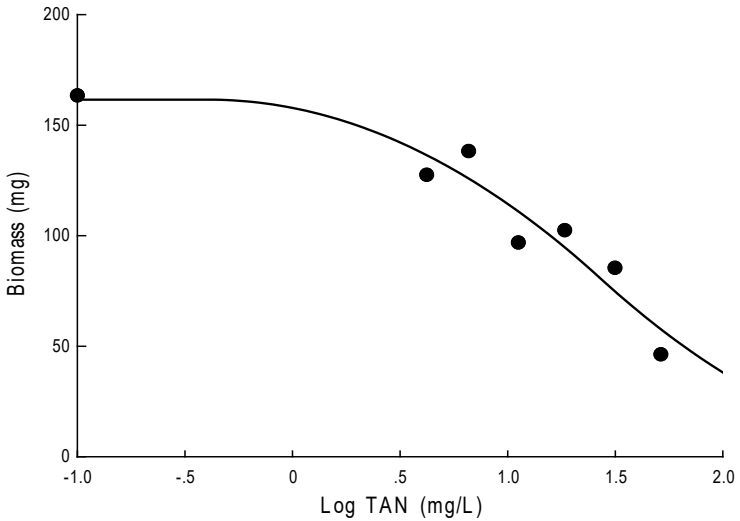
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.3	1.2958	3.26E-02	1.2053	1.3863
S	1	0.95465	8.17E-02	0.72771	1.1816
Y0	166.83	167.71	5.8153	151.56	183.85

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	19.761	16.044	24.339	3.26E-02	1.2958
20	**8.1432**	5.6472	11.742	5.73E-02	0.91079
10	5.209	3.1384	8.6456	7.93E-02	0.71675
5	**3.7979**	1.9973	7.2218	0.10053	0.57954
0	1.7713	0.79684	3.9374	0.12495	0.24829

EC20:EC5 = 2.144

Notes: No effect within area of concern.

Broderius et al. 1985	
Species: *Micropterus dolomieu*	
Test Endpoint: 32-d ELS Biomass	
C-R Curve Label: Am-Chronic-29	
Test: pH 7.25	
TAN, mg/L	**Biomass (mg)**
0.05	163.4934
4.2	127.596
6.58	138.2976
11.2	96.9612
18.4	102.48
31.5	85.5
51.5	46.371



	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.4299	0.12276	1.089	1.7707
S	0.75	0.549	0.14909	0.13507	0.96293
Y0	163.49	161.51	13.368	124.4	198.63

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	26.906	12.275	58.977	0.12276	1.4299
20	**5.7593**	1.2975	25.565	0.23313	0.76037
10	2.6482	0.32296	21.715	0.32913	0.42296
5	**1.5289**	0.10976	21.296	0.41202	0.18437
0	0.40584	4.86E-03	33.912	0.69225	-0.39164

EC20:EC5 = 3.767

Notes: No effect within area of concern.

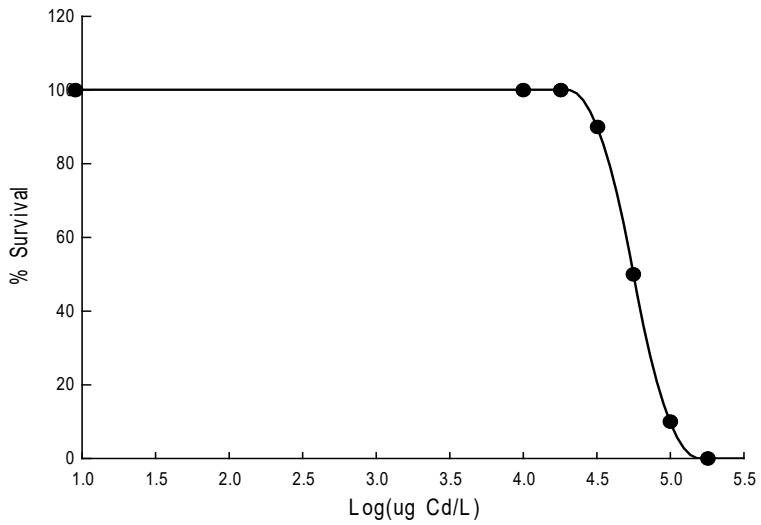
Appendix B

Test Information, C-R Data and Resulting TRAP models for Acute and Chronic Cadmium Toxicity Tests Considered Acceptable or Unacceptable for TAF and MAF Calculation

Appendix B.1

Test Information, C-R Data and Resulting TRAP models for Acute Cadmium Toxicity Tests Acceptable for TAF and MAF Calculation

Rathore and Khangarot 2002	
Species: *Tubifex tubifex*	
Test Endpoint: 96 hr survival	
C-R Curve Label: Cd-Acute-2	
Test: 15°C	
Cd, µg/L	**%Survival**
5	100
10000	100
18000	100
32000	90
56000	50
100000	10
180000	0



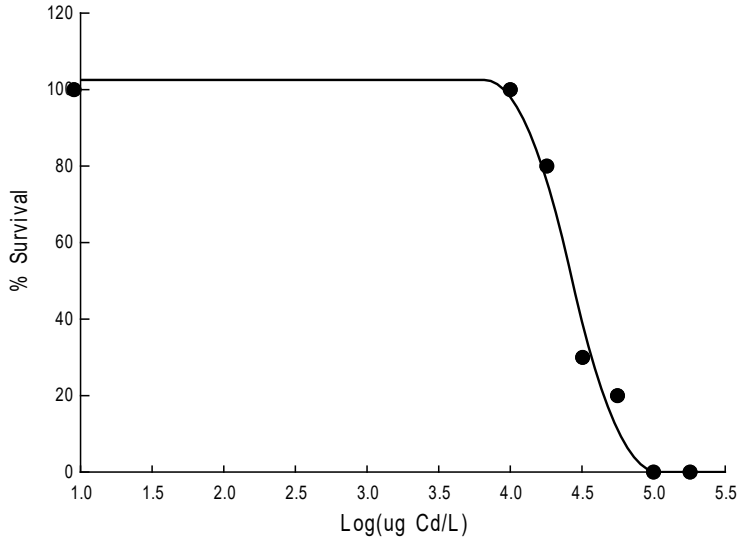
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.75	4.7493	1.07E-03	4.7463	4.7523
S	2.2	2.2324	1.72E-02	2.1846	2.2802
Y0	100	100.05	0.14604	99.649	100.46

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50.0	56141.0	55758.0	56526.0	0.0	4.7
20.0	38427.0	37986.0	38873.0	0.0	4.6
10.0	31744.0	31220.0	32276.0	0.0	4.5
5.0	27732.0	27139.0	28338.0	0.0	4.4
0.0	20014.0	19399.0	20648.0	0.0	4.3

LC50:LC5 = 2.024

Notes: Acceptable model fit.

Rathore and Khangarot 2002	
Species: *Tubifex tubifex*	
Test Hardness: 237 mg/L	
Test Endpoint: 96 hr survival	
C-R Curve Label: Cd-Acute-5	
Test: 30°C	
Cd, µg/L	**%Survival**
5	100
10000	100
18000	80
32000	30
56000	20
100000	0
180000	0



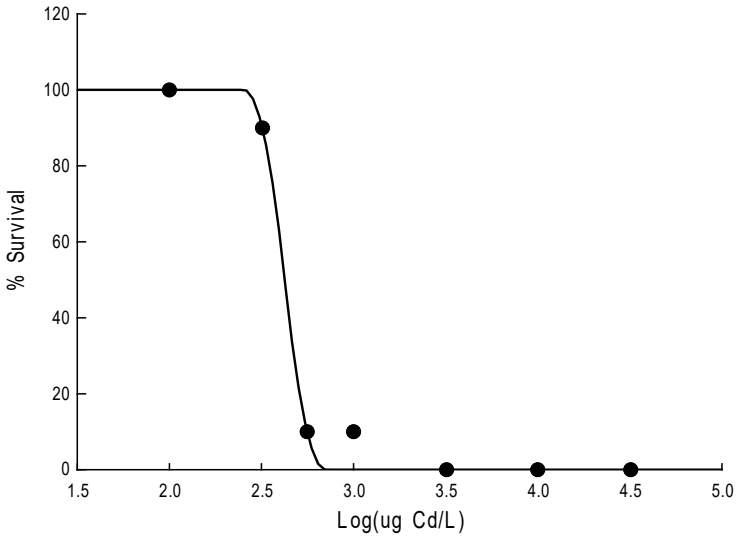
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.425	4.4257	4.18E-02	4.3095	4.5419
S	1.65	1.6544	3.21E-01	0.76438	2.5444
Y0	100	102.5	6.0941	85.581	119.42

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50.0	26650.0	20396.0	34822.0	0.0	4.4
20.0	15978.0	10093.0	25296.0	0.1	4.2
10.0	12347.0	6893.5	22115.0	0.1	4.1
5.0	10289.0	5407.9	19577.0	0.1	4.0
0.0	6625.8	3139.2	13985.0	0.1	3.8

LC50:LC5 = 2.590

Notes: Acceptable model fit.

Rathore and Khangarot 2003	
Species: *Tubifex tubifex*	
Test End Point: 96 hr survival	
C-R Curve Label: Cd-Acute-6	
Test: Hardness = 45 mg/L	
Cd, µg/L	**%Survival**
100	100
320	90
560	10
1000	10
3200	0
10000	0
32000	0



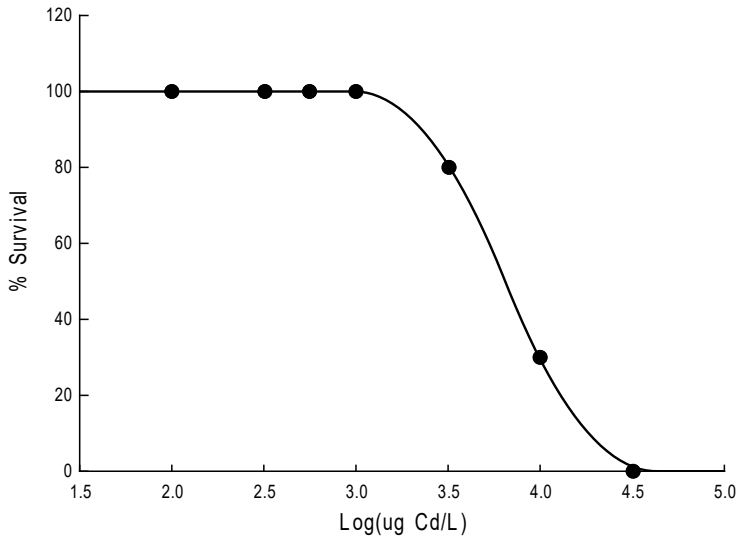
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.65	2.6267	2.13E-02	2.5676	2.6858
S	3.5	4.549	7.47E-01	2.4737	6.6242
Y0	100	100	5	86.118	113.88

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50.0	423.3	369.5	485.0	0.0	2.6
20.0	351.5	293.4	421.0	0.0	2.5
10.0	320.0	259.0	395.3	0.0	2.5
5.0	299.5	234.8	381.9	0.0	2.5
0.0	255.2	177.7	366.5	0.1	2.4

LC50:LC5 = 1.414

Notes: Acceptable model. No TRAP flags or errors. There is also a no effect concentration that defines the plateau prior to the breakpoint of the decline in response, which passes through the first effect (10%) concentration.

Rathore and Khangarot 2003	
Species: *Tubifex tubifex*	
Test End Point: 96 hr survival	
C-R Curve Label: Cd-Acute-8	
Test: Hardness = 305 mg/L	
Cd, µg/L	**%Survival**
100	100
320	100
560	100
1000	100
3200	80
10000	30
32000	0



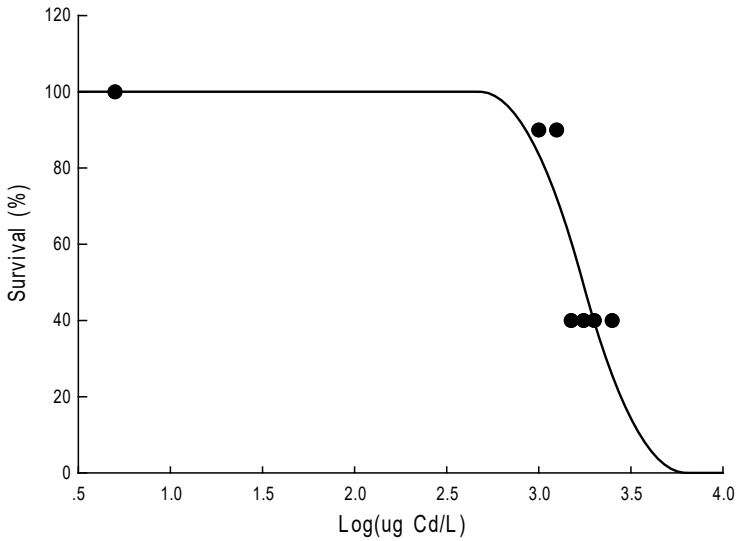
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.8	3.8104	5.61E-03	3.7948	3.826
S	1.2	1.2201	2.51E-02	1.1505	1.2898
Y0	100	99.975	0.32254	99.079	100.87

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50.0	6462.5	6235.0	6698.4	0.0	3.8
20.0	3229.7	3049.3	3420.9	0.0	3.5
10.0	2276.9	2109.5	2457.6	0.0	3.4
5.0	1778.2	1630.1	1939.9	0.0	3.3
0.0	979.1	888.4	1079.0	0.0	3.0

LC50:LC5= 3.634

Notes: Acceptable model fit.

Coeurdassier et al. 2004	
Species: *Lymnaea stagnalis*	
Test End Point: 96 hr Survival	
C-R Curve Label: Cd-Acute-9	
Test: Juvenile-S2	
Cd, µg/L	**%Survival**
5	100
1000	90
1250	90
1500	40
1750	40
2000	40
2500	40



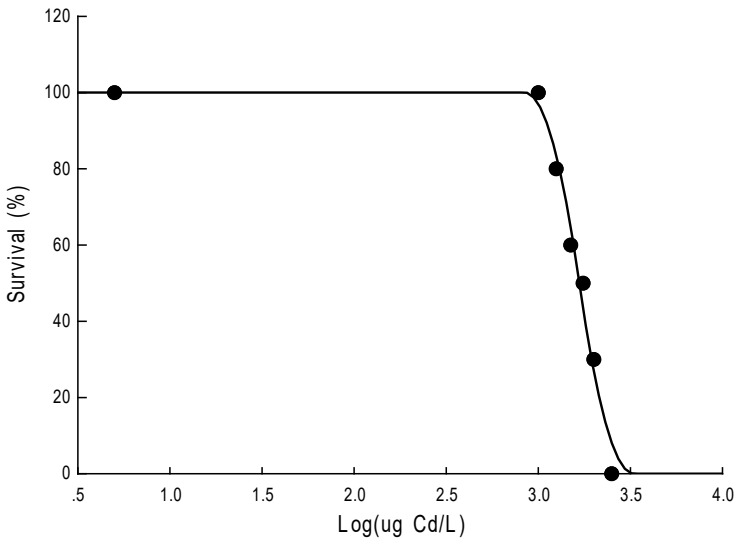
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.1844	3.2393	0.041883	3.1316	3.347
S	3.5591	1.7845	0.67098	0.059722	3.5093
Y0	100	100			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1735	1354	2223.1	0.041883	3.2393
20	1079.8	659.99	1766.6	0.08317	3.0333
10	850.21	405.32	1783.4	0.12516	2.9295
5	718	273.26	1886.6	0.16321	2.8561
0	477.44	69.134	3297.2	0.32647	2.6789

LC50:LC5= 2.416

Notes: Acceptable model. No TRAP flags or errors. There is also a no effect concentration that defines the plateau prior to the breakpoint of the decline in response, which passes near the first effect concentrations.

Coeurdassier et al. 2004	
Species: *Lymnaea stagnalis*	
Test End Point: 96 hr Survival	
C-R Curve Label: Cd-Acute-10	
Test: Adult	
Cd, µg/L	**%Survival**
5	100
1000	100
1250	80
1500	60
1750	50
2000	30
2500	0



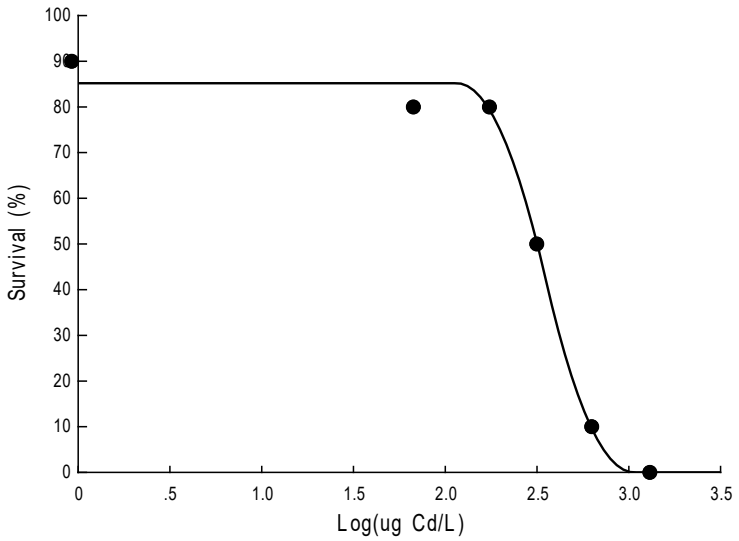
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3	3.2227	0.016394	3.1771	3.2682
S	3.5	3.3971	0.57652	1.7965	4.9978
Y0	100	99.994	5.5517	84.58	115.41

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1669.8	1503.6	1854.3	0.016394	3.2227
20	1301.6	1073.1	1578.7	0.030196	3.1145
10	1148	878.29	1500.5	0.041888	3.0599
5	1050.5	746.97	1477.3	0.053335	3.0214
0	847.8	502.76	1429.6	0.081734	2.9283

LC50:LC5= 1.590

Notes: Acceptable model fit.

Pais 2012	
Species: *Lymnaea stagnalis*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-12	
Test: 25 mm length	
Cd, µg/L	**%Survival**
0.5	90
67	80
174	80
315	50
628	10
1301	0



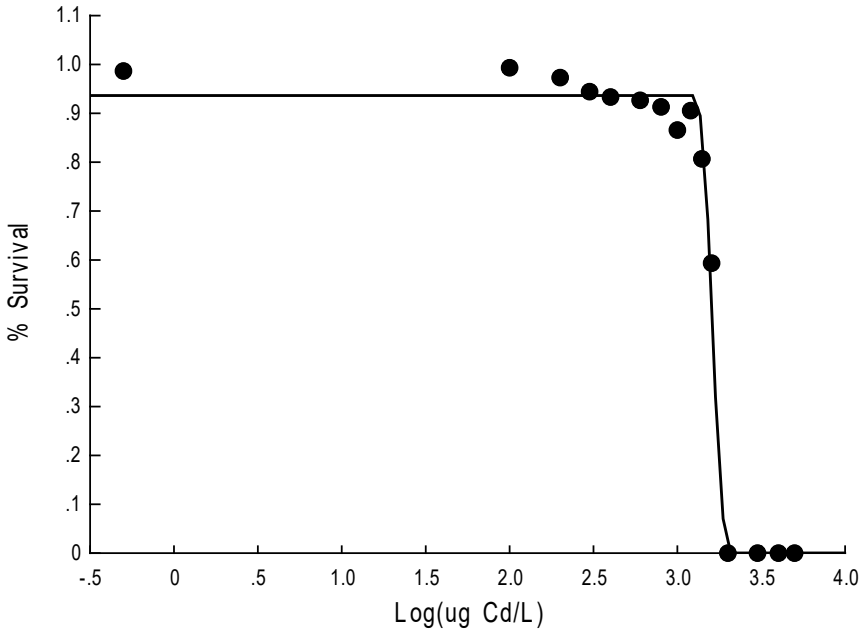
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.5	2.5451	0.024484	2.4671	2.623
S	2	2.0763	0.30884	1.0934	3.0591
Y0	90	85.166	2.8024	76.247	94.084

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	350.81	293.19	419.75	0.024484	2.5451
20	233.37	176.52	308.52	0.038096	2.368
10	190.03	127.53	283.17	0.054431	2.2788
5	164.34	96.2	280.74	0.073077	2.2157
0	115.73	49.165	272.4	0.11682	2.0634

LC50:LC5= 2.135

Notes: No TRAP errors or flags. Acceptable noise at low level effects.

Woodard 2005	
Species: *Physa acuta* (adult)	
Test End Point: 96 hr Survival	
C-R Curve Label: Cd-Acute-14	
Test: Single	
Cd, µg/L	**%Survival**
0.5	98.67
100	99.33
200	97.32
300	94.44
400	93.33
600	92.67
800	91.33
1000	86.58
1200	90.54
1400	80.67
1600	59.33
2000	0
3000	0
4000	0
5000	0



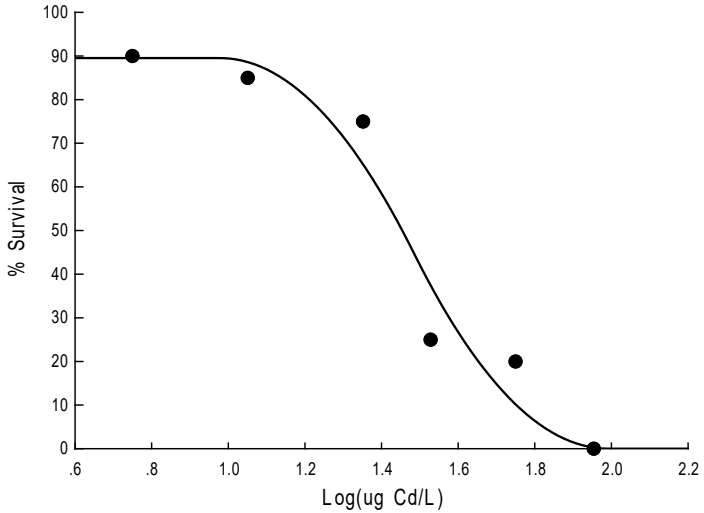
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.1964	3.2092	3.57E-03	3.20E+00	3.2162
StDev	5.55E-02	4.23E-02	2.61E-03	3.78E-02	4.82E-02
Y0	0.93801	0.93617	6.65E-03	0.92179	0.94861

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1618.700	1592.700	1645.200	0.004	3.209
20	1482.700	1450.600	1515.500	0.005	3.171
10	1418.500	1382.400	1455.700	0.006	3.152
5	1374.900	1335.400	1415.400	0.006	3.138
0	1274.900	1227.900	1323.600	0.008	3.106

LC50:LC5= 1.177

Notes: Acceptable model.

Shaw et al. 2006	
Species: *Ceriodaphnia dubia* (< 24 h old)	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Cd-Acute-17	
Test: Single	
Cd, µg/L	**%Survival**
6	90
11	85
22	75
34	25
56	20
90	0



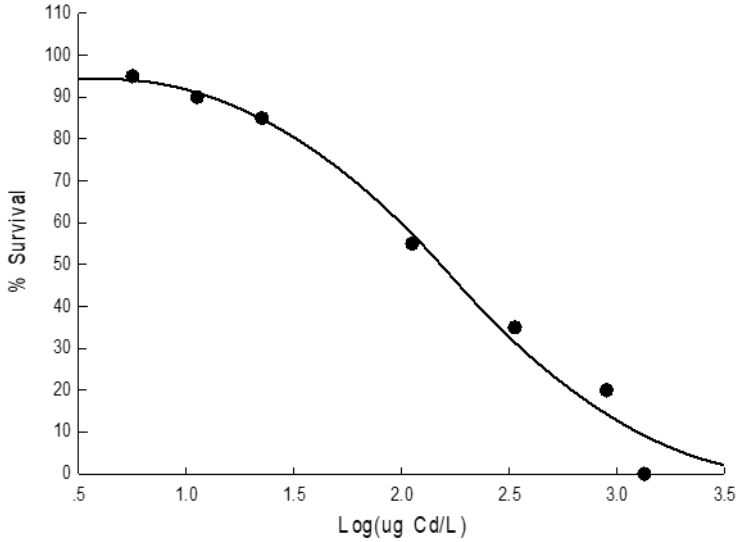
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.4848	0.060731	1.2916	1.6781
S	2	1.9744	0.77123	-0.48003	4.4288
Y0	90	89.505	8.8753	61.26	117.75

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	30.537	19.569	47.655	0.060731	1.4848
20	19.892	8.6052	45.983	0.11435	1.2987
10	16.027	5.2605	48.829	0.15203	1.2049
5	13.757	4.0303	46.955	0.16754	1.1385
0	9.5136	2.4694	36.653	0.18406	0.97835

LC50:LC5 = 2.220

Notes: No TRAP flags or errors. Acceptable model fit.

Shaw et al. 2006	
Species: *Daphnia magna* (<24 h old)	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Cd-Acute-19	
Test: Single	
Cd, µg/L	**%Survival**
5.6205	95
11.241	90
22.482	85
112.41	55
337.23	35
899.28	20
1348.92	0



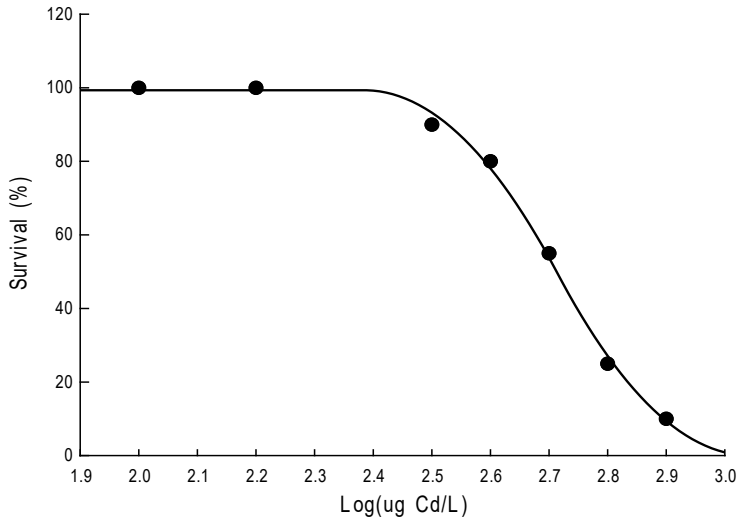
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.2	2.2325	0.10946	1.9286	2.5364
S	0.65	0.62348	0.11077	0.31594	0.93103
Y0	95	94.318	5.9716	77.738	110.9

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	170.81	84.837	343.89	0.10946	2.2325
20	43.954	12.166	158.8	0.20092	1.643
10	22.177	3.8257	128.55	0.27488	1.3459
5	13.671	1.4185	131.76	0.35441	1.1358
0	4.2522	0.096408	187.55	0.5923	0.62861

LC50:LC5 = 12.49

Notes: Acceptable model fit despite no true control.

Perez and Beiras 2010	
Species: *Daphnia magna* (<24 h old)	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Cd-Acute-22	
Test: Single	
Cd, µg/L	**%Survival**
100	100
158	100
316	90
398	80
501	55
631	25
794	10



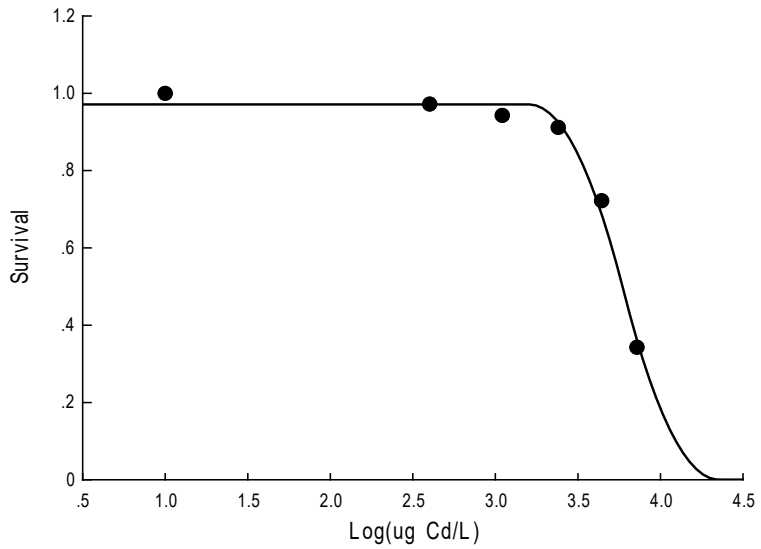
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.7	2.714	0.0063449	2.6964	2.7316
S	3	3.0385	0.1747	2.5534	3.5235
Y0	100	99.306	1.56	94.974	103.64

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	517.6	497.02	539.03	0.0063449	2.714
20	391.77	365.9	419.47	0.010687	2.593
10	340.46	309.83	374.11	0.014745	2.5321
5	308.29	273.39	347.64	0.018791	2.489
0	242.6	200.94	292.88	0.029467	2.3849

LC50:LC5 = 1.679

Notes: Acceptable model fit.

Mirenda 1986	
Species: *Orconectes virilis* (adult)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-30	
Test: Single	
Cd, µg/L	**%Survival**
10	100
400	97.22
1100	94.29
2400	91.18
4400	72.22
7200	34.29



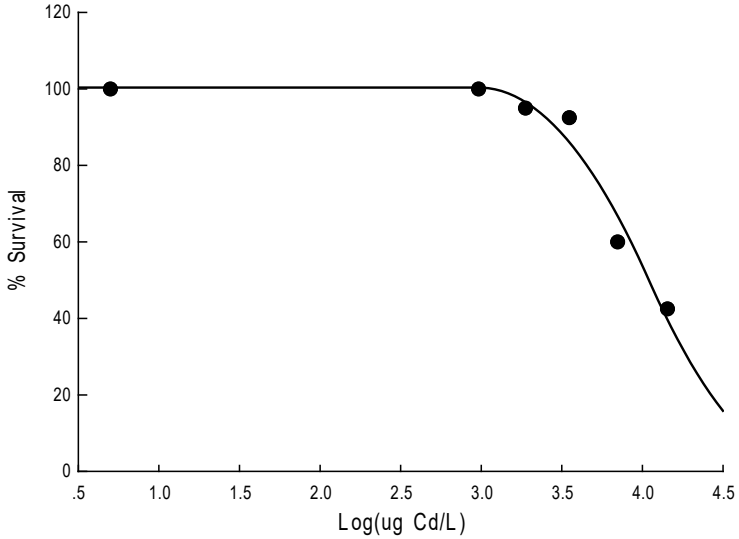
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.75	3.7786	0.041905	3.6932	3.8641
StDev	0.25	0.23494	0.051081	0.1655	0.40425
Y0	0.97169	0.97113	0.016126	0.91933	0.99377

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	6006.8	4934.3	7312.4	0.041905	3.7786
20	3690.8	2910.9	4679.7	0.048149	3.5671
10	2887.5	2051.9	4063.4	0.064925	3.4605
5	2427.4	1554.5	3790.3	0.079352	3.3851
0	1596.4	684.94	3721	0.11901	3.2032

LC50:LC5 = 2.475

Notes: Acceptable model fit.

Brinkman and Vieira 2007; Brinkman and Johnston 2008	
Species: *Rhithrogena hageni* (nymph)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-35	
Test: Single	
Cd, µg/L (dissolved)	**%Survival**
5	100
963	100
1880	95
3520	92.5
7020	60
14300	42.5



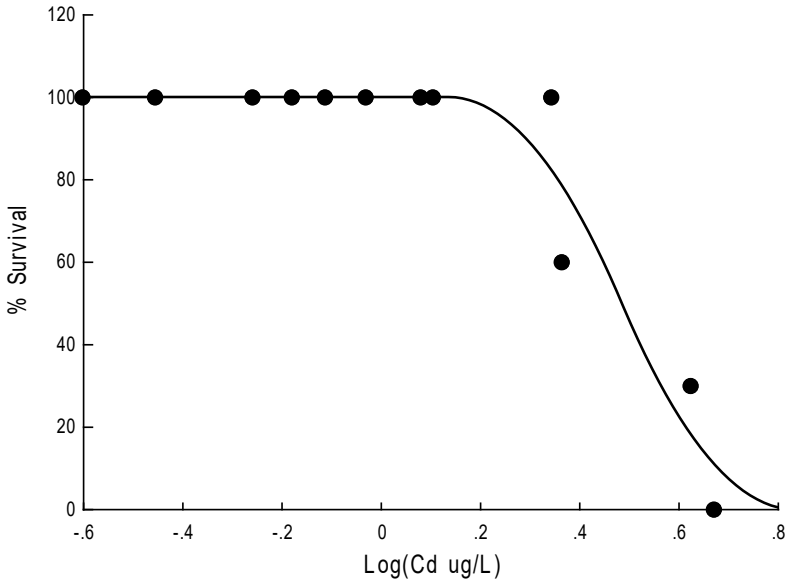
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.05	4.0384	5.53E-02	3.8624	4.2143
S	0.95	0.94933	0.1901	0.34436	1.5543
Y0	100	100.32	3.9035	87.9	112.75

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	10924	7285.3	16379	5.53E-02	4.0384
20	4479.3	2338.2	8580.9	8.87E-02	3.6512
10	2858.1	1144.9	7134.8	0.12484	3.4561
5	2080.2	662	6536.7	0.15625	3.3181
0	966.05	137.43	6790.8	0.26612	2.985

LC50:LC5 = 5.251

Notes: Acceptable model fit.

Phipps and Holcombe 1985	
Species: *Oncorhynchus mykiss* (8.8 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-47	
Test: Single	
Cd, (µg/L)	**%Survival**
0.25	100
0.35	100
0.55	100
0.66	100
0.77	100
0.93	100
1.2	100
1.27	100
2.2	100
2.31	60
4.2	30
4.68	0



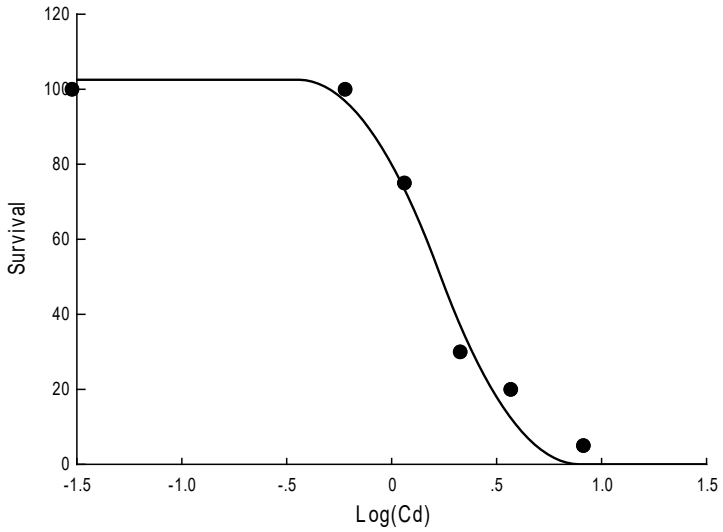
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.485	0.48496	0.03197	0.41264	0.55728
S	2.85	2.8514	0.61501	1.4601	4.2426
Y0	100	100.08	3.5668	92.015	108.15

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	3.0546	2.586	3.6081	0.03197	0.48496
20	2.2702	1.8168	2.8366	0.042768	0.35606
10	1.9548	1.4683	2.6023	0.054935	0.29109
5	1.7585	1.2118	2.5519	0.071488	0.24515
0	1.3622	0.43612	4.2549	0.21866	0.13425

LC50:LC5 = 1.737

Notes: Acceptable model fit despite noise in falling limb.

Stubblefield 1990	
Species: *Oncorhynchus mykiss* (18.3 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-48	
Test: Single	
Cd, (µg/L)	**%Survival**
0.03	100
0.6	100
1.15	75
2.12	30
3.69	20
8.19	5



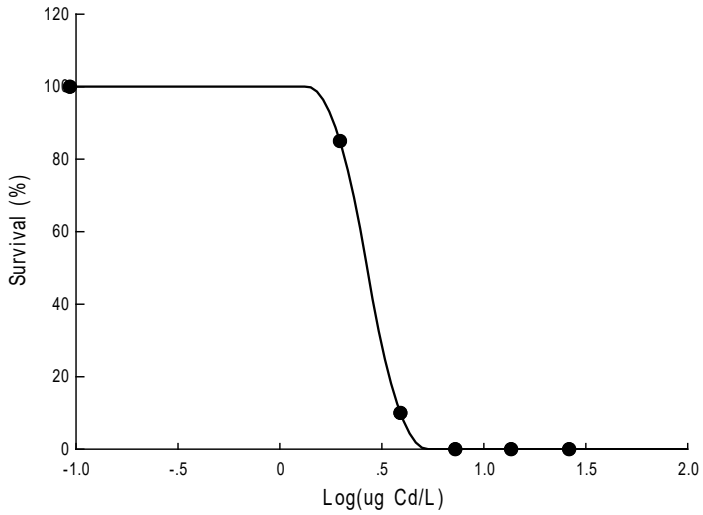
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.225	0.22594	0.048977	0.070072	0.38181
S	1.5	1.4901	0.30513	0.51905	2.4612
Y0	100	102.51	6.5946	81.522	123.5

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.6824	1.1751	2.4088	0.048977	0.22594
20	0.95342	0.51386	1.769	0.084351	-0.02072
10	0.71609	0.31236	1.6417	0.11322	-0.14503
5	0.58488	0.20684	1.6539	0.14185	-0.23293
0	0.3588	0.057941	2.2218	0.24882	-0.44515

LC50:LC5 = 2.876

Notes: Acceptable model fit.

Davies et al. 1993	
Species: *Oncorhynchus mykiss* (36 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-49	
Test: Acute 1 – 50 mg/L hardness	
Cd, (µg/L)	**%Survival**
0.07	100
1.97	85
3.90	10
7.24	0
13.6	0
26.2	0

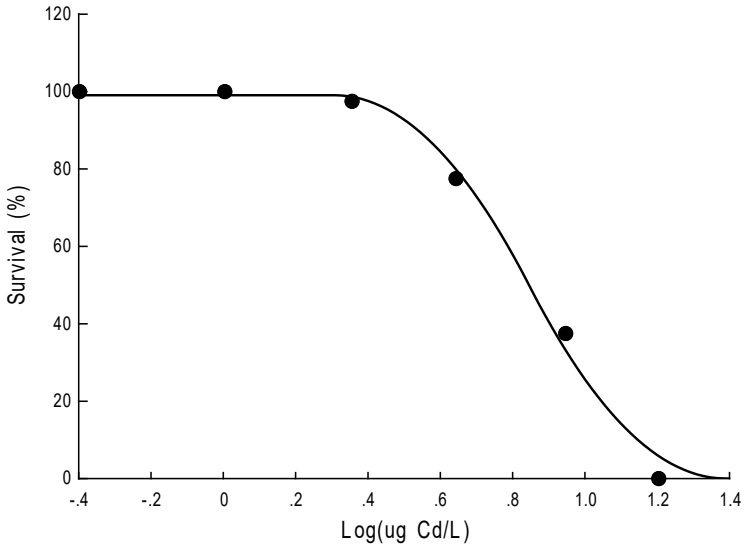


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.4	0.42794	0	0.42794	0.42794
S	3	3.3886	0	3.3886	3.3886
Y0	100	100	0	100	100
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.6788	2.6788	2.6788	0	0.42794
20	2.0868	2.0868	2.0868	0	0.31947
10	1.8399	1.8399	1.8399	0	0.26481
5	1.6833	1.6833	1.6833	0	0.22615
0	1.3578	1.3578	1.3578	0	0.13283

LC50:LC5 = 1.591

Notes: Acceptable model fit.

Davies et al. 1993	
Species: *Oncorhynchus mykiss* (36 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-53	
Test: Acute 2 – 200 mg/L hardness	
Cd, (µg/L)	**%Survival**
0.40	100
1.01	100
2.27	97.5
4.40	77.5
8.85	37.5
16.0	0



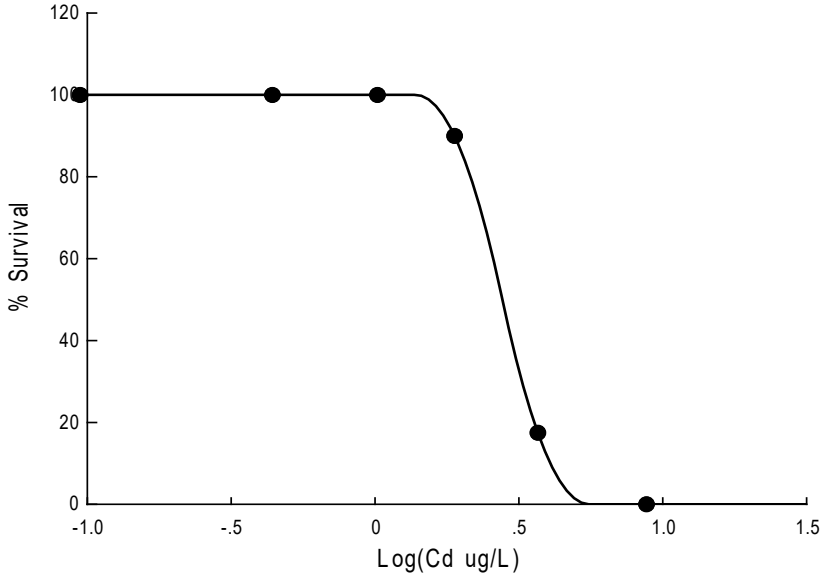
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.80976	0.84828	0.02619	0.76493	0.93163
S	2	1.8471	0.25073	1.0491	2.645
Y0	99.2	99.034	2.7908	90.153	107.92

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	7.0515	5.8202	8.5434	0.02619	0.84828
20	4.4596	3.2414	6.1355	0.043539	0.64929
10	3.54	2.2963	5.4572	0.059064	0.549
5	3.0067	1.7442	5.1831	0.074314	0.47809
0	2.0271	1.0107	4.0658	0.09498	0.30688

LC50:LC5 = 2.345

Notes: Acceptable model fit.

Davies and Brinkman 1994b	
Species: *Oncorhynchus mykiss* (fry, 1 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-55	
Test: Acute 1 – unaged soft (29 mg/L hardness)	
Cd, (µg/L)	**%Survival**
0.05	100
0.44	100
1.02	100
1.89	90
3.68	17.5
8.78	0



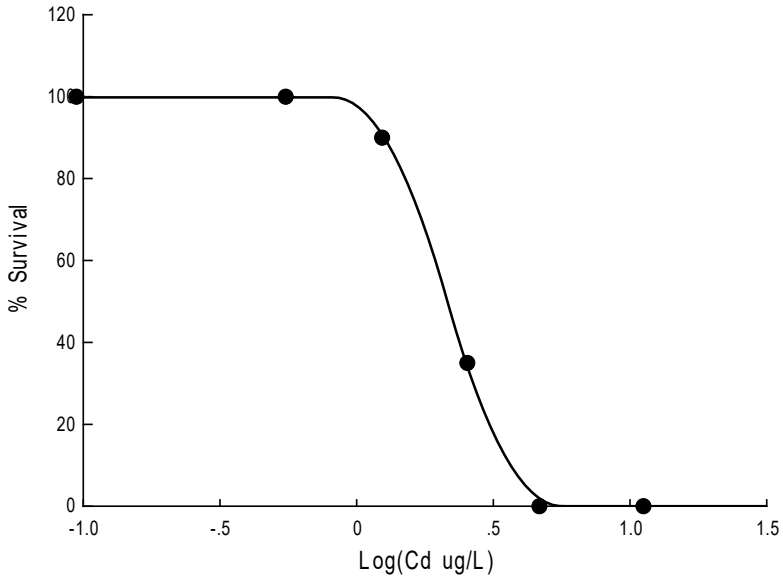
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.44	0.44289	0	0.44289	0.44289
S	3.3	3.3214	0	3.3214	3.3214
Y0	100	100	0	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.7726	2.7726	2.7726	0	0.44289
20	2.149	2.15E+00	2.149	0	0.33223
10	1.8900	1.8900	1.8900	0.0000	0.2765
5	1.7259	1.7259	1.7259	0.0000	0.2370
0	1.39E+00	1.39E+00	1.39E+00	0	0.14182

Notes: Acceptable model fit.

LC50:LC5 = 1.606

Davies and Brinkman 1994b	
Species: *Oncorhynchus mykiss* (fry, 1 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-58	
Test: Acute 2 - unaged soft (28 mg/L hardness)	
Cd, (µg/L)	**%Survival**
0.07	100
0.55	100
1.24	90
2.54	35
4.66	0
11.2	0



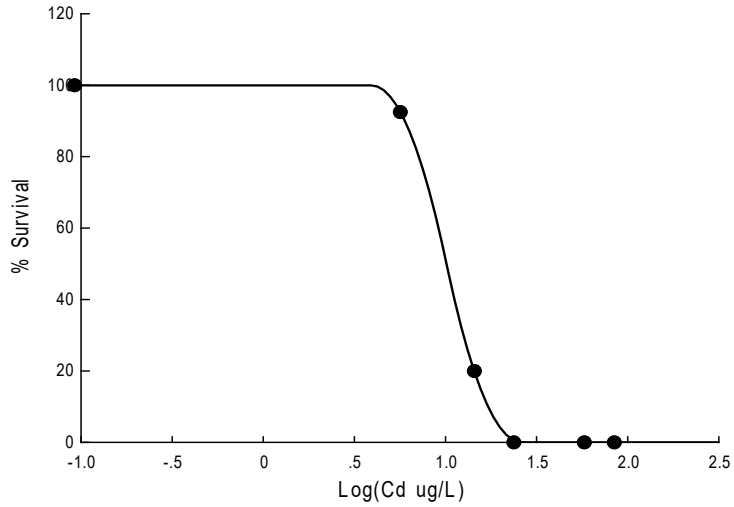
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.33	0.3329	6.55E-03	0.31206	0.35374
S	2.4	2.3978	1.06E-01	2.0612	2.7343
Y0	100	99.787	0.90252	96.915	102.66

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.1523	2.0515	2.2581	6.55E-03	0.3329
20	1.5122	1.39E+00	1.641	1.12E-02	0.17962
10	1.2658	1.1372	1.4089	0.0146	0.1024
5	1.1162	0.9876	1.2615	0.0167	0.0477
0	8.24E-01	7.12E-01	9.53E-01	1.99E-02	-8.41E-02

LC50:LC5 = 1.928

Notes: Acceptable model fit.

Davies and Brinkman 1994b	
Species: *Oncorhynchus mykiss* (fry, 2.5 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-60	
Test: Acute 2 - unaged hard (281 mg/L hardness)	
Cd, (µg/L)	**%Survival**
0.05	100
5.65	92.5
14.4	20
23.7	0
57.8	0
84.4	0



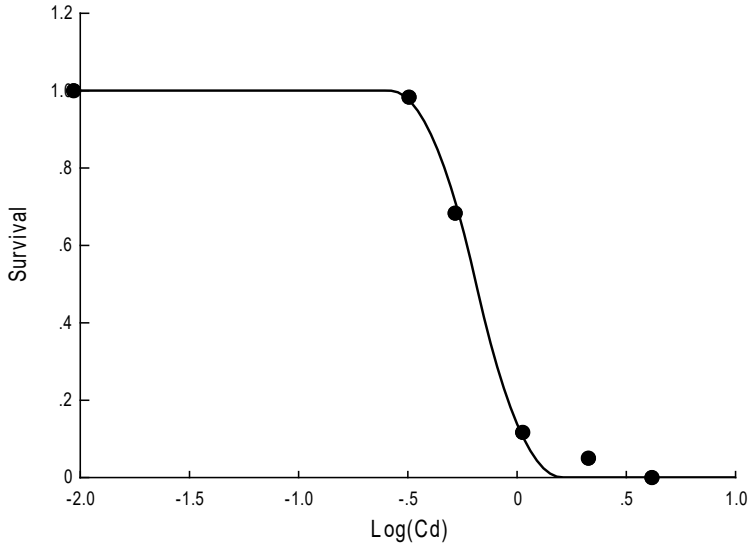
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	1.006	2.46E-03	0.99816	1.0138
S	2.5	2.4258	2.96E-02	2.3316	2.5201
Y0	100	99.95	0.33445	98.886	101.01

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	10.139	9.9578	10.323	2.46E-03	1.006
20	7.1528	6.9565	7.3546	3.80E-03	0.85447
10	5.9994	5.8019	6.2038	4.57E-03	0.77811
5	5.298	5.1054	5.498	5.05E-03	0.72412
0	3.9243	3.7483	4.1084	6.26E-03	0.59376

LC50:LC5 = 1.914

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-61	
Test: Bank 1- hardness 30.4 mg/L; 263 mg fish	
Cd, (µg/L)	**Proportion Surviving**
0.0065	100
0.32	98
0.52	68
1.06	12
2.12	5
4.14	0



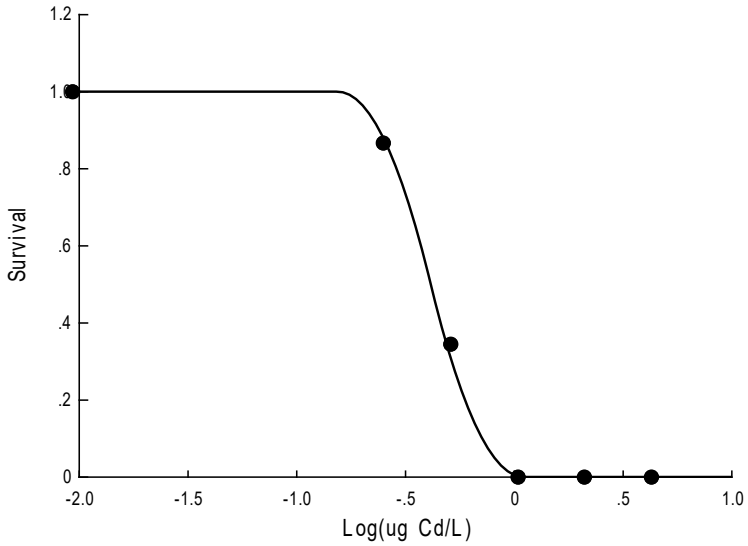
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.08599	-0.18706	0.019976	-0.22696	-0.14717
S	0.12	0.16109	0.01512	0.13614	0.19732
Y0	0.99167	0.9999	0.0012906	0.9402	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.65004	0.59299	0.71258	0.019976	-0.18706
20	0.46549	0.42265	0.51268	0.020812	-0.33209
10	0.39338	0.35104	0.44084	0.024273	-0.40518
5	0.34925	0.30647	0.39799	0.027548	-0.45687
0	0.26203	0.21833	0.31448	0.037103	-0.58165

LC50:LC5 = 1.861

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-62	
Test: Bank 3- 31.6 m/L hardness; 659 mg fish	
Cd, (µg/L)	**Proportion Surviving**
0.0065	100
0.25	87
0.51	34
1.04	0
2.1	0
4.27	0



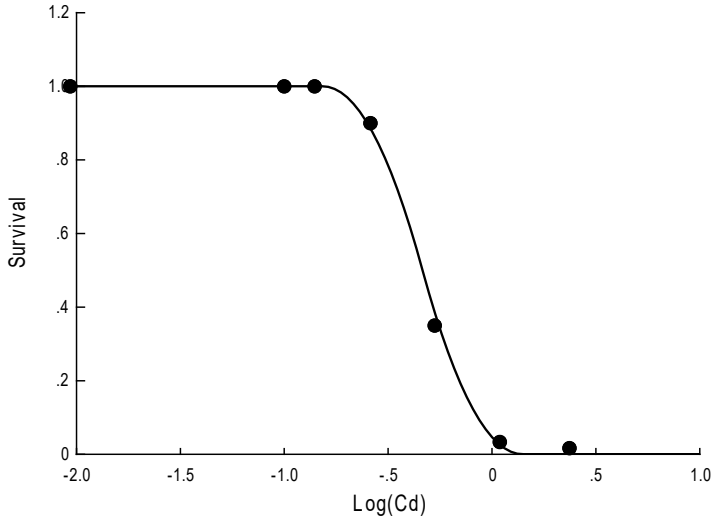
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.38779	-0.38367	0.021916	-0.42746	-0.33988
S	0.19335	0.17456	0.015269	0.14909	0.21063
Y0	1	0.9999	0.0012909	0.94017	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.41336	0.37371	0.45721	0.021916	-0.38367
20	0.28785	0.25113	0.32994	0.029436	-0.54083
10	0.23986	0.2039	0.28217	0.034697	-0.62004
5	0.21084	0.17562	0.25312	0.038677	-0.67605
0	0.15443	0.12193	0.1956	0.04847	-0.81126

LC50:LC5 = 1.961

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-63	
Test: Bank 2- 32 mg/L hardness; 1,150 mg fish	
Cd, (µg/L)	**Proportion Surviving**
0.0065	100
0.14	100
0.26	90
0.53	35
1.09	3
2.36	2



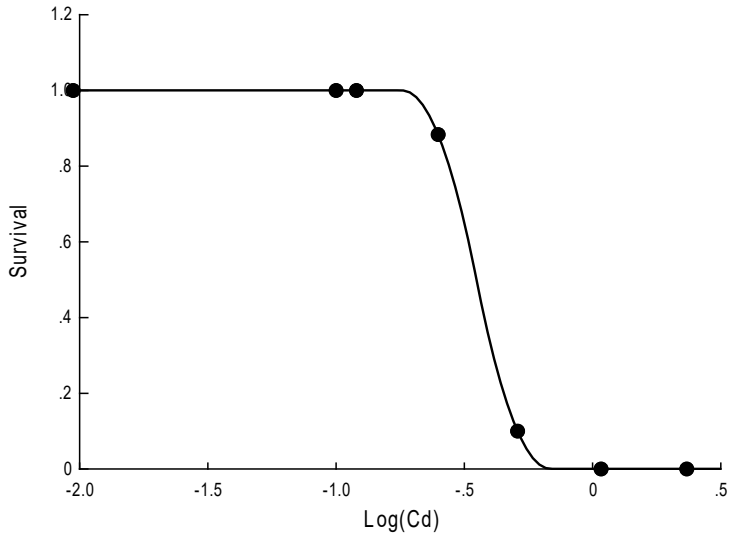
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.33	-0.33402	0.023102	-0.38007	-0.28797
S	0.2	0.19626	0.01889	0.16522	0.24178
Y0	1	0.9999	0.000877	0.97182	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.46342	0.4168	0.51526	0.023102	-0.33402
20	0.30852	0.26617	0.35761	0.031872	-0.51072
10	0.25132	0.20912	0.30203	0.039209	-0.59977
5	0.2174	0.1767	0.26748	0.043721	-0.66274
0	0.15319	0.11601	0.20229	0.056444	-0.81477

LC50:LC5 = 2.132

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-64	
Test: Bank 3 – 31.9 mg/L hardness; 1,130 mg fish	
Cd, (µg/L)	**%Survival**
0.0065	100
0.12	100
0.25	88
0.51	10
1.08	0
2.33	0



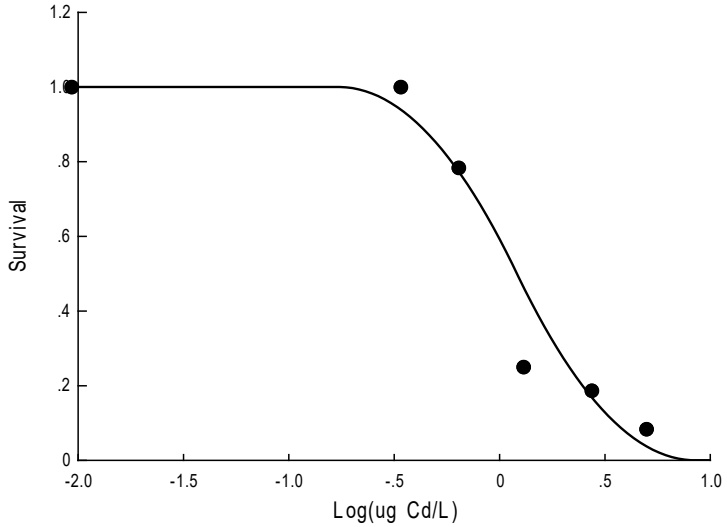
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.45	-0.45243	0.017653	-0.48799	-0.41687
S	0.12	0.11813	0.013466	0.096648	0.15197
Y0	1	0.9999	0.00087701	0.97182	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.35283	0.32509	0.38294	0.017653	-0.45243
20	0.2762	0.24945	0.30581	0.021669	-0.55878
10	0.24413	0.21592	0.27602	0.025686	-0.61238
5	0.22373	0.19432	0.25758	0.029005	-0.65028
0	0.18122	0.14913	0.22022	0.037975	-0.74178

LC50:LC5 = 1.577

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-65	
Test: Bank 3- 30.9 mg/L hardness; 299 mg fish	
Cd, (µg/L)	**%Survival**
0.0065	100
0.34	100
0.64	78
1.3	25
2.74	19
4.98	8



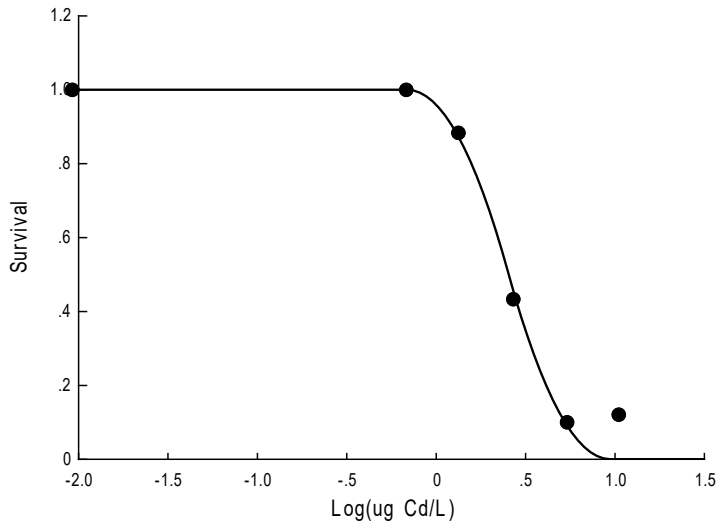
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	9.00E-02	8.29E-02	3.05E-02	2.25E-02	0.14326
S	0.2	0.3451	2.72E-02	0.29903	0.40809
Y0	1	0.9999	1.29E-03	0.94018	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.2103	1.0533	1.3908	3.05E-02	8.29E-02
20	0.59186	0.49058	0.71404	4.09E-02	-0.22778
10	0.41269	0.32721	0.52051	5.02E-02	-0.38437
5	0.31982	0.24434	0.41862	5.78E-02	-0.49509
0	0.17282	0.1198	0.24932	7.68E-02	-0.7624

LC50:LC5 = 3.784

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-66	
Test: Bank 2- 88.6 mg/L hardness; 289 mg fish	
Cd, (µg/L)	**%Survival**
0.0065	100
0.68	100
1.33	88
2.7	43
5.39	10
10.5	12



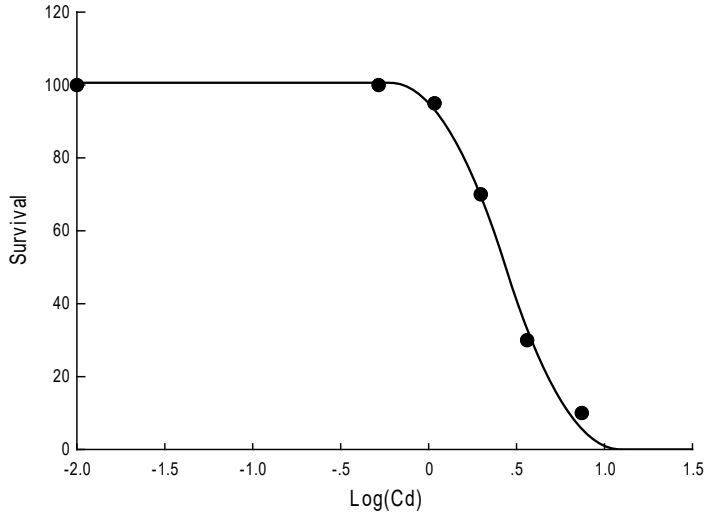
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.40588	0.40619	0.025753	0.35495	0.45743
S	0.2	0.23177	0.026398	0.18966	0.2981
Y0	1	0.9999	0.00091281	0.96952	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.548	2.2644	2.867	0.025753	0.40619
20	1.5759	1.3263	1.8725	0.037155	0.19753
10	1.237	0.99184	1.5427	0.046804	0.092366
5	1.0423	0.80341	1.3523	0.054291	0.018003
0	0.6894	0.47589	0.99872	0.073206	-0.16153

LC50:LC5 = 2.445

Notes: Acceptable model fit.

Stubblefield 1990	
Species: *Salmo trutta* (22.4 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-76	
Test: Single	
Cd, (µg/L)	**%Survival**
0.01	100
0.52	100
1.08	95
1.98	70
3.63	30
7.43	10



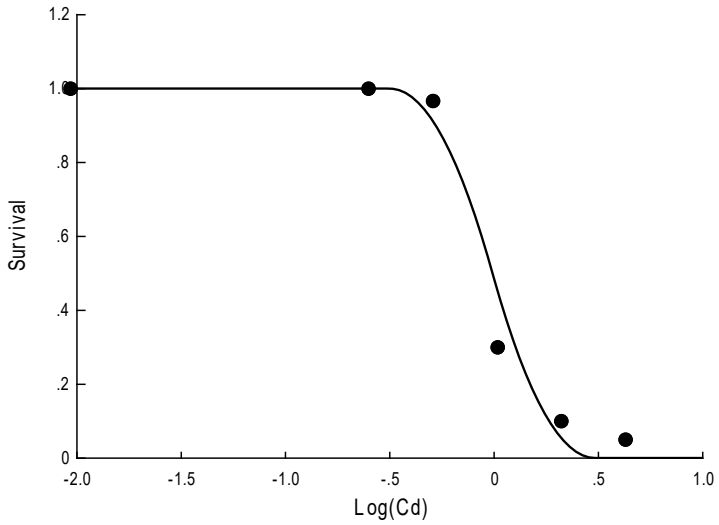
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.4365	0.43652	0.020497	0.37129	0.50175
S	1.53	1.531	0.13852	1.0902	1.9719
Y0	100	100.6	2.264	93.393	107.8

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.7323	2.3512	3.1751	0.020497	0.43652
20	1.572	1.2328	2.0046	0.033169	0.19646
10	1.1898	0.85002	1.6654	0.045888	0.075468
5	0.97704	0.63571	1.5017	0.058653	-0.010086
0	0.60725	0.34778	1.0603	0.076064	-0.21663

LC50:LC5 = 2.797

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Salvelinus confluentus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-79	
Test: Bank 3-32.1 mg/L hardness; 200 mg fish	
Cd, (µg/L)	**Proportion surviving**
0.0065	100
0.25	100
0.51	97
1.04	30
2.1	10
4.27	5



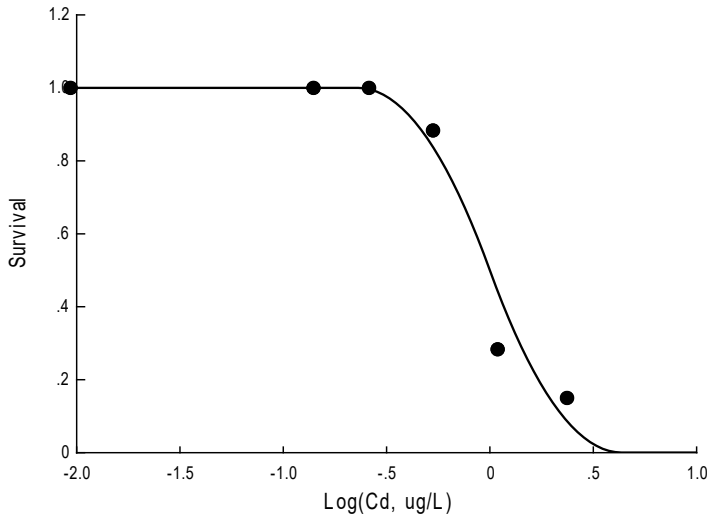
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.008	-0.0075579	0.022623	-0.052589	0.037473
S	0.15	0.20081	0.020007	0.16812	0.2494
Y0	0.98889	0.9999	0.0009128	0.96952	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.98275	0.88595	1.0901	0.022623	-0.0075579
20	0.64811	0.56219	0.74718	0.030726	-0.18835
10	0.52545	0.44035	0.627	0.037687	-0.27947
5	0.453	0.36835	0.55712	0.043595	-0.3439
0	0.31663	0.23905	0.4194	0.056854	-0.49945

LC50:LC5 = 2.169

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Salvelinus confluentus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-80	
Test: Bank 2- 33.1 mg/L hardness; 221 mg fish	
Cd, (µg/L)	**Proportion surviving**
0.0065	100
0.14	100
0.26	100
0.53	88
1.09	28
2.36	15

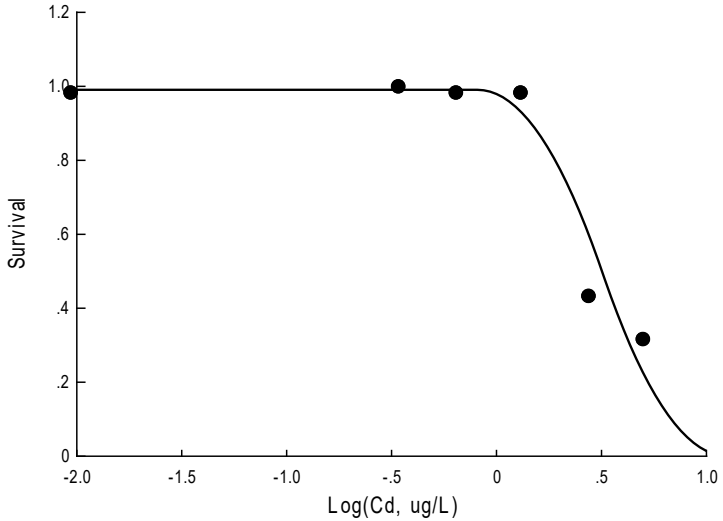


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.025	-0.0002606	0.026789	-0.053445	0.052924
S	0.26	0.26076	0.020684	0.22576	0.30872
Y0	1	0.9999	0.00087564	0.9719	1
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.9994	0.88421	1.1296	0.026789	-0.0002606
20	0.58207	0.50913	0.66545	0.029104	-0.23502
10	0.44326	0.37831	0.51935	0.034169	-0.35335
5	0.36559	0.30511	0.43805	0.038703	-0.43701
0	0.22962	0.17933	0.294	0.051572	-0.639

LC50:LC5 = 2.734

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Salvelinus confluentus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-82	
Test: Bank 3 – 30.6 mg/L hardness; 84.2 mg fish	
Cd, (µg/L)	**Proportion surviving**
0.0065	98
0.34	100
0.64	98
1.3	98
2.74	43
4.98	32



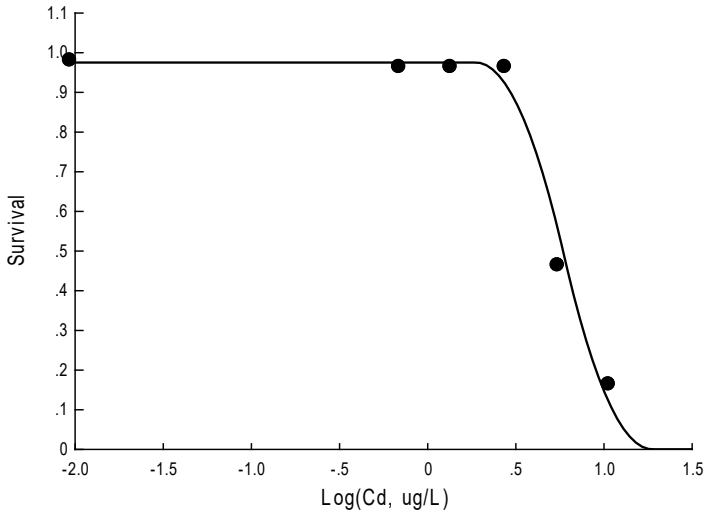
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.505	0.50514	0.029004	0.4473	0.56299
S	0.243	0.24291	0.031194	0.19431	0.32412
Y0	0.99	0.99078	0.0069255	0.9646	0.9991

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	3.1999	2.8009	3.6558	0.029004	0.50514
20	1.934	1.6403	2.2803	0.035278	0.28645
10	1.5005	1.2088	1.8625	0.045316	0.17623
5	1.254	0.96507	1.6294	0.05379	0.098298
0	0.8131	0.54417	1.2149	0.076875	-0.089858

LC50:LC5 = 2.552

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Salvelinus confluentus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-83	
Test: Bank 2- 90.3 mg/L hardness; 72.7 mg fish	
Cd, (µg/L)	**Proportion surviving**
0.0065	98
0.68	97
1.33	97
2.7	97
5.39	47
10.5	17



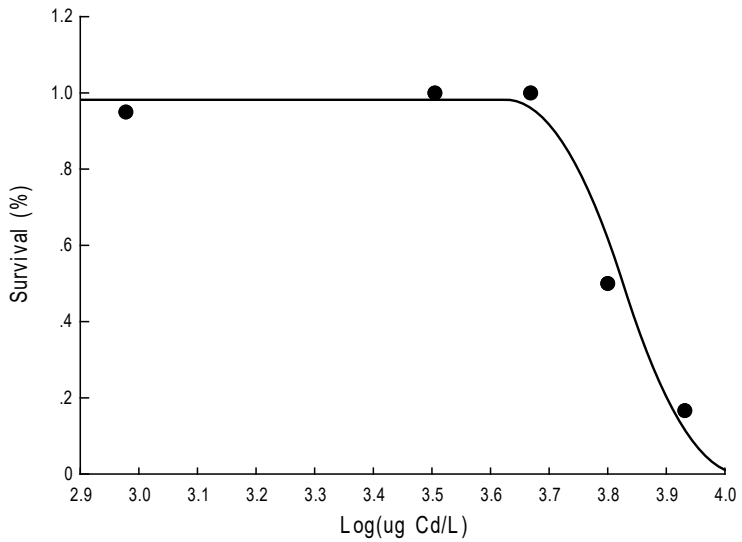
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.775	0.77394	0.025227	0.72357	0.82432
S	0.205	0.20455	0.024364	0.16602	0.26655
Y0	1	0.97634	0.010961	0.94359	0.9928

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	5.9422	5.2914	6.6729	0.025227	0.77394
20	3.8885	3.3281	4.5433	0.033369	0.58979
10	3.1403	2.5777	3.8257	0.041563	0.49697
5	2.6999	2.1387	3.4083	0.048204	0.43134
0	1.8746	1.3366	2.6289	0.065892	0.2729

LC50:LC5 = 2.201

Notes: Acceptable model fit.

Carrier 1987; Carrier and Beitinger 1988a	
Species: *Cyprinella lutrensis* (adult)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-85	
Test: Single	
Cd, (µg/L)	**%Survival**
10	Not reported
950	95
3200	100
4660	100
6310	50
8540	17



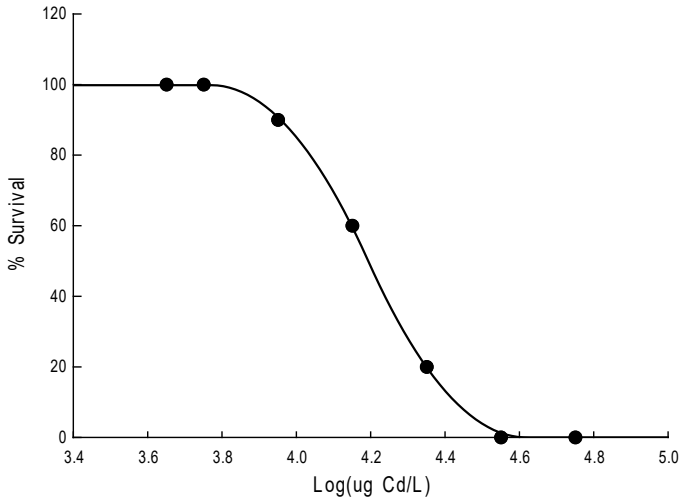
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.8	3.828	0.018929	3.7884	3.8677
StDev	0.08	0.08217	0.017175	0.058531	0.1377
Y0	0.983	0.98177	0.020725	0.88276	0.99983

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	6730.5	6143.4	7373.8	0.018929	3.828
20	5676.4	5019.2	6419.8	0.02436	3.7541
10	5209.5	4435.4	6118.7	0.029951	3.7168
5	4902.7	4025.5	5970.9	0.034529	3.6904
0	4234.3	3036.4	5905	0.046788	3.6268

LC50:LC5 = 1.373

Notes: Acceptable model fit.

Vergauwen 2012; Vergauwen et al. 2013	
Species: *Danio rerio* (adult)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-86	
Test: 18C	
Cd, (µg/L)	**%Survival**
4475	100
5634	100
8929	90
14152	60
22429	20
35547	0
56338	0

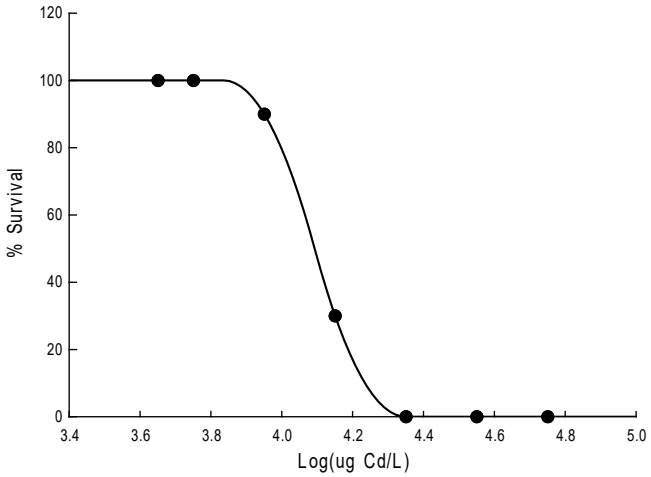


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.19	4.194	0.0032331	4.185	4.203
S	2.36	2.3559	0.052654	2.2097	2.5021
Y0	100	99.819	0.53491	98.333	101.3
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	15631	15311	15957	0.003233	4.194
20	10914	10553	11286	0.005255	4.038
10	9106.2	8695.2	9536.7	0.007224	3.9593
5	8012	7587.5	8460.2	0.008514	3.9037
0	5881.8	5543	6241.3	0.009279	3.7695

LC50:LC5 = 1.951

Notes: Acceptable model fit.

Vergauwen 2012; Vergauwen et al. 2013	
Species: *Danio rerio* (adult)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-87	
Test: 26C	
Cd, (µg/L)	**%Survival**
4475	100
5634	100
8929	90
14152	60
22429	20
35547	0
56338	0



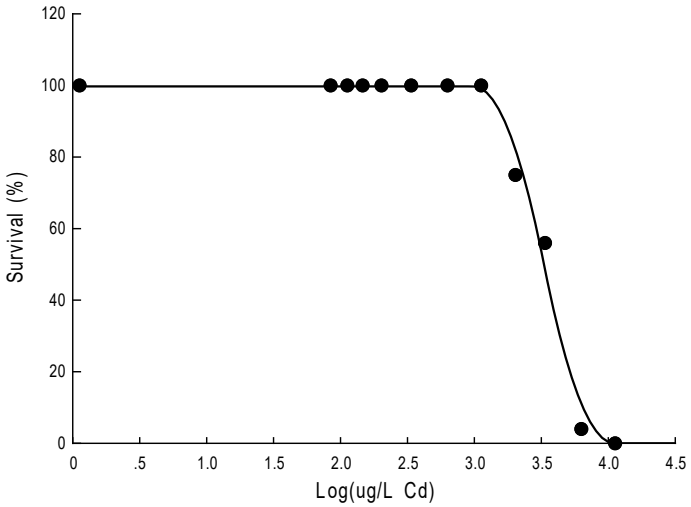
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.1	4.0929	0	4.0929	4.0929
S	3.9	3.8909	0	3.8909	3.8909
Y0	100	100	0	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	12384	12384	12384	0	4.0929
20	9963.5	9963.5	9963.5	0	3.9984
10	8929	8929	8929	0	3.9508
5	8263.1	8263.1	8263.1	0	3.9171
0	6852.8	6852.8	6852.8	0	3.8359

LC50:LC5 = 1.499

Notes: Acceptable model fit.

Sunderman et al. 1991	
Species: *Xenopus laevis*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-101	
Test: Single	
Cd, (µg/L)	**%Survival**
1.12	100
84.3	100
112	100
146	100
202	100
337	100
630	100
1124	100
2023	75
3372	56
6295	4
11241	0



LC50:LC5 = 2.290

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.5	3.5203	1.87E-02	3.478	3.5627
S	2	1.8999	0.22982	1.38	2.4198
Y0	100	99.696	1.5247	96.247	103.14

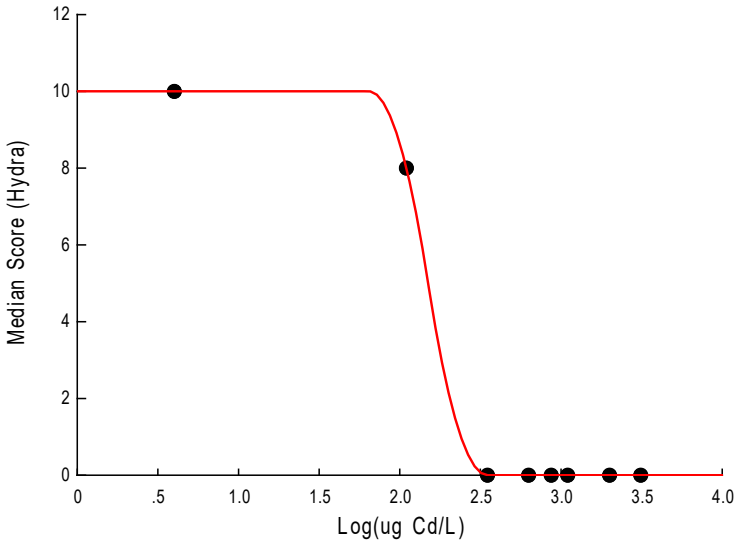
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	3314	3006.1	3653.4	1.87E-02	3.5203
20	2122.7	1800.8	2502.2	3.16E-02	3.3269
10	1695.9	1338.9	2148.1	4.54E-02	3.2294
5	1447	1061.3	1972.8	5.95E-02	3.1605
0	986.31	583.98	1665.8	0.10062	2.994

Notes: Acceptable model fit.

Appendix B.2

Test Information, C-R Data and Resulting TRAP models for Acute Cadmium Toxicity Tests Unacceptable for TAF and MAF Calculation

Karntanut and Pascoe 2000	
Species: *Hydra vulgaris*	
Test Endpoint: 96 hr survival	
C-R Curve Label: Cd-Acute-1	
Test: 15°C	
Cd, µg/L	**Median Score**
0	10
4	10
110	8
350	0
630	0
870	0
1100	0
2000	0
3120	0



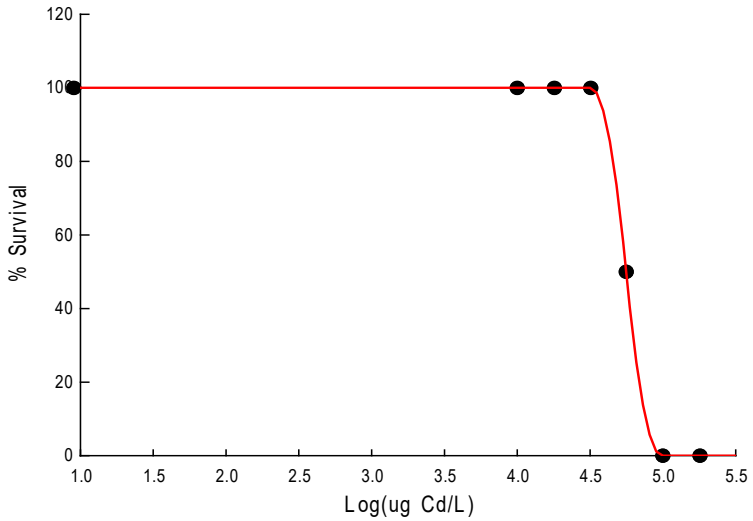
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.1734	2.1765	5.263E-08	2.1765	2.1765
S	2.625	2.7205	1.06E-06	2.7205	2.7205
Y0	10	10	1.269E-11	10	10

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	150.14	150.14	150.14	5.3E-08	2.1765
20	110	110	110	9.4E-13	2.0414
10	94.038	94.038	94.038	1.1E-12	1.9733
5	84.17	84.17	84.17	1.2E-12	1.9252
0	64.405	64.405	64.405	1.5E-12	1.8089

LC50:LC5 = 1.784

Notes: TRAP Flagged for IP (No Unique Solution).

Rathore and Khangarot 2002	
Species: *Tubifex tubifex*	
Test Endpoint: 96 hr survival	
C-R Curve Label: Cd-Acute-3	
Test: 20°C	
Cd, µg/L	**%Survival**
5	100
10000	100
18000	100
32000	100
56000	50
100000	0
180000	0



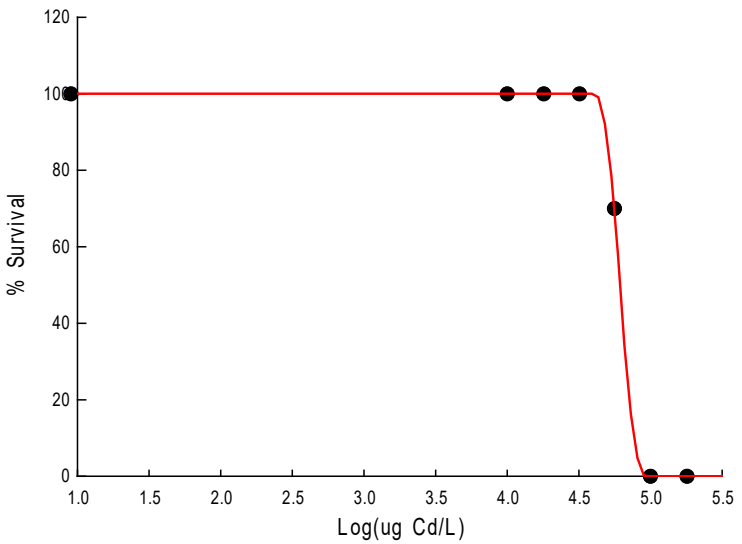
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.75	4.7482			
S	4.1	4.115			
Y0	100	100			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50.0	56000.0				4.7
20.0	45590.0				4.7
10.0	41101.0				4.6
5.0	38196.0				4.6
0.0	32002.0				4.5

LC50:LC5 = 1.466

Notes: TRAP Flagged for IP (No Unique Solution).

Rathore and Khangarot 2002	
Species: *Tubifex tubifex*	
Test Endpoint: 96 hr survival	
C-R Curve Label: Cd-Acute-4	
Test: 25°C	
Cd, µg/L	**%Survival**
5	100
10000	100
18000	100
32000	100
56000	70
100000	0
180000	0



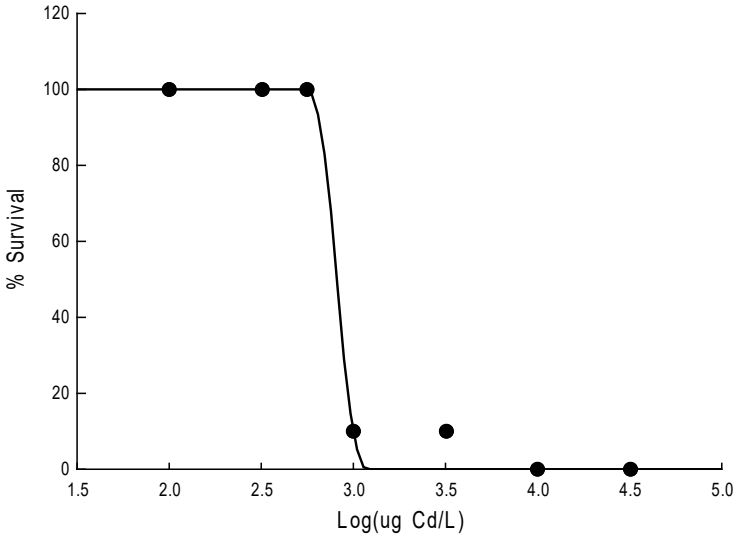
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.8	4.7877			
S	5.7	5.6999			
Y0	100	100			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50.0	61339.0				4.8
20.0	52875.0				4.7
10.0	49063.0				4.7
5.0	46534.0				4.7
0.0	40953.0				4.6

LC50:LC5 = 1.318

Notes: TRAP Flagged for IP (No Unique Solution)

Rathore and Khangarot 2003	
Species: *Tubifex tubifex*	
Test End Point: 96 hr survival	
C-R Curve Label: Cd-Acute-7	
Test: Hardness = 173 mg/L	
Cd, µg/L	**%Survival**
100	100
320	100
560	100
1000	10
3200	10
10000	0
32000	0



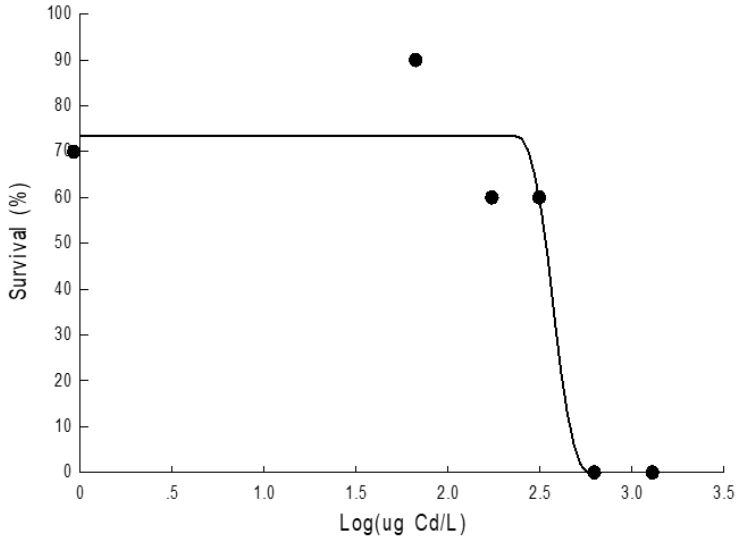
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.9	2.9108			
S	3.5	6.1995			
Y0	100	100			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50.0	814.4				2.9
20.0	710.5				2.9
10.0	663.2				2.8
5.0	631.7				2.8
0.0	561.7				2.7

LC50:LC5= 1.289

Notes: Poor model fit (at high level effects) with inadequate partials between 0% and 90% effect.

Pais 2012	
Species: *Lymnaea stagnalis*	
Test Endpoint: 96 hr survival	
C-R Curve Label: Cd-Acute-11	
Test: Juvenile, 18mm	
Cd, µg/L	**%Survival**
0.5	70
67	90
174	60
315	60
628	0
1301	0



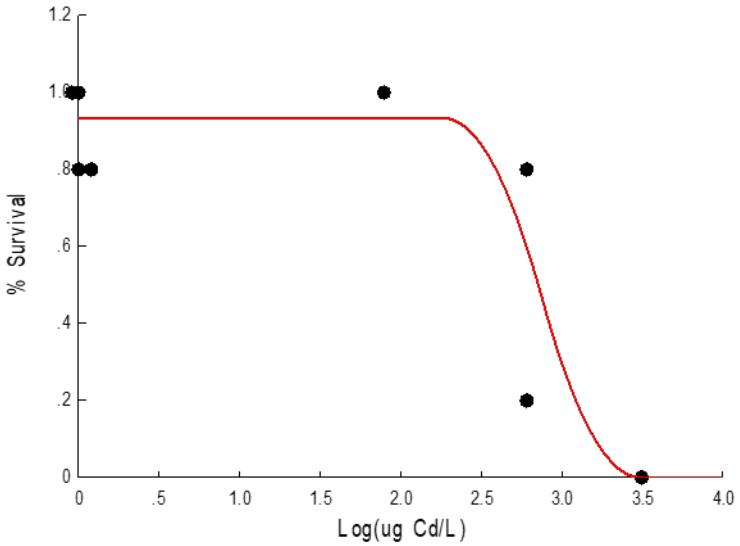
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.5	2.5741			
S	4.5	5.2389			
Y0	80	73.333			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	375.05				2.5741
20	319.1				2.5039
10	294.150				2.469
5	277.690				2.444
0	241.66				2.38

LC50:LC5 = 1.351

Notes: Not core data. Unacceptable noise at low level effects.

Mebane et al 2012		
Species: *Gyralus sp*		
Test End Point: 96 hr survival		
C-R Curve Label: Cd-Acute-13		
Test: Single		
Cd, µg/L	**Fish**	**Survivors**
0.5	10	10
0.5	10	10
0.5	10	10
1.2	10	8
1.2	10	8
1.2	10	8
79	10	10
79	10	10
79	10	10
605	10	8
605	10	8
605	10	2
3130	10	0
3130	10	0
3130	10	0



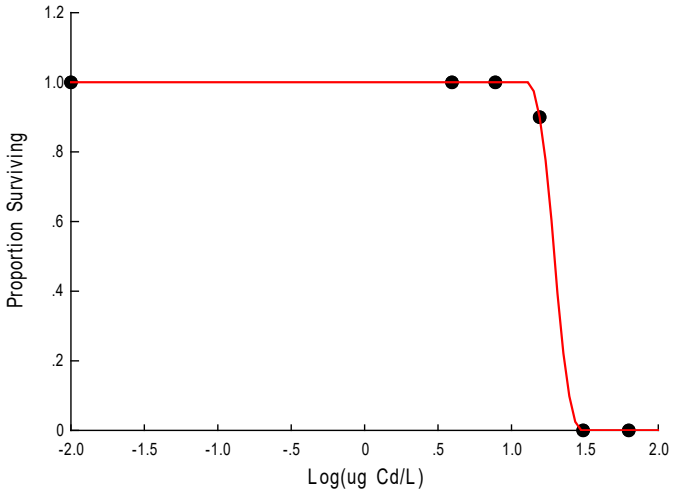
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.7682	2.876			
StDev	0.37379	0.24931			
Y0	0.9333	0.9333			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	751.68				2.876
20	448.32				2.6516
10	345.51				2.5385
5	287.39				2.4585
0	184.23				2.2654

LC50:LC5 = 2.616

Notes: TRAP Flagged for IP (No Unique Solution)

Wang et al. 2010d	
Species: *Lampsilis rafinesqueana* (5-d old juv.)	
Test End Point: 96 hr Survival	
C-R Curve Label: Cd-Acute-15	
Test: Single	
Cd, µg/L	**Proportion Surviving**
0.011	100
3.93	100
7.765	100
15.55	90
30.75	0
62.85	0



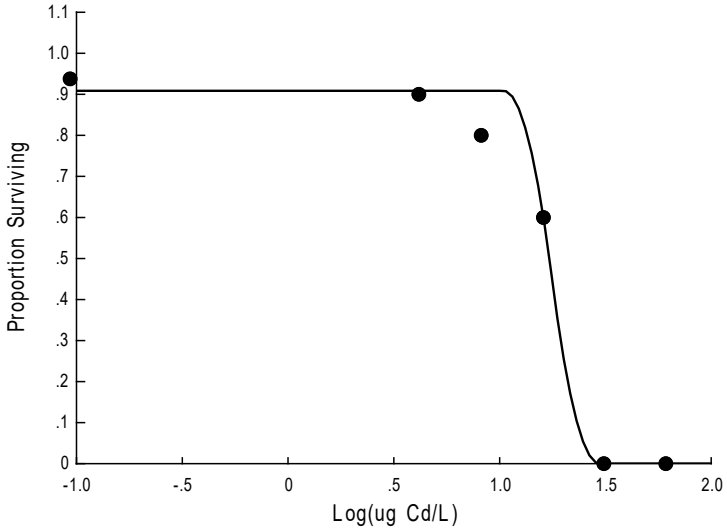
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.25	1.29			
StDev	0.14	0.07			
Y0	1.00	1.00			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**19.61**				1.29
20	16.81				1.23
10	15.55				1.19
5	**14.72**				1.17
0	12.89				1.11

LC50:LC5= 1.332

Notes: TRAP Flagged for IP (No Unique Solution)

Wang et al. 2010d	
Species: *Lampsilis siliquoidea* (5-d old juv.)	
Test End Point: 96 hr Survival	
C-R Curve Label: Cd-Acute-16	
Test: Single	
Cd, µg/L	**%Survival**
0.00	93.75
4.00	90
8.00	80
16.00	60
32.00	0
64.00	0



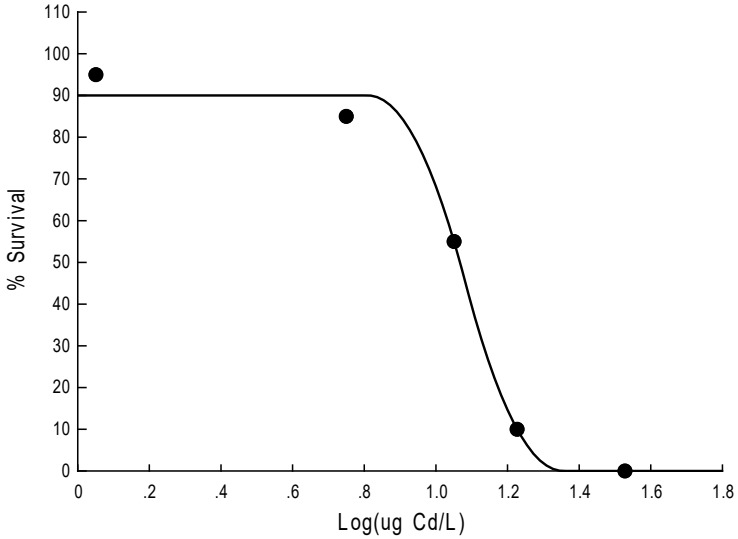
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.20	1.25			
StDev	0.15	0.09			
Y0	0.92	0.91			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**17.64**				1.25
20	14.58				1.16
10	13.24				1.12
5	**12.37**				1.09
0	10.50				1.02

LC50:LC5= 1.426

Notes: Poor model fit.

Shaw et al. 2006	
Species: *Daphnia ambigua* (<24 h old)	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Cd-Acute-18	
Test: Single	
Cd, µg/L	**%Survival**
1	95
6	85
11	55
17	10
34	0



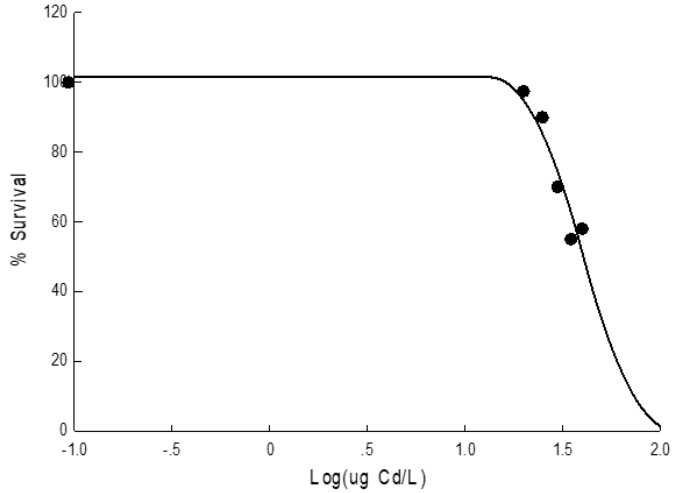
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.1	1.083	0.016536	1.0118	1.1541
S	3.7	3.6724	0.7657	0.37788	6.9669
Y0	95	90	3.5355	74.788	105.21

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	12.105	10.276	14.26	0.016536	1.083
20	9.6134	7.1347	12.953	0.030098	0.98288
10	8.5592	5.2255	14.02	0.049807	0.93243
5	7.8844	3.3319	18.657	0.086939	0.89677
0	6.4663	1.0264	40.738	0.18578	0.81066

LC50:LC5 = 1.535

Notes: Poor model fit.

Jemec et al 2007	
Species: *Daphnia magna* (<24 h old)	
Test End Point: 48 hr survival	
C-R Curve Label: Cd-Acute-20	
Test: Single	
Cd, µg/L	**%Survival**
0.05	100
20	97.5
25	90
30	70
35	55
40	58

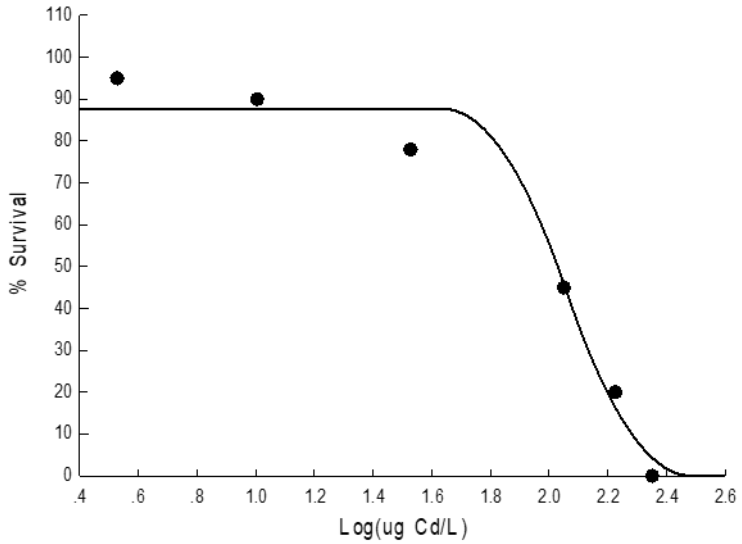


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.6	1.6048	0.031561	1.5044	1.7053
S	2.1	2.112	0.65339	0.032677	4.1914
Y0	100	101.47	7.0559	79.019	123.93
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	40.257	31.945	50.732	0.031561	1.6048
20	26.966	17.955	40.5	0.055505	1.4308
10	22.035	12.301	39.471	0.079552	1.3431
5	19.103	9.3472	39.039	0.097538	1.2811
0	13.532	4.7713	38.379	0.14226	1.1314

LC50:LC5= 2.107

Notes: Not core data. No treatment with greater than 50% effect.

Xie et al. 2007	
Species: *Daphnia magna* (24 h old)	
Test End Point: 48 hr Immobilization	
C-R Curve Label: Cd-Acute-21	
Test: Single	
Cd, µg/L	**%Survival**
3.3723	95
10.1169	90
33.723	78
112.41	45
168.615	20
224.82	0



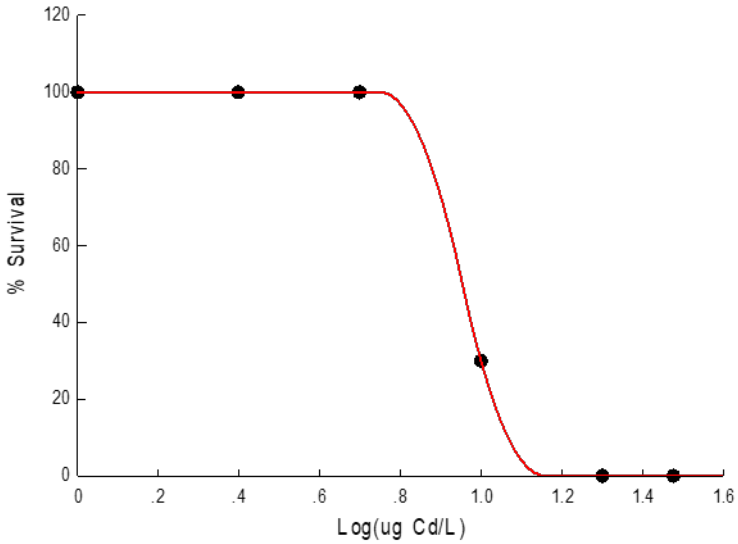
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.05	2.0613	3.84E-02	1.94E+00	2.1836
S	2.35	2.3647	0.76172	-5.95E-02	4.7888
Y0	87.7	87.659	4.5498	73.179	102.14

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	115.160	86.903	152.600	0.038	2.061
20	80.513	43.253	149.870	0.085	1.906
10	67.225	23.847	189.510	0.141	1.828
5	59.175	11.476	305.140	0.224	1.772
0	43.492	9.042	209.200	0.214	1.638

LC50:LC5= 1.946

Notes: Poor Model Fit.

Tan and Wang 2011	
Species: *Daphnia magna* (7 d old)	
Test End Point: 48 hr Survival	
C-R Curve Label: Cd-Acute-23	
Test: Ca 0.46, pH 8.1	
Cd, µg/L	**%Survival**
1	100
2.5	100
5	100
10	30
20	0
30	0



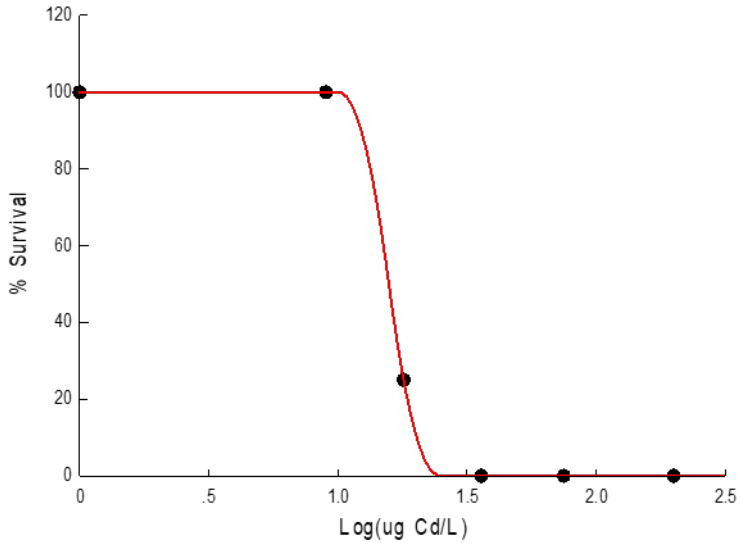
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.95	0.954			
S	4.9	4.9			
Y0	100	100			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	8.995				0.954
20	7.568				0.879
10	6.937				0.841
5	6.523				0.814
0	5.622				0.750

LC50:LC5= 1.379

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Tan and Wang 2011	
Species: *Daphnia magna* (7 d old)	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Cd-Acute-24	
Test: Ca 19, pH 8.1	
Cd, µg/L	**%Survival**
1	100
9	100
18	25
36	0
75	0
200	0

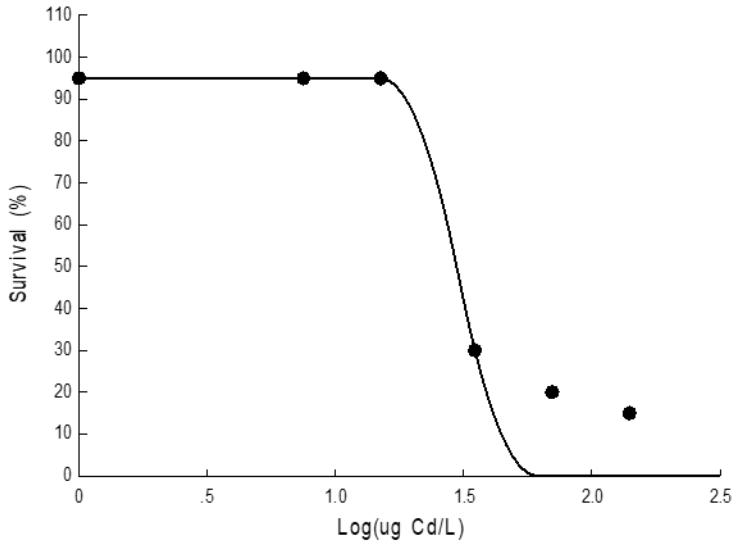


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.2	1.1984			
S	5	5.1474			
Y0	100	100			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	15.790				1.198
20	13.396				1.127
10	12.330				1.091
5	11.629				1.066
0	10.095				1.004

LC50:LC5= 1.358

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Tan and Wang 2011	
Species: *Daphnia magna* (7 d old)	
Test End Point: 48 hr Survival	
C-R Curve Label: Cd-Acute-25	
Test: Ca 192, pH 8.1	
Cd, µg/L	**%Survival**
1	95
7.5	95
15	95
35	30
70	20
140	15



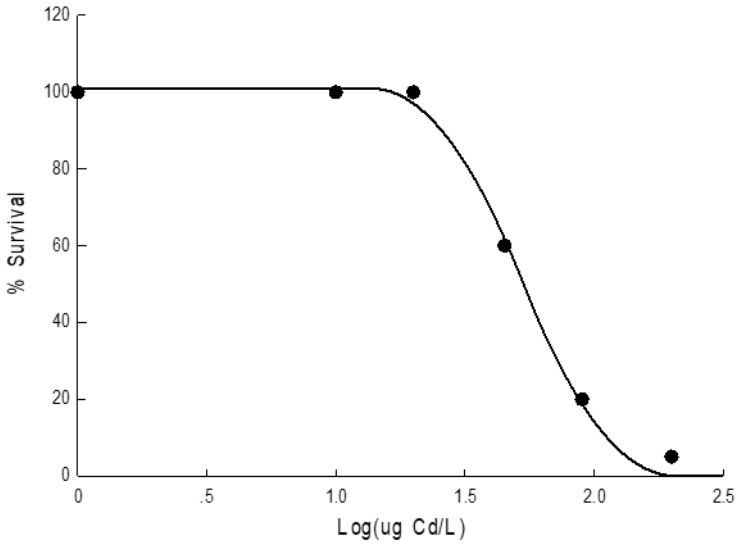
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.4813	3.9374	-11.049	14.012
S	2.8	3.2687	204.53	-647.63	654.17
Y0	95	95	10.206	62.519	127.48

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	30.288	8.92E-12	1.028E+14	3.9374	1.4813
20	23.379	2.82E-34	1.9412E+36	10.972	1.3688
10	20.519	0	Infinity	14.518	1.3122
5	18.71	0	Infinity	17.026	1.2721
0	14.974	0	Infinity	23.08	1.1753

LC50:LC5= 1.619

Notes: Not core data. Poor model fit at tail.

Tan and Wang 2011	
Species: *Daphnia magna* (7 d old)	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Cd-Acute-26	
Test: Ca 19, pH 7.0	
Cd, µg/L	**%Survival**
1	100
10	100
20	100
45	60
90	20
200	5



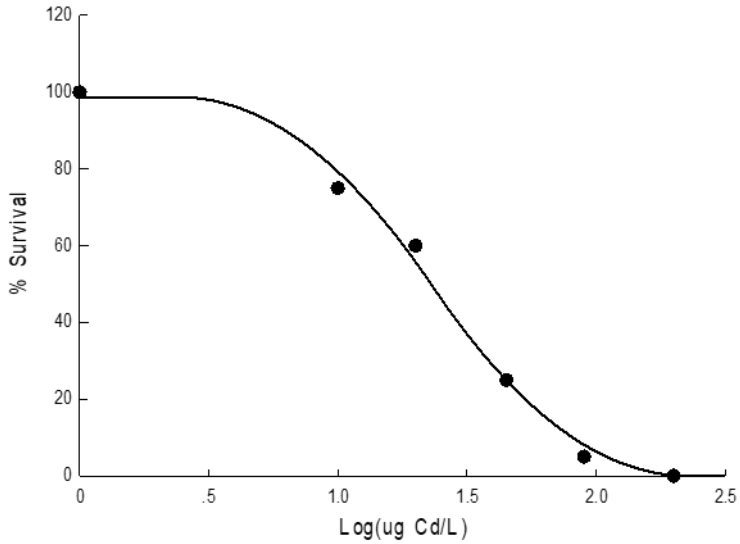
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.75	1.7243	2.23E-02	1.65E+00	1.7952
S	1.7	1.7004	0.20544	1.0466	2.3542
Y0	100	100.96	2.4792	93.073	108.85

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	53.005	45.020	62.407	0.022	1.724
20	32.223	24.512	42.359	0.037	1.508
10	25.074	17.824	35.274	0.047	1.399
5	20.999	14.512	30.386	0.050	1.322
0	13.684	9.094	20.593	0.056	1.136

LC50:LC5 = 2.524

Notes: Not core data.

Tan and Wang 2011	
Species: *Daphnia magna* (7 d old)	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Cd-Acute-27	
Test: Ca 19, pH 8.2	
Cd, µg/L	**%Survival**
1	100
10	75
20	60
45	25
90	5
200	0



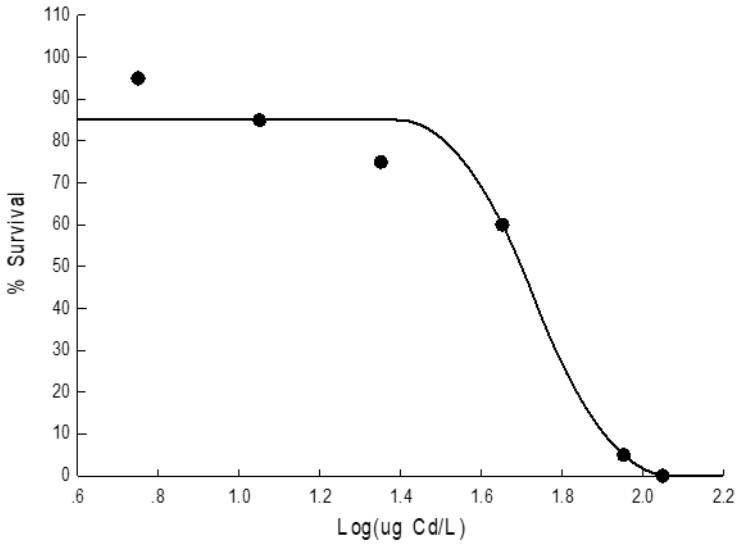
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.35	1.368	3.87E-02	1.24E+00	1.491
S	1	1.0142	0.11118	0.66043	1.3681
Y0	100	98.681	3.9012	86.266	111.1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	23.332	17.575	30.976	0.039	1.368
20	10.129	6.270	16.363	0.065	1.006
10	6.652	3.554	12.450	0.086	0.823
5	4.941	2.451	9.961	0.096	0.694
0	2.410	1.114	5.214	0.105	0.382

LC50:LC5 = 4.722

Notes: Not core data. No effect within area of concern.

Shaw et al. 2006	
Species: *Daphnia pulex* (<24 h old)	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Cd-Acute-28	
Test: Single	
Cd, µg/L	**%Survival**
5.6205	95
11.241	85
22.482	75
44.964	60
89.928	5
112.41	0

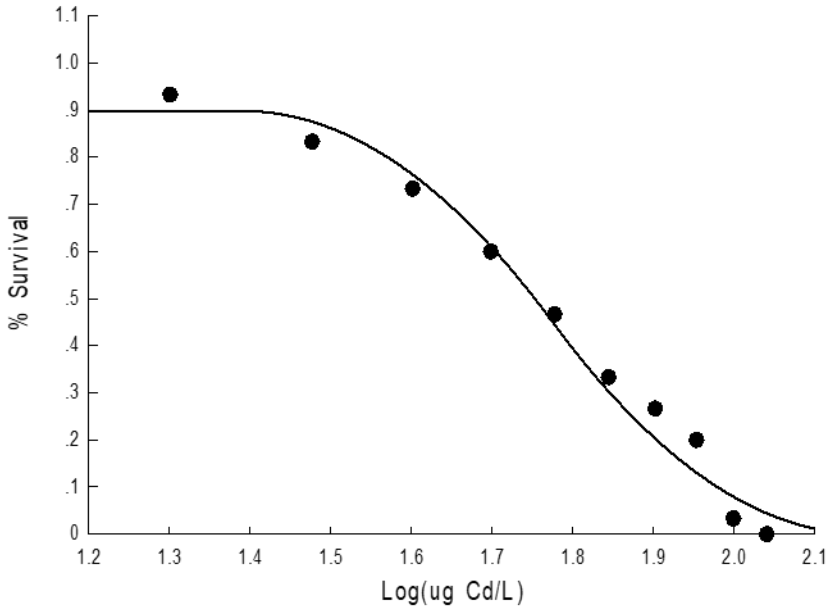


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.7	1.7316	0.041918	1.5982	1.865
S	3	2.96	1.0103	-0.25542	6.1753
Y0	95	85	4.7142	69.997	100
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	53.903	39.647	73.284	0.041918	1.7316
20	40.498	26.872	61.034	0.055973	1.6074
10	35.064	20.08	61.228	0.076072	1.5449
5	31.667	17.558	57.112	0.08048	1.5006
0	24.761	13.171	46.548	0.086139	1.3938

LC50:LC5 = 1.702

Notes: Poor model fit.

Sowdeswari et al. 2012	
Species: *Macrobrachium rosenbergii* (post-larvae)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-29	
Test: Single	
Cd, µg/L	**%Survival**
20	93.4
30	83.4
40	73.4
50	60
60	47
70	33.4
80	27.7
90	20
100	4



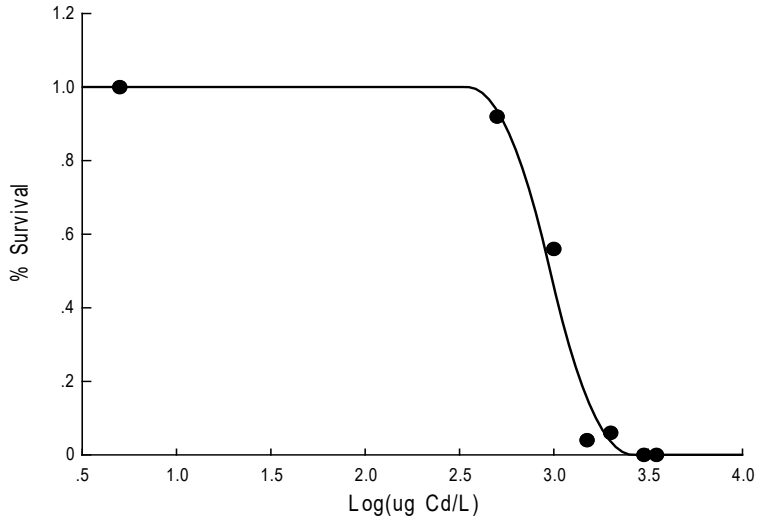
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.75	1.7762	2.54E-02	1.7249	1.8275
StDev	0.15	0.15749	2.24E-02	0.12332	0.21799
Y0	0.93333	0.89823	4.77E-02	0.76162	0.971

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	59.73	53.077	67.218	0.02535	1.7762
20	43.093	35.328	52.566	0.041774	1.6344
10	36.555	28.397	47.057	0.051693	1.5629
5	32.54	23.856	44.386	0.061921	1.5124
0	24.571	16.042	37.635	0.077772	1.3904

LC50:LC5 = 1.836

Notes: No core data.

Naqvi and Howell 1993	
Species: *Procambarus clarkia* (juvenile)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-31	
Test: Single	
Cd, µg/L	**Proportion Surviving**
5	1.00
500	0.92
1000	0.56
1500	0.04
2000	0.06
3000	0.00

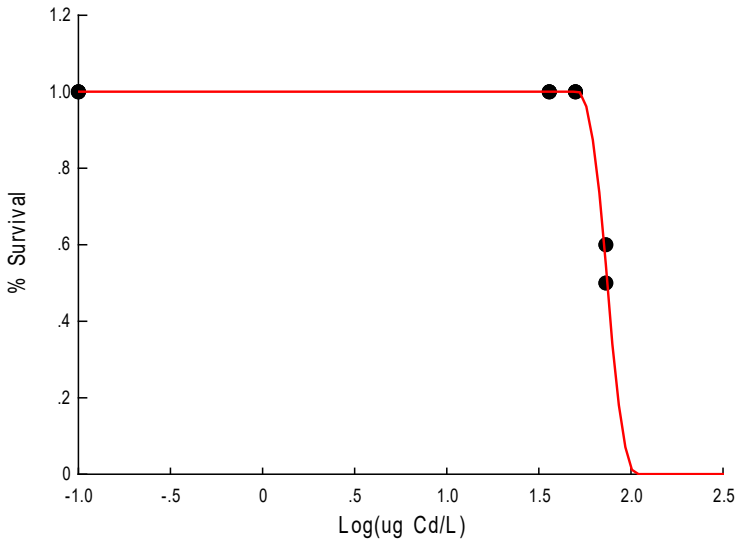


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.9646	2.9807	0.0201	2.9407	3.0207
StDev	0.20942	0.17871	0.016714	0.15112	0.21873
Y0	1	0.9999	0.0014172	0.92869	1
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	956.57	872.39	1048.9	0.0201	2.9807
20	660.43	578.31	754.2	0.028718	2.8198
10	547.94	465.21	645.39	0.035012	2.7387
5	480.17	397.72	579.72	0.03987	2.6814
0	349.12	271.12	449.55	0.05162	2.543

LC50:LC5 = 1.992

Notes: No core data.

Mebane et al. 2012	
Species: *Baetis tricaudatus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-32	
Test: #4	
Cd, µg/L (dissolved)	**%Survival**
0.1	100
0.1	100
36	100
36	100
50	100
50	100
73	50
73	60

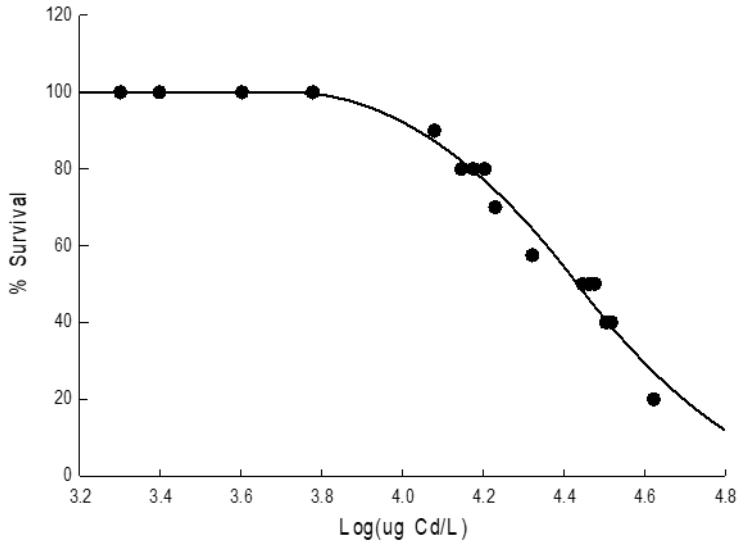


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.8723	1.8714			
StDev	0.080147	0.064299			
Y0	1	0.9999			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	74.372				1.8714
20	65.091				1.8135
10	60.862				1.7843
5	58.038				1.7637
0	51.75				1.7139

LC50:LC5 = 1.281

Notes: TRAP Flagged for IP (No Unique Solution).

Clubb et al. 1975	
Species: *Drunella grandis*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-33	
Test: Single	
Cd, µg/L (dissolved)	**%Survival**
2000	100
2500	100
4000	100
6000	100
12000	90
14000	80
15000	80
16000	80
17000	70
21000	57.5
28000	50
29000	50
30000	50
32000	40
33000	40
42000	20



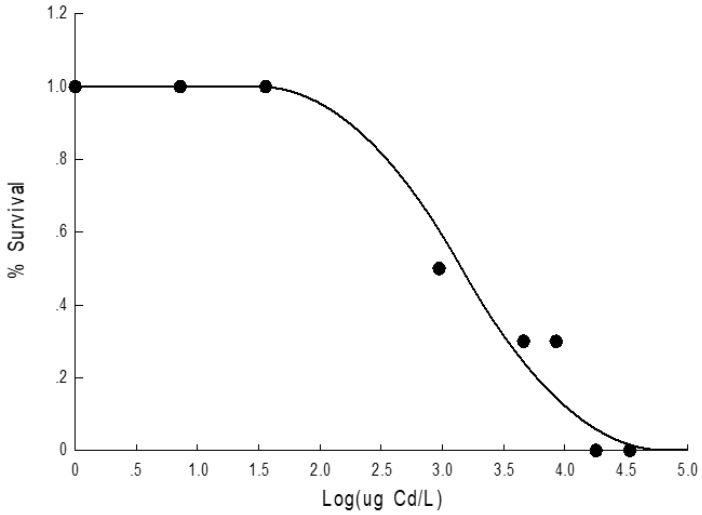
LC50:LC5 = 3.085

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.4	4.4342	1.34E-02	4.4052	4.4632
S	1.4	1.3976	0.10789	1.1645	1.6307
Y0	100	99.921	1.9925	95.616	104.23

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	27178	25421	29056	1.34E-02	4.4342
20	14833	13025	16893	2.61E-02	4.1712
10	10932	9111.6	13115	3.66E-02	4.0387
5	8809.8	7020.1	11056	4.57E-02	3.945
0	5232.3	3486.6	7852.2	8.16E-02	3.7187

Notes: No core data.

Leonhard et al. 1980	
Species: *Hexagenia rigida* (nymph)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-34	
Test: Single	
Cd, µg/L	**# Survival**
1	10
7.2	10
36	10
940	5
4600	3
8500	3
18000	0
34000	0

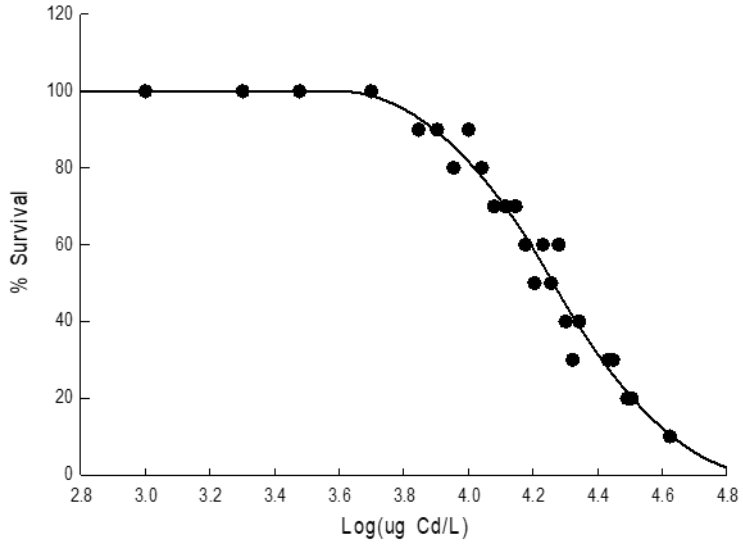


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3	3.1583	0.15126	2.843	3.4737
StDev	0.5	0.67992	0.1078	0.51985	0.98304
Y0	1	0.9999	2.22E-03	0.83385	1
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1439.9	696.67	2976.2	0.15126	3.1583
20	351.73	125.93	982.42	0.20841	2.5462
10	172.86	49.015	609.63	0.24713	2.2377
5	104.6	24.395	448.53	0.27608	2.0195
0	31.108	3.9272	246.42	0.34948	1.4929

LC50:LC5 = 13.77

Notes: No effect within area of concern.

Clubb et al. 1975	
Species: *Pteronarcella badia*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-36	
Test: Single	
Cd, µg/L	**% Survival**
1000	100
2000	100
3000	100
5000	100
7000	90
8000	90
9000	80
10000	90
11000	80
12000	70
13000	70
14000	70
15000	60
16000	50
17000	60
18000	50
19000	60
20000	40
21000	30
22000	40
27000	30
28000	30
31000	20
32000	20
42000	10



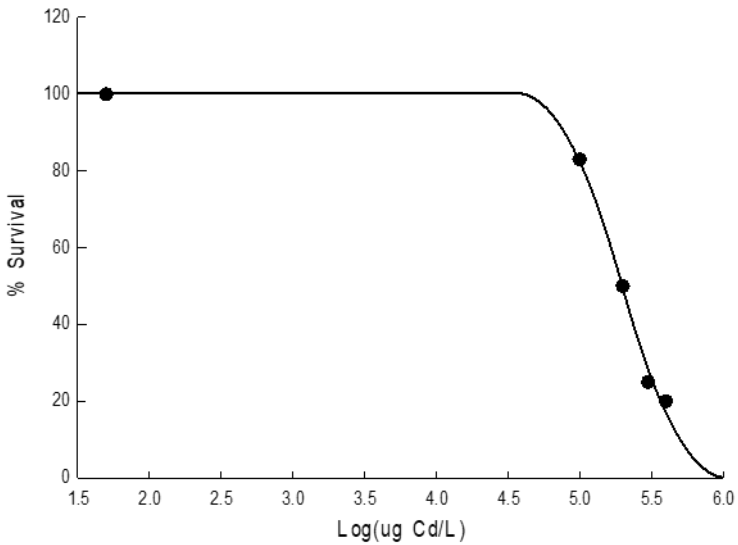
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.3	4.2626	1.48E-02	4.2318	4.2933
S	1.5	1.5019	0.11425	1.265	1.7388
Y0	100	99.97	2.6172	94.542	105.4

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	18306	17054	19649	1.48E-02	4.2626
20	10420	9095.2	11938	2.85E-02	4.0179
10	7843.9	6486.4	9485.5	3.98E-02	3.8945
5	6416.8	5046.1	8159.8	5.03E-02	3.8073
0	3951.6	2629.4	5938.6	8.53E-02	3.5968

LC50:LC5 = 2.853

Notes: Not core data.

Lee et al. 2006a	
Species: *Chironomus riparius* (3rd instar)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-37	
Test: Single	
Cd, µg/L	**% Survival**
50	100
100000	83
200000	50
300000	25
400000	20

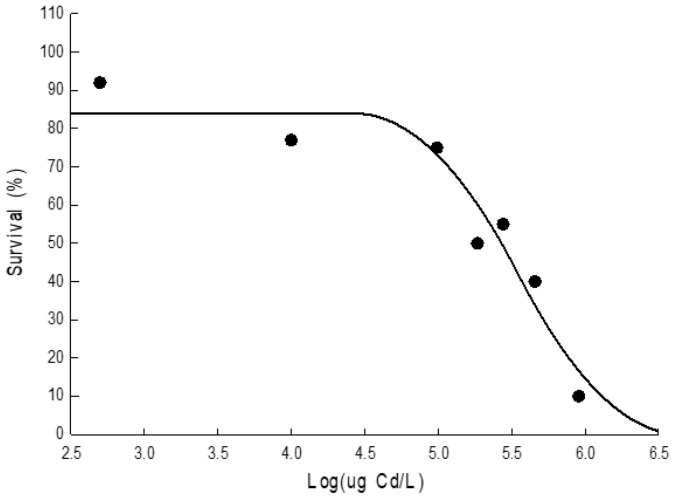


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	5.3	5.2966	0.02241	5.2002	5.3931
S	1.35	1.3695	0.13085	0.80651	1.9325
Y0	100	100.19	3.1867	86.48	113.9
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	197990	158570	247210	0.02241	5.2966
20	106720	70244	162150	0.042219	5.0283
10	78163	44336	137800	0.057231	4.893
5	62713	31091	126500	0.070821	4.7974
0	36851	9799	138580	0.1337	4.5664

LC50:LC5 = 3.157

Notes: Not core data.

Gillis and Wood 2008	
Species: *Chironomus riparius* (3rd-4th instar)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-38	
Test: Hardness = 10 mg/L	
Cd, µg/L	**% Survive**
500	92
10000	77
98000	75
185000	50
277000	55
456000	40
905000	10



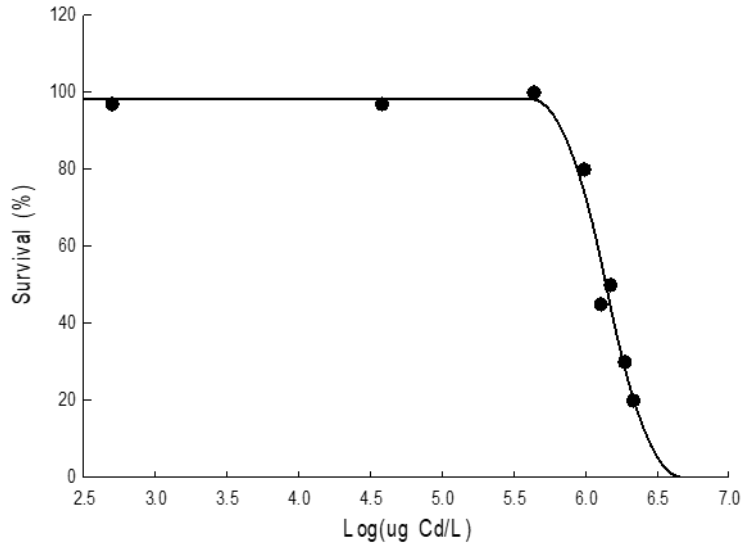
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	5.5	5.543	0.0914	5.2893	5.7968
S	0.85	0.89538	0.26239	0.16688	1.6239
Y0	84.5	83.951	6.3798	66.238	101.66

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	349170	194650	626320	0.0914	5.543
20	135690	48289	381280	0.16161	5.1325
10	84267	19571	362820	0.22836	4.9257
5	60168	9278.4	390170	0.29242	4.7794
0	26680	793.12	897510	0.54993	4.4262

LC50:LC5 = 5.803

Notes: Not core data. Unacceptable noise at low level effects.

Gillis and Wood 2008	
Species: *Chironomus riparius* (3rd-4th instar)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-39	
Test: Hardness = 140 mg/L	
Cd, µg/L	**% Survive**
500	97
38000	97
437000	100
979000	80
1279000	45
1495000	50
1879000	30



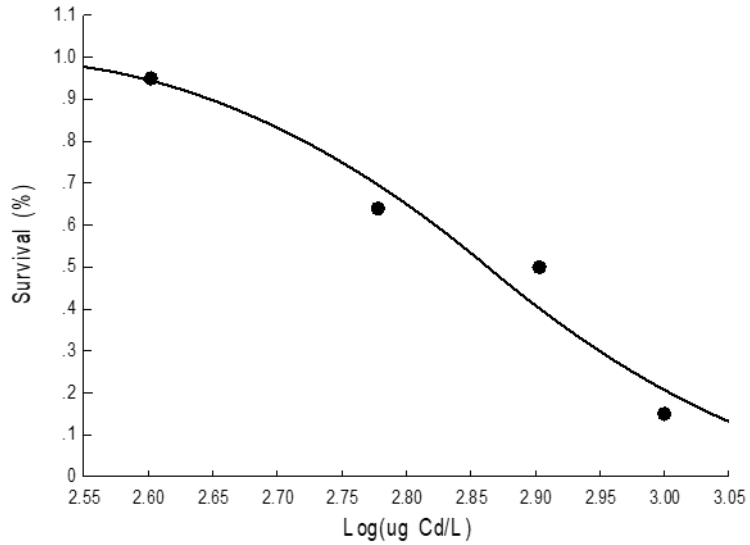
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	6	6.1476	0.023267	6.0878	6.2074
S	2	1.9067	0.35684	0.98942	2.824
Y0	98	98.286	3.7936	88.534	108.04

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1404700	1224000	1612100	0.023267	6.1476
20	901190	671190	1210000	0.049783	5.9548
10	720550	471230	1101800	0.071748	5.8577
5	615130	354960	1066000	0.092894	5.789
0	419870	129060	1366000	0.19931	5.6231

LC50:LC5 = 2.284

Notes: Not core data.

Pardue and Wood 1980	
Species: *Pectinatella magnifica* (ancenstrulae 2-3 d)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-40	
Test: Single	
Cd, µg/L	**Survival**
400	0.95
600	0.64
800	0.50
1000	0.15

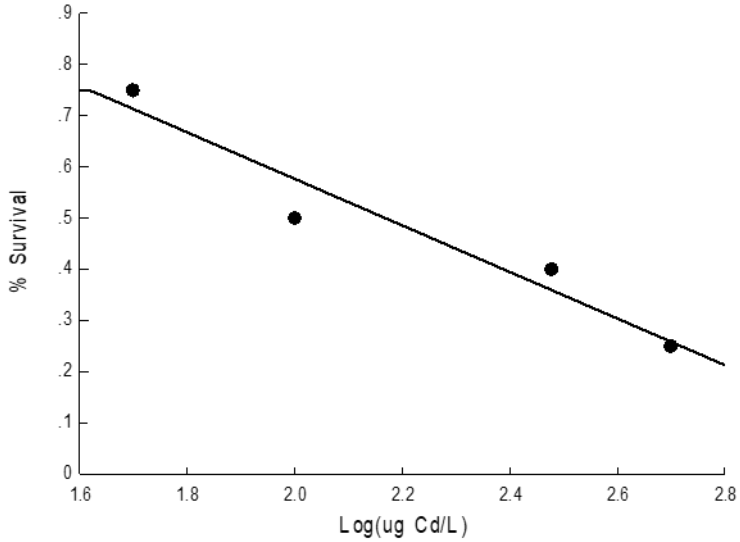


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3	2.8646	0.058164	2.735	2.9942
StDev	0.15	0.15581	0.072734	0.10887	0.27343
Y0	0.95	0.99268	0.17007	0.68005	1
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	732.09	543.21	986.64	0.058164	2.8646
20	530.02	276.7	1015.2	0.11977	2.7243
10	450.39	178.74	1134.9	0.1581	2.6536
5	401.42	122.41	1316.4	0.18864	2.6036
0	304.03	30.809	3000.1	0.27813	2.4829

LC50:LC5 = 1.824

Notes: No effect within area of concern.

Pardue and Wood 1980	
Species: *Lophopodella carteri* (ancenstrulae 2-3 d)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-41	
Test: Single	
Cd, µg/L	**Survival**
50	0.75
100	0.50
300	0.40
500	0.25

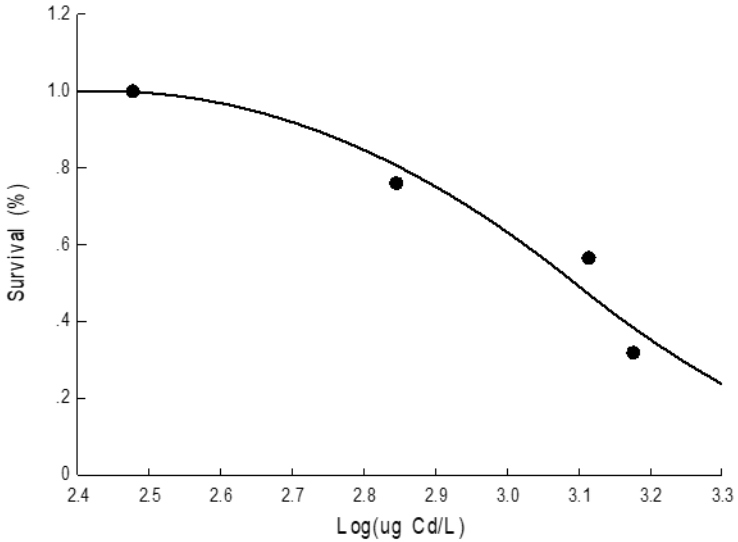


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.416	2.1586	1.4776	-1.1338	5.451
StDev	0.97068	0.80552	1.0785	0.56283	1.4136
Y0	0.75	0.9999	1.2223	0.69134	1
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	144.07	0.073484	282460	1.4776	2.1586
20	27.125	9.76E-06	75375000	2.7341	1.4334
10	11.691	3.18E-09	4.2935E+10	3.7676	1.0679
5	6.4478	1.01E-12	4.1207E+13	4.6833	0.80941
0	1.5327	9.42E-25	2.4933E+24	6.773	0.18546

LC50:LC5 = 22.34

Notes: No effect within area of concern.

Pardue and Wood 1980	
Species: *Plumatella emarginata* (ancenstrulae 2-3 d)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-42	
Test: Single	
Cd, µg/L	**Survival**
300	1.00
700	0.76
1300	0.57
1500	0.32



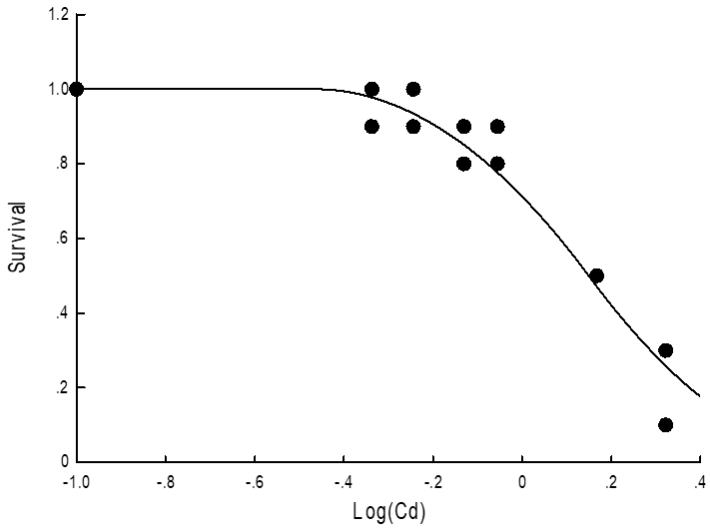
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3	3.0941	0.046809	2.9989	3.1893
StDev	0.3	0.26926	0.098725	0.18814	0.47254
Y0	1	0.9999	0.025305	0.69134	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1241.9	997.4	1546.4	0.046809	3.0941
20	710.68	435.34	1160.2	0.099327	2.8517
10	536.41	252.97	1137.4	0.14217	2.7295
5	439.65	163.05	1185.5	0.17508	2.6431
0	271.98	40.378	1832	0.26168	2.4345

LC50:LC5 = 2.825

Notes: No effect within area of concern.

Mebane et al. 2012	
Species: *Oncorhynchus clarkii lewisi*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-43	
Test: #20	
Cd, µg/L	**Survival**
0.10	1.00
0.10	1.00
0.57	1.00
0.57	0.90
0.46	0.90
0.46	1.00
0.74	0.80
0.74	0.90
0.88	0.90
0.88	0.80
1.47	0.50
1.47	0.50
2.10	0.10
2.10	0.30



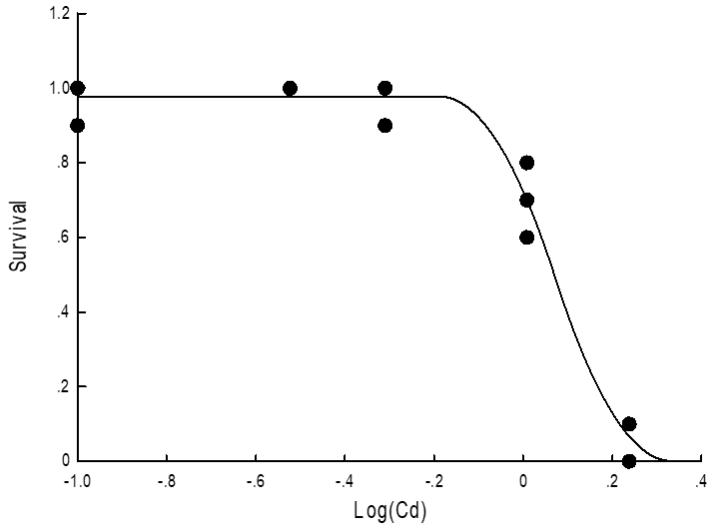
LC50:LC5 = 2.640

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.15	0.14903	0.042782	0.062147	0.23592
StDev	0.25	0.2517	0.039059	0.1934	0.36056
Y0	1	0.9999	0.002235	0.83149	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.4094	1.1538	1.7215	0.042782	0.14903
20	0.83642	0.70035	0.99894	0.037043	-0.07757
10	0.64301	0.51427	0.80398	0.045142	-0.19178
5	0.5339	0.40525	0.70338	0.053996	-0.27254
0	0.34079	0.21434	0.54184	0.081499	-0.46751

Notes: Not core data.

Mebane et al. 2012	
Species: *Oncorhynchus clarkii lewisi*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-44	
Test: #21	
Cd, µg/L	**Survival**
0.10	1.00
0.10	0.90
0.10	1.00
0.30	1.00
0.30	1.00
0.30	1.00
0.49	1.00
0.49	0.90
0.49	1.00
1.02	0.70
1.02	0.80
1.02	0.60
1.73	0.00
1.73	0.10
1.73	0.10



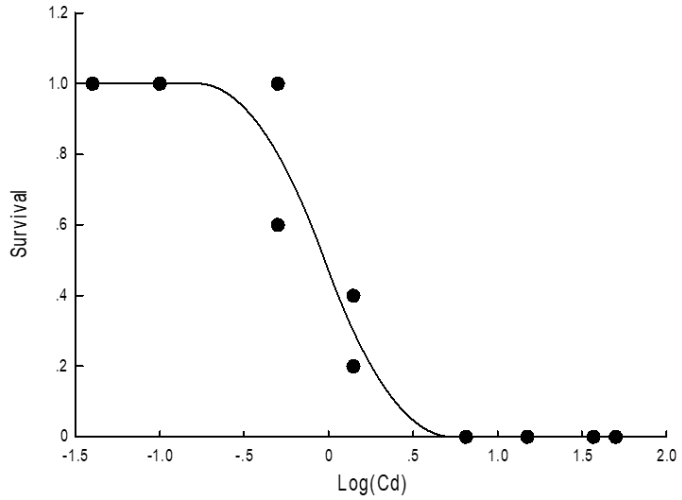
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.075	0.072996	0.023484	0.024112	0.12188
StDev	0.105	0.10679	0.020721	0.077638	0.17097
Y0	1	0.97778	0.015538	0.92202	0.9973

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.183	1.0571	1.324	0.023484	0.072996
20	0.9481	0.7986	1.1256	0.034407	-0.02315
10	0.84801	0.67962	1.0581	0.042132	-0.0716
5	0.78368	0.60039	1.0229	0.048159	-0.10586
0	0.64777	0.42653	0.98376	0.062878	-0.18858

LC50:LC5 = 1.510

Notes: Not core data.

Mebane et al. 2012	
Species: *Oncorhynchus clarkii lewisi*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-45	
Test: #23	
Cd, µg/L	**Survival**
0.04	1.00
0.04	1.00
0.5	1.00
0.5	0.60
1.4	0.40
1.4	0.20
6.5	0.00
6.5	0.00
15	0.00
15	0.00
37	0.00
37	0.00
50	0.00
50	0.00



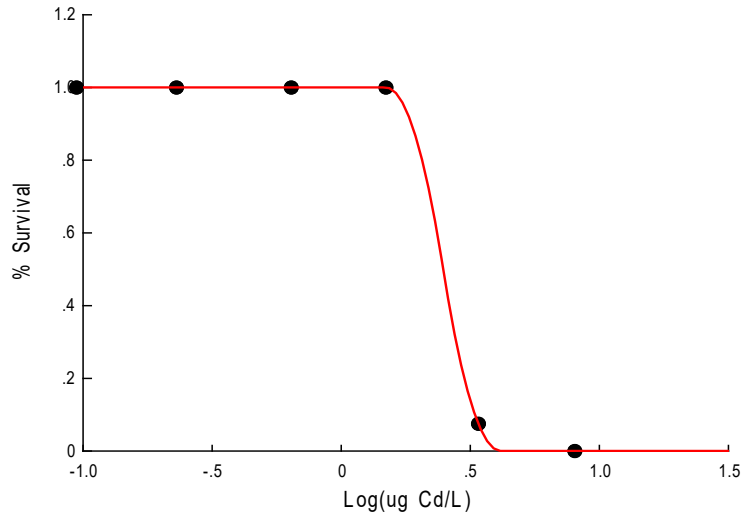
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.024	-0.023852	0.10458	-0.25688	0.20917
StDev	0.3	0.3078	0.14217	0.21506	0.54016
Y0	1	0.9999	0.002236	0.83138	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.94656	0.55351	1.6187	0.10458	-0.02385
20	0.50008	0.22058	1.1338	0.15083	-0.30096
10	0.36256	0.11018	1.193	0.20375	-0.44062
5	0.28882	0.061248	1.3619	0.24632	-0.53938
0	0.1668	0.0086686	3.2097	0.35926	-0.77779

LC50:LC5 = 3.277

Notes: Not core data.

Brinkman 2012	
Species:*Oncorhynchus clarkii virginalis* (fry, 0.26 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-46	
Test: Single	
Cd, µg/L	**%Survival**
0.05	100
0.23	100
0.64	100
1.49	100
3.4	7.5
8.03	0

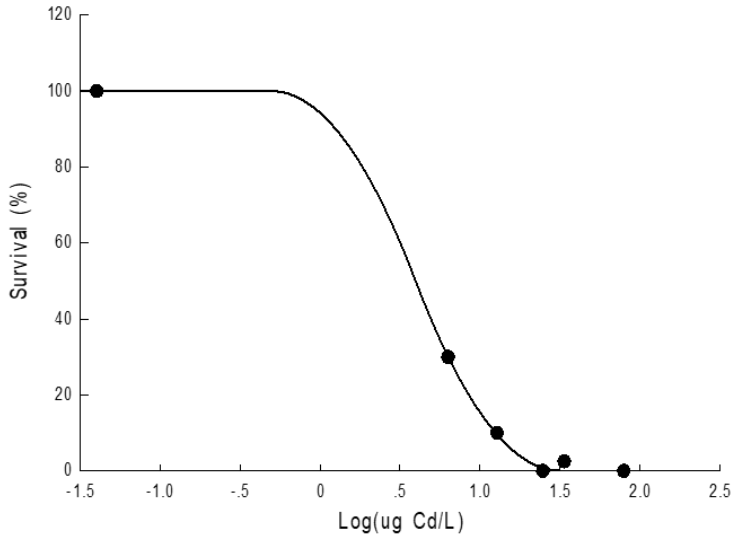


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.4	0.39534			
S	9.00E-02	9.07E-02			
Y0	1	0.9999			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**2.4851**				0.39534
20	2.0592				0.31371
10	1.8731				0.27256
5	**1.7517**				0.24347
0	1.4902				0.17323

LC50:LC5 = 1.419

Notes: TRAP Flagged for IP (No Unique Solution).

Davies et al. 1993	
Species: *Oncorhynchus mykiss* (36 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-50	
Test: Acute 1 – 200 mg/L hardness	
Cd, (µg/L)	**%Survival**
0.04	100
6.33	30
12.8	10
24.8	0
33.8	2.5
79.6	0

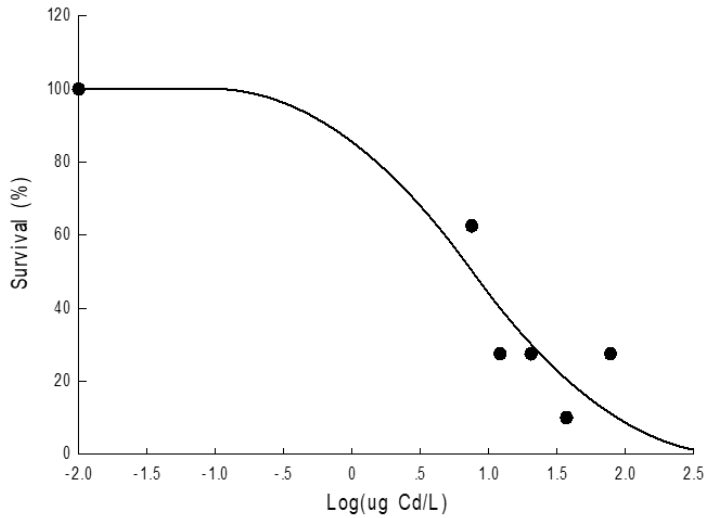


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.64996	0.59852	0.034248	0.48953	0.70751
S	1.2815	1.1042	0.11539	0.73694	1.4714
Y0	100	100	1.5226	95.154	104.85
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	3.9675	3.087	5.0993	0.034248	0.59852
20	1.8435	0.94376	3.6011	0.091372	0.26565
10	1.2528	0.47853	3.2799	0.13134	0.097882
5	0.95335	0.38834	2.3404	0.12256	-0.02075
0	0.49301	0.10909	2.228	0.20583	-0.30714

LC50:LC5 = 4.162

Notes: No effect within area of concern.

Davies et al. 1993	
Species: *Oncorhynchus mykiss* (36 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-51	
Test: Acute 1 – 400 mg/L hardness	
Cd, (µg/L)	**%Survival**
0.01	100
7.56	62.5
12.2	27.5
20.6	27.5
37.4	10
78.6	27.5



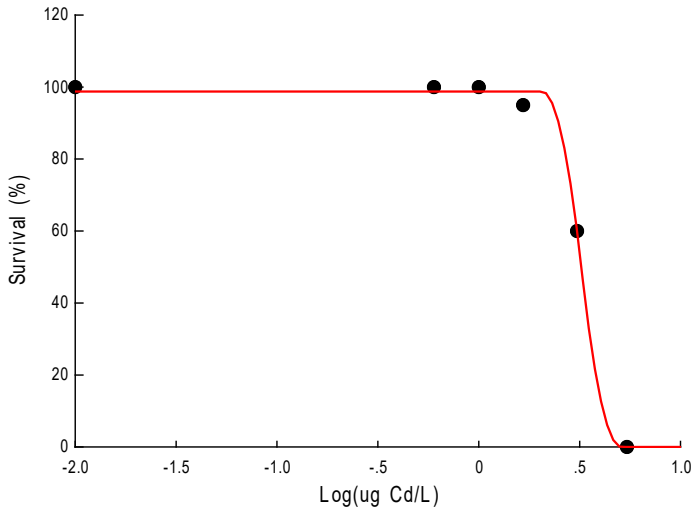
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.95406	0.88398	0.2764	0.004223	1.7637
S	0.87533	0.52249	0.2868	-0.39024	1.4352
Y0	100	100.03	15.165	51.772	148.3

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	7.6556	1.0098	58.041	0.27644	0.88398
20	1.5154	0.01166	196.95	0.66421	0.18052
10	0.66986	0.000398	1128.1	1.0138	-0.17402
5	0.37609	1.02E-05	13830	1.4346	-0.42471
0	0.093336			3.7468	-1.03

LC50:LC5 = 20.36

Notes: Not core data. Large SE for slope (S). No effect within area of concern.

Davies et al. 1993	
Species: *Oncorhynchus mykiss* (36 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-52	
Test: Acute 2 – 50 mg/L hardness	
Cd, (µg/L)	**%Survival**
0.01	100
0.60	100
1.00	100
1.66	95
3.07	60
5.42	0



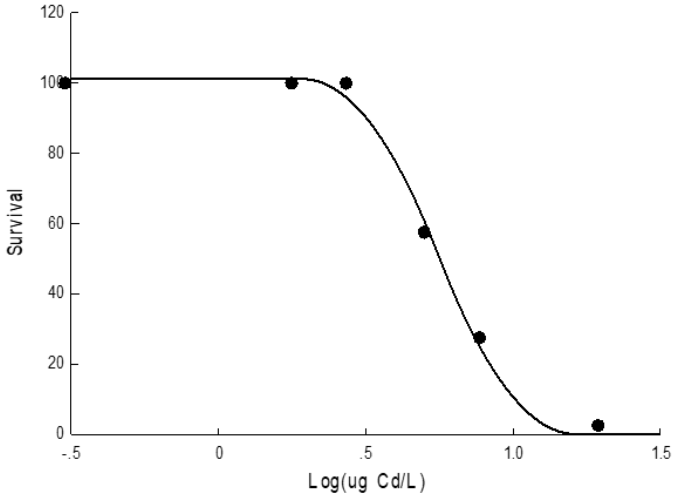
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.5	0.50947			
S	4	5.1094			
Y0	98.75	98.75			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	3.232				0.50947
20	2.7386				0.43754
10	2.5193				0.40128
5	2.3749				0.37564
0	2.0595				0.31375

LC50:LC5 = 1.361

Notes: TRAP Flagged for IP (No Unique Solution).

Davies et al. 1993	
Species: *Oncorhynchus mykiss* (36 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-54	
Test: Acute 2 – 400 mg/L hardness	
Cd, (µg/L)	**%Survival**
0.2	100
1.77	100
2.71	100
4.99	57.5
7.7	27.5
19.4	2.5

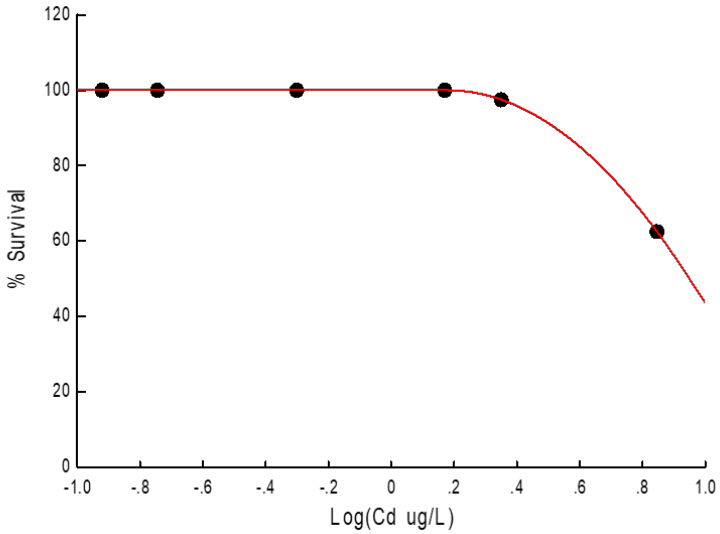


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.75	0.74834	1.71E-02	0.69398	0.80271
S	2.15	2.1566	0.28046	1.2641	3.0492
Y0	100	101.17	2.5925	92.923	109.42
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	5.602	4.9429	6.349	1.71E-02	0.74834
20	3.7837	3.0214	4.7384	3.07E-02	0.57792
10	3.1047	2.272	4.2426	4.26E-02	0.49202
5	2.6995	1.8205	4.003	5.38E-02	0.43129
0	1.926	0.94721	3.9162	9.68E-02	0.28466

LC50:LC5 = 2.075

Notes: Not core data.

Davies and Brinkman 1994b	
Species: *Oncorhynchus mykiss* (fry, 2.5 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-56	
Test: Acute 1 – aged hard (258 mg/L hardness)	
Cd, (µg/L)	**%Survival**
0.12	100
0.18	100
0.5	100
1.48	100
2.24	97.5
7.02	62.5

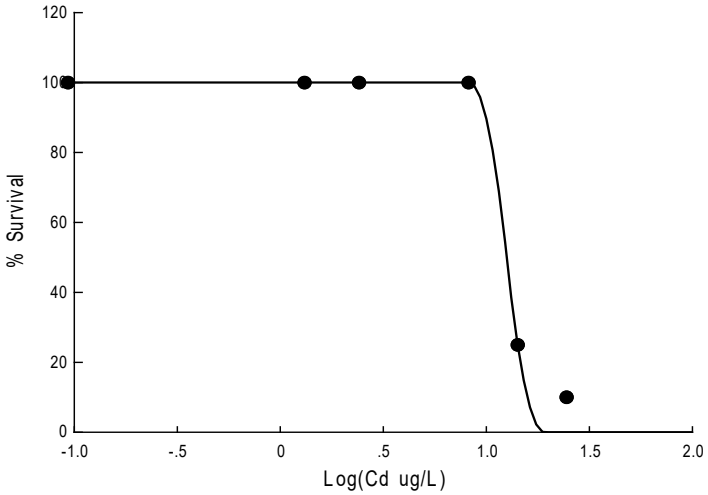


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.95	0.9498	0	0.9498	0.9498
S	1.3	1.295	0	1.295	1.295
Y0	99.5	100	0	100	100
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	8.9083	8.9083	8.9083	0	0.9498
20	4.6341	4.6341	4.6341	0	0.66597
10	3.3337	3.3337	3.3337	0	0.52292
5	2.641	2.641	2.641	0	0.42177
0	1.5051	1.5051	1.5051	0	0.17757

LC50:LC5 = 3.373

Notes: TRAP Flagged for IP (No Unique Solution).

Davies and Brinkman 1994b	
Species: *Oncorhynchus mykiss* (fry, 2.5 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-57	
Test: Acute 1 - unaged hard (281 mg/L hardness)	
Cd, (µg/L)	**%Survival**
0.08	100
1.31	100
2.41	100
8.2	100
14.2	25
24.5	10

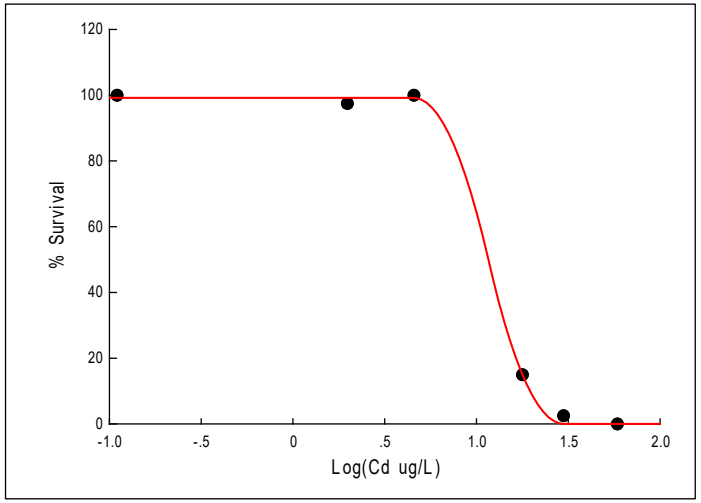


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.1	1.099			
S	5.4	5.4998			
Y0	100	100			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	12.561				1.099
20	10.77				1.0322
10	9.9661				0.99852
5	9.4342				0.97471
0	8.2644				0.91721

LC50:LC5 = 1.331

Notes: Poor model fit at low level effects (other, more certain, *O. mykiss* ratios available).

Davies and Brinkman 1994b	
Species: *Oncorhynchus mykiss* (fry, 2.5 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-59	
Test: Acute 2 - aged hard (276 mg/L hardness)	
Cd, (µg/L)	**%Survival**
0.11	100
1.98	97.5
4.56	100
17.8	15
29.8	2.5
58.6	0



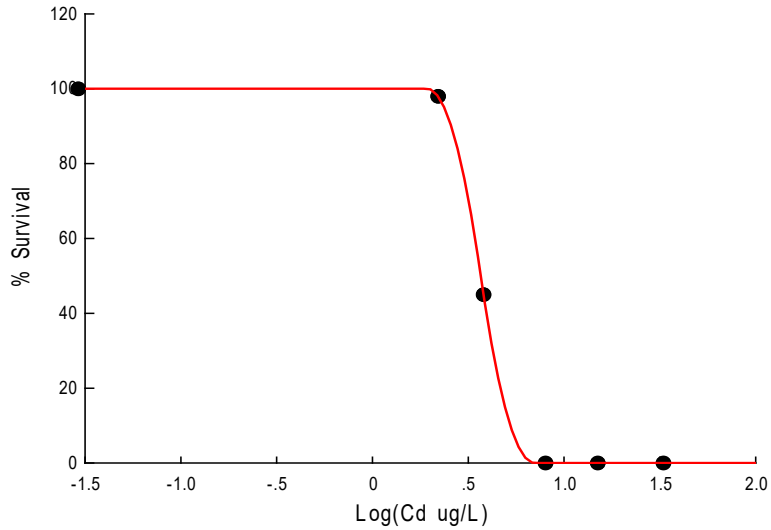
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.07	1.0665	0.71961	-1.2236	3.3566
S	2.45	2.4445	9.5526	-27.956	32.845
Y0	100	99.166	1.2859	95.074	103.26

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	11.655	0.059755	2273.1	0.71961	1.0665
20	8.2442	3.3466	20.309	0.12303	0.91615
10	6.9242	3.4934	13.724	0.093361	0.84037
5	6.1205	2.7367	13.688	0.10984	0.78678
0	4.5438	0.017702	1166.3	0.75709	0.65742

LC50:LC5 = 1.904

Notes: TRAP Flagged for IP (No Unique Solution).

Besser et al. 2007	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-67	
Test: Acute 2 (swim up fry)	
Cd, (µg/L)	**%Survival**
0.02	100
2.2	98
3.8	45
8	0
15	0
33	0



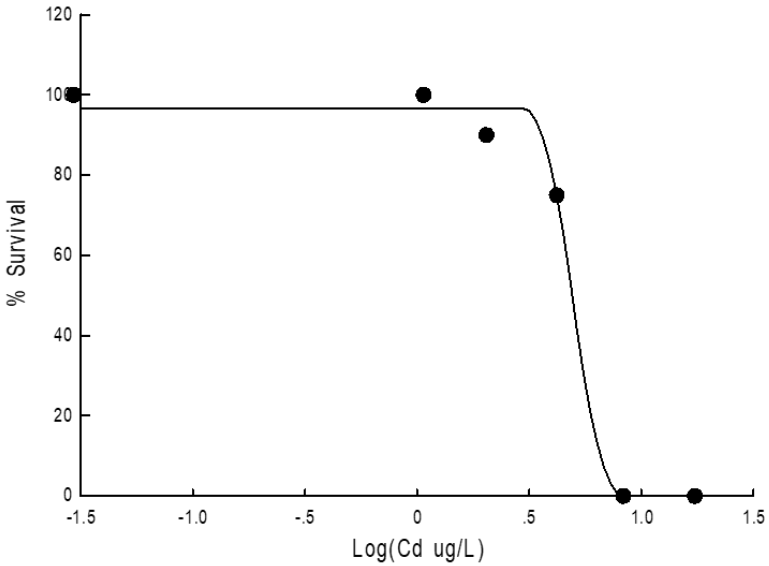
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.565	0.56548	0	0.56548	0.56548
S	3.6	3.5866	0	3.5866	3.5866
Y0	100	100	0	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	3.6768	3.6768	3.6768	0	0.56548
20	2.904	2.904	2.904	0	0.463
10	2.5784	2.5784	2.5784	0	0.41135
5	2.3704	2.3704	2.3704	0	0.37483
0	1.9349	1.9349	1.9349	0	0.28666

LC50:LC5 = 1.551

Notes: TRAP Flagged for IP (No Unique Solution).

Bresser et al 2007	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-68	
Test: Acute 4 (juvenile)	
Cd, (µg/L)	**%Survival**
0.02	100
1.07	100
2.04	90
4.2	75
8.32	0
17.35	0

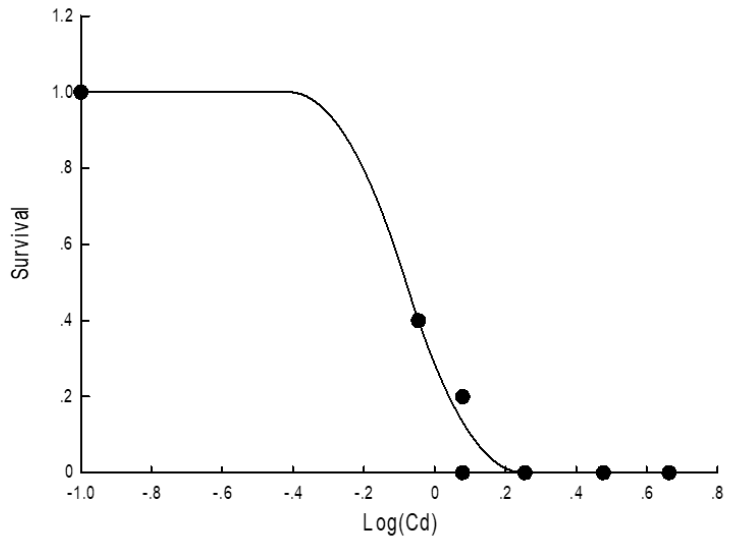


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.697	0.69701	7.6449	-23.632	25.026
S	4.48	4.4804	464.38	-1473.4	1482.3
Y0	97	96.667	2.7217	88.005	105.33
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	4.9775	2.33E-24	1.06E+25	7.6449	0.69701
20	4.1207	3.5969	4.7208	1.86E-02	0.61497
10	3.7465	3.1758	4.4198	2.26E-02	0.57363
5	3.5026	2.9259	4.1931	2.46E-02	0.54439
0	2.9772	2.4119	3.6751	2.87E-02	0.47381

LC50:LC5 = 1.421

Notes: Large SE for X50 and slope (S). Poor model fit.

Mebane et al. 2012	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-69	
Test: Test 8, LNF water	
Cd, (µg/L)	**Survival**
0.1	1.00
0.1	1.00
0.1	1.00
0.9	0.40
0.9	0.40
0.9	0.40
1.2	0.00
1.2	0.20
1.2	0.20
1.8	0.00
1.8	0.00
1.8	0.00
3	0.00
3	0.00
3	0.00
4.6	0.00
4.6	0.00
4.6	0.00



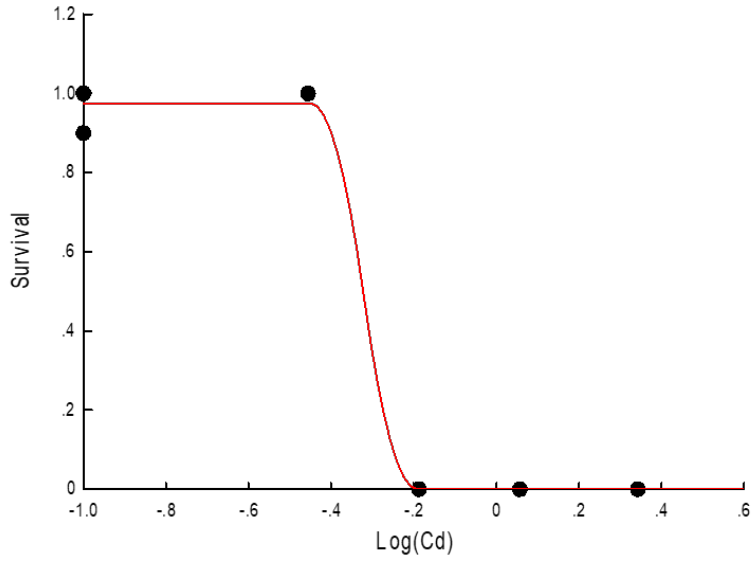
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.0806	-0.080646	0.043707	-0.17803	0.016741
StDev	0.135	0.13488	0.055789	0.094245	0.23671
Y0	1	0.9999	0.0018257	0.88411	1

LC50:LC5 = 1.682

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.83053	0.66369	1.0393	0.043707	-0.080646
20	0.62794	0.37589	1.049	0.094558	-0.20208
10	0.5454	0.26185	1.136	0.12552	-0.26328
5	0.49367	0.19349	1.2595	0.14877	-0.30656
0	0.38811	0.07057	2.1345	0.20711	-0.41104

Notes: Not core data. No effect within area of concern.

Mebane et al. 2012	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-70	
Test: Test 9, LNF water	
Cd, (µg/L)	**Survival**
0.1	1.00
0.1	0.90
0.35	1.00
0.35	1.00
0.65	0.00
0.65	0.00
1.14	0.00
1.14	0.00
2.20	0.00
2.20	0.00

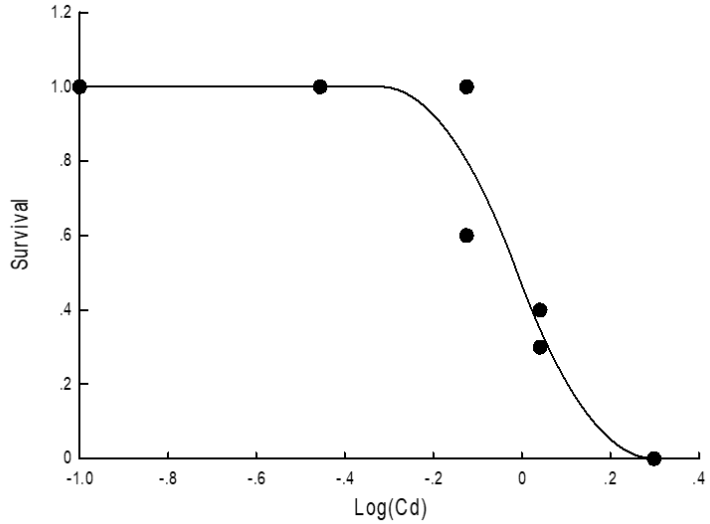


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.32	-0.32091			
StDev	0.055	0.052798			
Y0	0.975	0.975			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.47763				-0.32091
20	0.42811				-0.36845
10	0.40513				-0.3924
5	0.38963				-0.40934
0	0.35462				-0.45024

LC50:LC5 = 1.266

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Mebane et al. 2012	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-71	
Test: Test 10, SF-km9 water	
Cd, (µg/L)	**Survival**
0.1	1.00
0.1	1.00
0.35	1.00
0.35	1.00
0.75	1.00
0.75	0.60
1.10	0.40
1.10	0.30
1.99	0.00
1.99	0.00

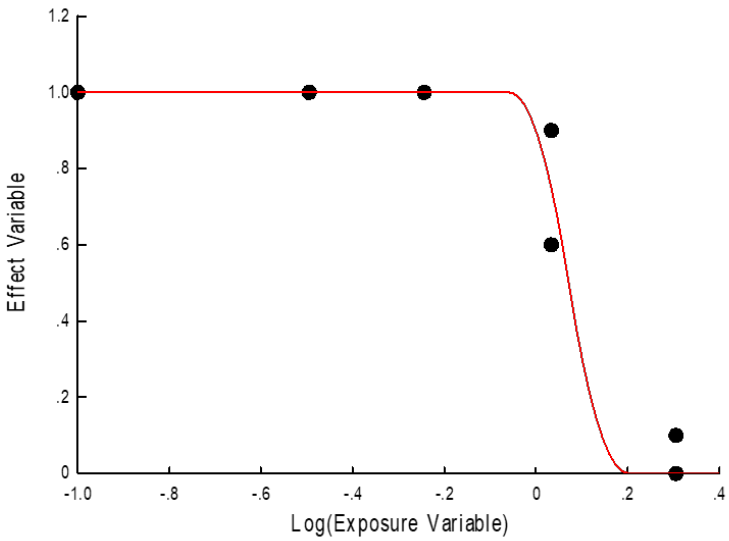


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.01	-0.01021	0.029512	-0.07211	0.051691
StDev	0.1275	0.12663	0.038821	0.088479	0.22223
Y0	1	0.9999	0.001581	0.91171	1
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.97676	0.84701	1.1264	0.029512	-0.01021
20	0.75125	0.61912	0.91157	0.037967	-0.12422
10	0.65815	0.51404	0.84266	0.045188	-0.18168
5	0.59937	0.44549	0.80641	0.050539	-0.22231
0	0.4782	0.29575	0.77319	0.063259	-0.32039

LC50:LC5 = 1.630

Notes: Not core data.

Mebane et al. 2012	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-72	
Test: Test 11, SF-km16 water	
Cd, (µg/L)	**Survival**
0.1	1.00
0.1	1.00
0.32	1.00
0.32	1.00
0.57	1.00
0.57	1.00
1.08	0.90
1.08	0.60
2.02	0.00
2.02	0.10

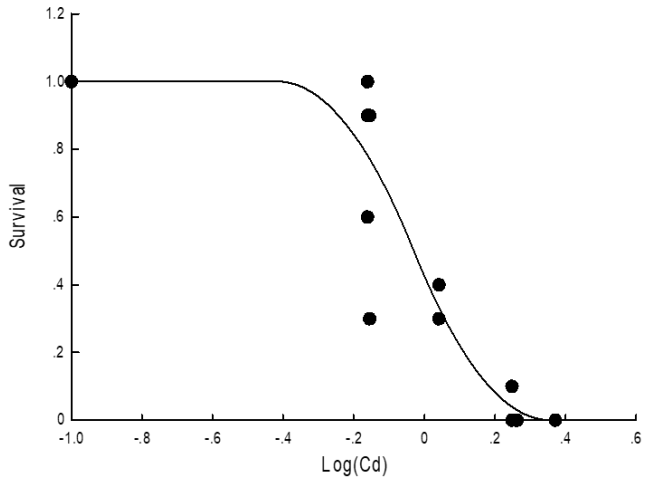


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.086403	0.071477			
StDev	0.025	0.053028			
Y0	1	0.9999			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.1789				0.071477
20	1.0562				0.023736
10	0.99925				-0.00032
5	0.96086				-0.01734
0	0.87415				-0.05841

LC50:LC5 = 1.227

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Mebane et al. 2012	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-73	
Test: Test 13, SFH-km8 water	
Cd, (µg/L)	**Survival**
0.1	1.00
0.10	1.00
0.10	1.00
0.69	1.00
0.69	0.60
0.69	0.90
0.70	0.30
0.70	0.90
0.70	0.90
1.10	0.40
1.10	0.30
1.10	0.40
1.77	0.10
1.77	0.10
1.77	0.00
1.83	0.00
1.83	0.00
1.83	0.00
2.35	0.00
2.35	0.00
2.35	0.00



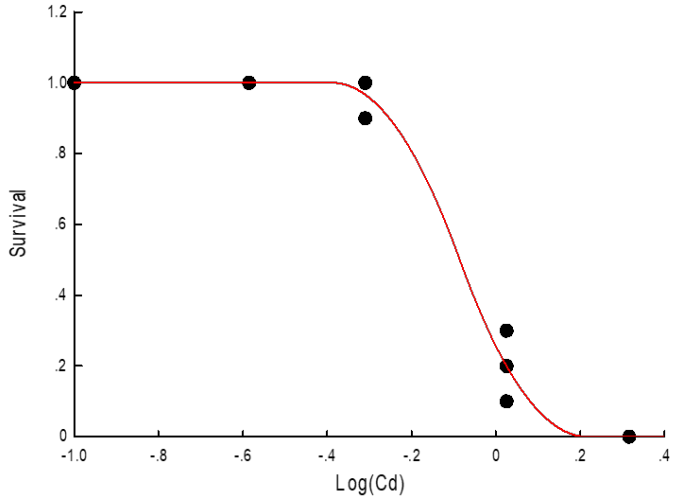
LC50:LC5 = 1.837

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-3.00E-02	-2.98E-02	2.12E-02	-7.23E-02	1.27E-02
StDev	1.60E-01	1.58E-01	1.77E-02	1.29E-01	0.20208
Y0	1	0.9999	1.83E-03	0.88411	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.93367	0.8466	1.0297	2.12E-02	-2.98E-02
20	0.67342	5.84E-01	0.77656	3.05E-02	-1.72E-01
10.0000	0.5712	0.4787	0.6815	0.0372	-0.2432
5.0000	0.5084	0.4145	0.6236	0.0423	-0.2938
0	3.84E-01	2.91E-01	5.06E-01	5.42E-02	-0.4159

Notes: Not core data. Unacceptable noise at low level effects.

Mebane et al. 2012	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-74	
Test: Test 14, SFH-km8 water	
Cd, (µg/L)	**Survival**
0.10	1.00
0.10	1.00
0.10	1.00
0.26	1.00
0.26	1.00
0.26	1.00
0.49	1.00
0.49	0.90
0.49	1.00
1.06	0.10
1.06	0.20
1.06	0.30
2.07	0.00
2.07	0.00
2.07	0.00



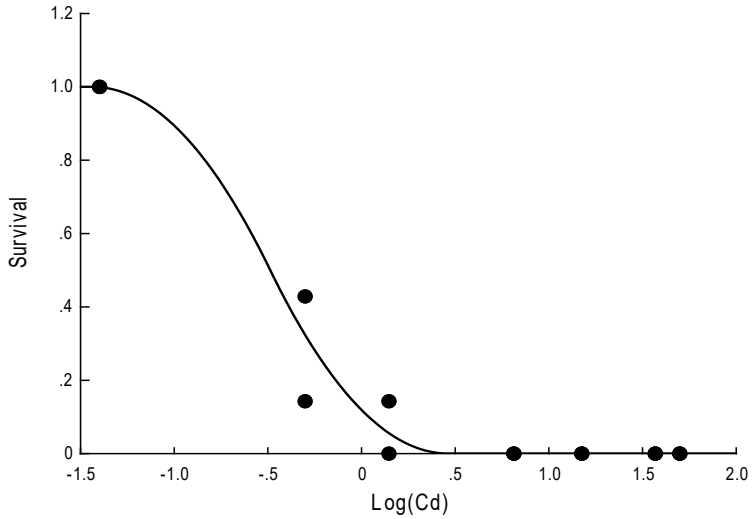
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-8.50E-02	-8.57E-02	2.66E-02	-1.41E-01	-3.05E-02
StDev	1.25E-01	1.23E-01	1.91E-02	9.48E-02	0.17642
Y0	1	0.9999	1.29E-03	0.94017	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.82091	0.72296	0.93212	2.66E-02	-8.57E-02
20	0.63579	5.54E-01	0.73015	2.82E-02	-1.97E-01
10.0000	0.5590	0.4742	0.6589	0.0325	-0.2526
5.0000	0.5103	0.4218	0.6174	0.0365	-0.2922
0	4.10E-01	3.09E-01	5.43E-01	4.83E-02	-0.38766

LC50:LC5 = 1.609

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Mebane et al. 2012	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-75	
Test: (Kootenai strain), Test 15, LNF water	
Cd, (µg/L)	**Survivors**
0.04	1.00
0.04	1.00
0.5	0.14
0.5	0.43
1.4	0.14
1.4	0.00
6.5	0.00
6.5	0.00
15	0.00
15	0.00
37	0.00
37	0.00
50	0.00
50	0.00



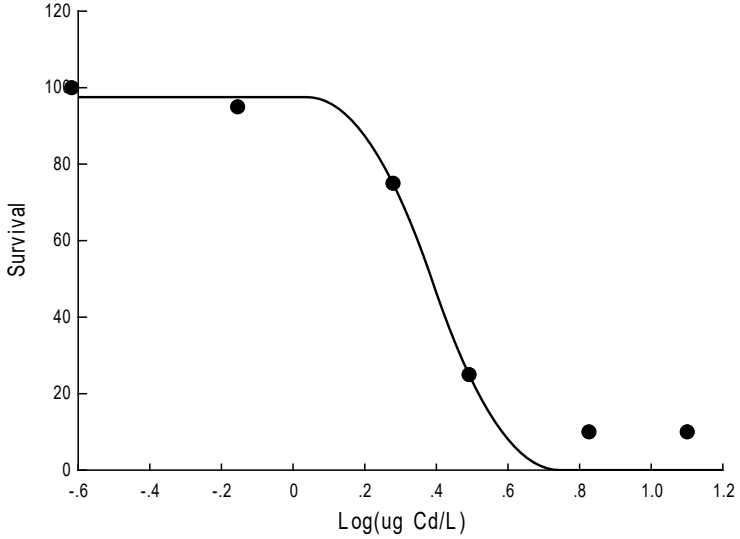
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-5.00E-01	-4.87E-01	2.34E-01	-1.01E+00	3.54E-02
StDev	3.90E-01	3.88E-01	2.04E-01	2.71E-01	0.6804
Y0	1	0.9999	3.07E-02	0.69134	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.32612	9.80E-02	1.085	2.34E-01	-4.87E-01
20	0.14599	1.49E-02	1.433	4.21E-01	-8.36E-01
10	0.0974	0.0044	2.1548	0.5298	-1.0116
5	0.0731	0.0014	3.9051	0.6318	-1.1360
0	3.66E-02	5.27E-05	2.54E+01	7.95E-01	-1.4363

LC50:LC5 = 4.460

Notes: Not core data. Large SE for steepness. No effect within area of concern.

Davies and Brinkman 1994c	
Species: *Salmo trutta* (fingerling)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-77	
Test: Single	
Cd, (µg/L)	**%Survival**
0.2	100
0.7	95
1.9	75
3.1	25
6.7	10
12.6	10



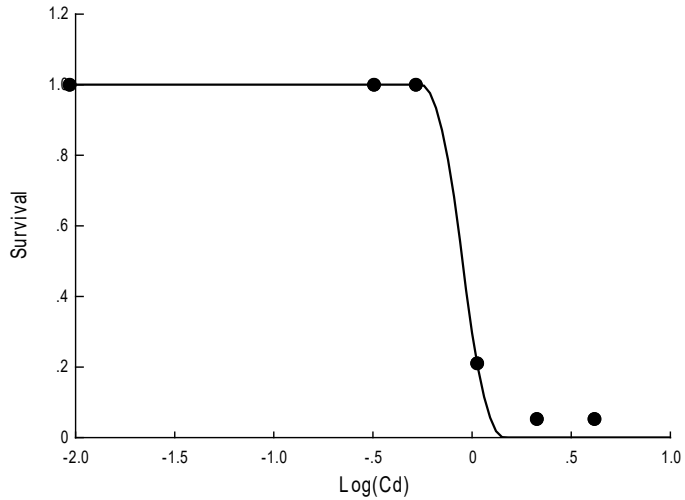
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.4	0.39152	3.44E-02	0.28192	0.50112
S	3	2.8433	0.85323	0.12798	5.5587
Y0	97.5	97.5	5.9512	78.561	116.44

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.4633	1.9139	3.1704	3.44E-02	0.39152
20	1.8292	1.225	2.7313	5.47E-02	0.26226
10	1.5744	0.92095	2.6914	7.32E-02	0.19711
5	1.4159	0.7233	2.7718	9.17E-02	0.15104
0	1.096	0.13786	8.7134	0.28292	3.98E-02

LC50:LC5 = 1.740

Notes: No effect within area of concern. No effect plateau is average of control and first treatment, but next partial is 25% effect.

Stratus Consulting 1999	
Species: *Salvelinus confluentus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-78	
Test: Bank 1- 32 mg/L hardness; 76.1 mg fish	
Cd, (µg/L)	**Proportion surviving**
0.0065	100
0.32	100
0.52	100
1.06	21
2.12	5
4.14	5

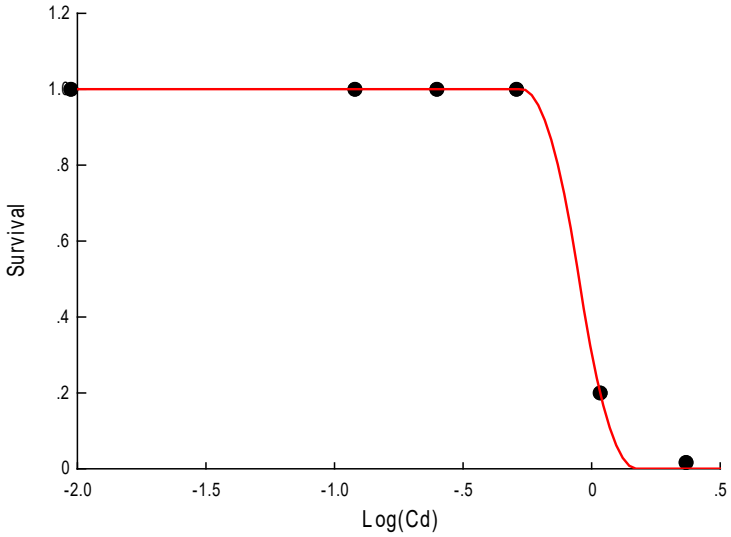


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.0055	-0.048305			
S	0.05	0.085567			
Y0	1	0.9999			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.89474				-0.048305
20	0.74931				-0.12534
10	0.68523				-0.16417
5	0.64325				-0.19162
0	0.5522				-0.2579

LC50:LC5 = 1.391

Notes: Poor model fit (at high level effects) with inadequate partials between 0% and 79% effect.

Stratus Consulting 1999	
Species: *Salvelinus confluentus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-81	
Test: Bank 3- 33.2 mg/L hardness; 218 mg fish	
Cd, (µg/L)	**Proportion surviving**
0.0065	100
0.12	100
0.25	100
0.51	100
1.08	20
2.33	2

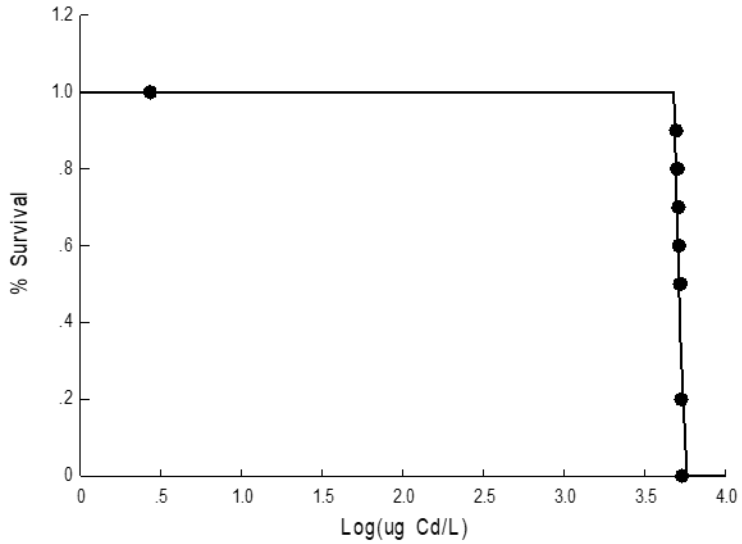


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.00311	-0.048589			
S	0.08	0.091071			
Y0	1	0.9999			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.89415				-0.048589
20	0.74032				-0.13058
10	0.67313				-0.1719
5	0.62933				-0.20112
0	0.53497				-0.27167

LC50:LC5 = 1.421

Notes: TRAP Flagged for IP (No Unique Solution).

Yorulmazlar and Gul 2003	
Species: *Ctenopharyngodon idellus* (18 mm, 17g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-84	
Test: Single	
Cd, (µg/L)	**Proportion surviving**
2.696071	100
4906.85	90
4960.771	80
5014.693	80
5068.614	70
5122.536	60
5176.457	50
5230.378	50
5284.3	20
5338.221	0



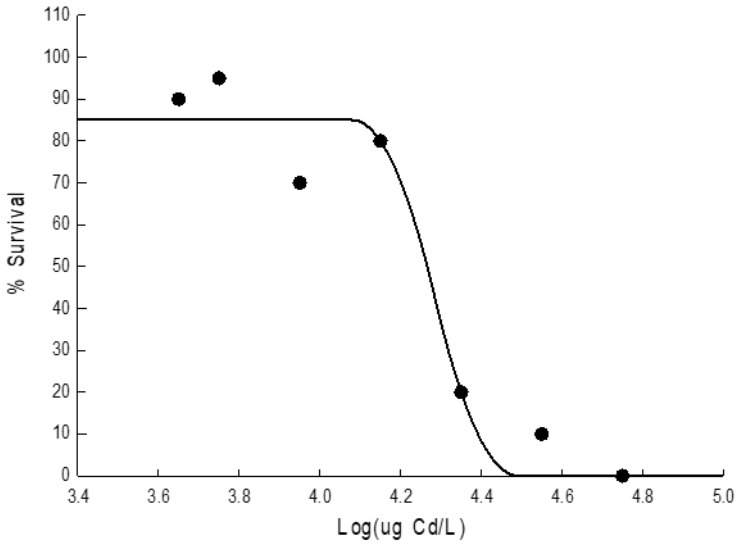
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.71	3.7118	0.002193	3.7074	3.7162
StDev	0.014	0.013909	0.00273	0.010081	0.02242
Y0	1	0.9999	0.003207	0.69138	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	5149.9	5097.7	5202.7	0.002193	3.7118
20	5003.6	4931.2	5077	0.003011	3.6993
10	4931.4	4832.1	5032.6	0.003986	3.693
5	4881	4757.5	5007.7	0.004773	3.6885
0	4761.4	4554.2	4977.9	0.00689	3.6777

LC50:LC5 = 1.055

Notes: Not core data. Curve slope based on arbitrary breakpoint.

Vergauwen 2012; Vergauwen et al. 2013	
Species: *Danio rerio*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-88	
Test: 30C	
Cd, (µg/L)	**%Survival**
4475.123	90
5633.846	95
8929.044	70
14151.58	80
22428.74	20
35547.16	10
56338.46	0



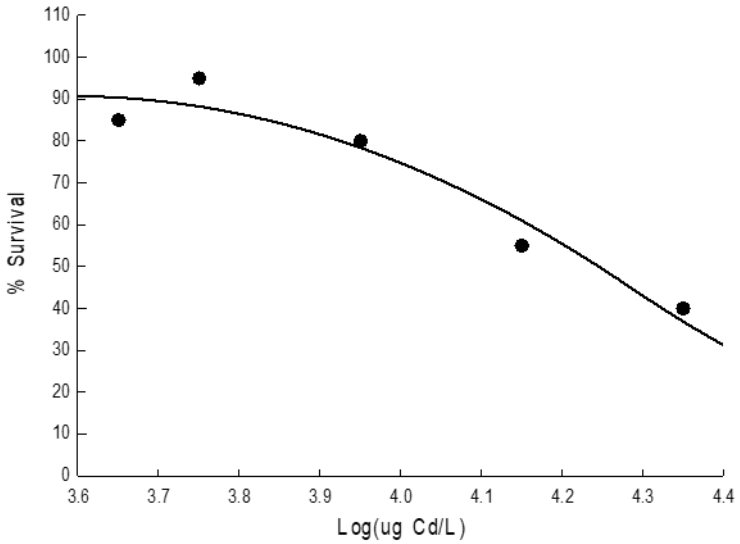
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.3	4.2861	0.038804	4.1784	4.3939
S	5	4.855	2.21	-1.2809	10.991
Y0	92.5	85	6.1237	67.998	102

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	19325	15080	24767	0.038804	4.2861
20	16234	10929	24114	0.061895	4.2104
10	14869	9115.7	24252	0.07653	4.1723
5	13973	7980.6	24465	0.087615	4.1453
0	12027	4710.5	30708	0.14662	4.0802

LC50:LC5 = 1.383

Notes: Unacceptable noise at low level effects.

Vergauwen 2012; Vergauwen et al. 2013	
Species: *Danio rerio*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-89	
Test: 36C	
Cd, (µg/L)	**%Survival**
4475.123	85
5633.846	95
8929.044	80
14151.58	55
22428.74	40



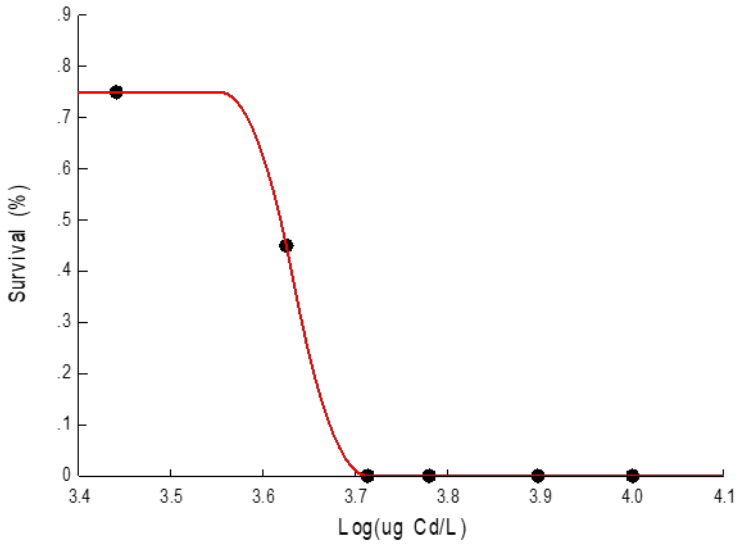
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.2727	4.2825	0.06314	4.0108	4.5541
S	1.7465	1.4415	0.60473	-1.1604	4.0435
Y0	90	90.698	9.3316	50.548	130.85

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	19163	10252	35821	0.06314	4.2825
20	10654	2697.4	42078	0.13865	4.0275
10	7925	1116.7	56242	0.1978	3.899
5	6428.8	545.21	75806	0.24905	3.8081
0	3879.4	52.614	286040	0.43407	3.5888

LC50:LC5 = 2.981

Notes: Unacceptable noise at low level effects.

Carrier 1987; Carrier and Beitinger 1988a	
Species: *Pimephales promelas* (0.8 – 2.0 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-90	
Test: Single	
Cd, (µg/L)	**Survival**
10	Not reported
2760	0.75
4220	0.45
5170	0.00
6030	0.00
7910	0.00
10020	0.00

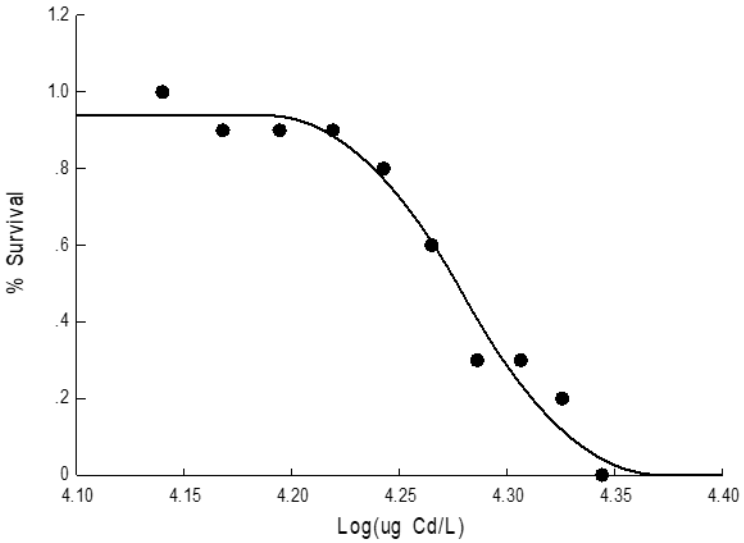


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.6336	3.6337			
StDev	0.036935	0.032561			
Y0	0.75	0.74995			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	4302.6				3.6337
20	4021.8				3.6044
10	3887.3				3.5896
5	3794.9				3.5792
0	3580.8				3.554

LC50:LC5 = 1.134

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Yilmaz et al. 2004	
Species: *Poecilia reticulata*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-91	
Test: Single	
Cd, (µg/L)	**# Survived**
13796.7761	100
14716.5612	90
15636.3463	90
16556.1314	90
17475.9164	80
18395.7015	60
19315.4866	30
20235.2717	30
21155.0567	20
22074.8418	0

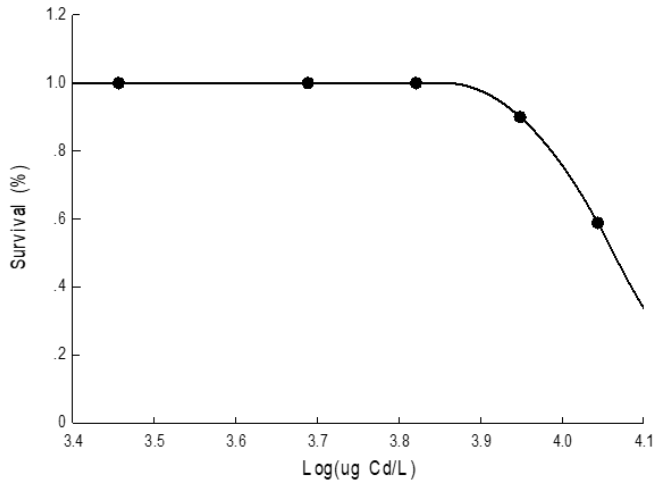


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.28	4.2796	0.008717	4.2613	4.2979
StDev	0.04	0.037314	0.008269	0.026141	0.065063
Y0	0.925	0.93808	0.04554	0.77821	0.99404
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	19037	18252	19856	0.008717	4.2796
20	17620	16445	18879	0.013556	4.246
10	16946	15458	18578	0.016841	4.2291
5	16486	14635	18570	0.020346	4.2171
0	15424	12722	18700	0.02558	4.1882

LC50:LC5 = 1.155

Notes: Not Core data.

Carrier 1987; Carrier and Beitinger 1988b	
Species: *Lepomis cyanellus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-92	
Test: Single	
Cd, (µg/L)	**Survival**
20	Not reported
2860	100
4880	100
6620	100
8880	90
11060	58.8

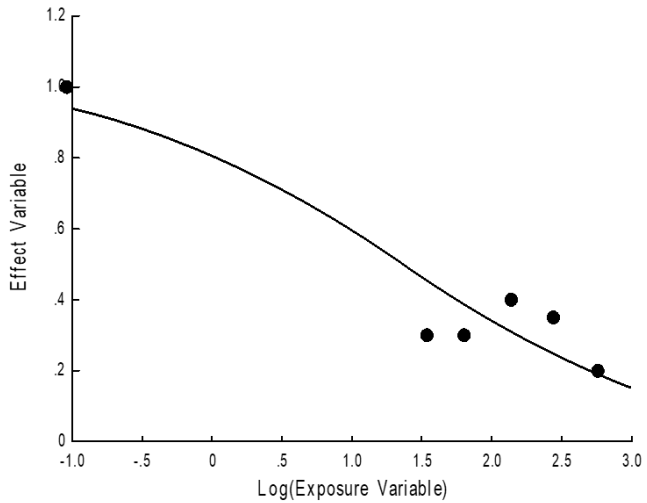


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4	4.0629	3.33E-02	3.9887	4.1371
StDev	1.00E-01	8.45E-02	3.66E-02	5.91E-02	0.14836
Y0	1	0.9999	1.29E-03	0.94017	1
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	11559	9743.1	13713	3.33E-02	4.0629
20	9700.8	8629.4	10905	2.16E-02	3.9868
10	8880.8	7405.7	10650	3.11E-02	3.9484
5	8343.1	6458.9	10777	4.07E-02	3.9213
0	7175.4	4143	12427	6.67E-02	3.8558

LC50:LC5 = 1.385

Notes: Not core data; no effect greater than 50%.

Calfee et al. 2014	
Species: *Acipenser transmontanus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-93	
Test: 61 dph, 1.15g, 62.5 cm	
Cd, (µg/L)	**% survival**
0.02	100
34.4	30
63.5	30
138	40
276	35
575	20



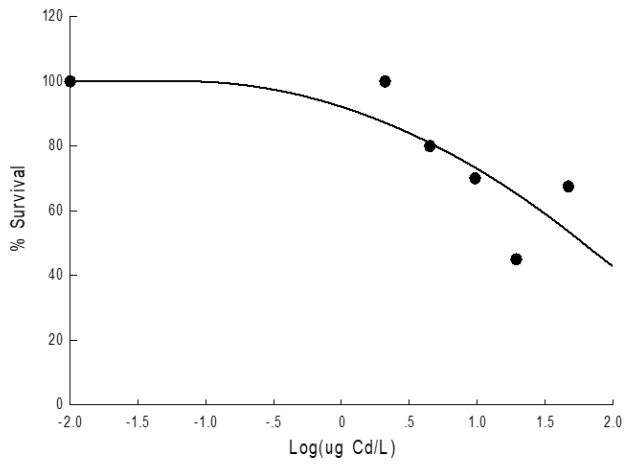
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.4	1.37	0.56	0.11	2.62
StDev	1.5	1.48	0.79	1.04	2.60
Y0	1	1.00	0.10	0.69	1.00

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	23.2360	1.296600000000	416.40	0.56	1.37
20	1.0739	0.000931030000	1238.80	1.30	0.03
10	0.2281	0.000009230500	5635.00	1.73	-0.64
5	0.0762	0.000000187190	31057.00	2.05	-1.12
0	0.0054	0.000000000000	161130000.00	2.93	-2.27

LC50:LC5 = 304.7

Notes: No effect within area of concern.

Wang et al. 2014	
Species: *Acipenser transmontanus* (larva, 27 dph)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-94	
Test: Single	
Cd, (µg/L)	**% survival**
0.01	100
2.1	100
4.49	80
9.69	70
19.5	45
47.2	67.5

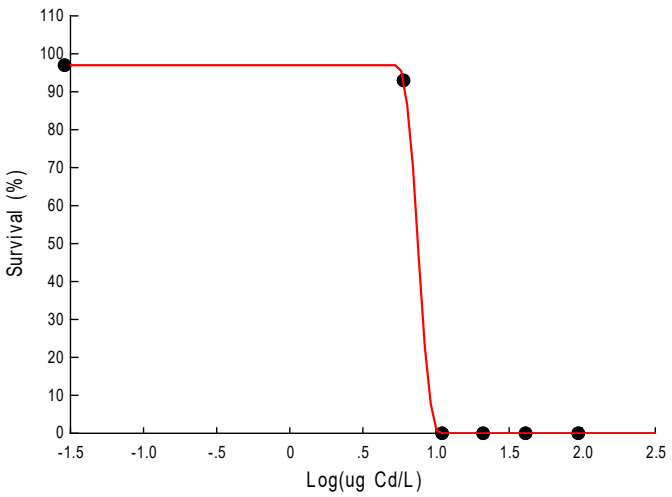


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.6	1.7813	0.41363	0.63293	2.9298
S	0.35	0.33881	0.18839	-0.18424	0.86186
Y0	100	100			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**60.443**	4.2947	850.67	0.41363	1.7813
20	4.972	0.47783	51.736	0.36639	0.69653
10	1.4119	0.025862	77.077	0.62567	0.14979
5	**0.57967**	0.00292	115.06	0.82759	-0.23682
0	0.067583	1.35E-05	337.33	1.332	-1.1702

LC50:LC5 = 104.3

Notes: Not core data. Large SE for X50 and slope (S). No effects within area of concern.

Besser et al. 2007	
Species: *Cottus bairdii*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-95	
Test: Acute 1 - Swim up	
Cd, (µg/L)	**%Survival**
0.02	97
6	93
11	0
21	0
41	0
94	0



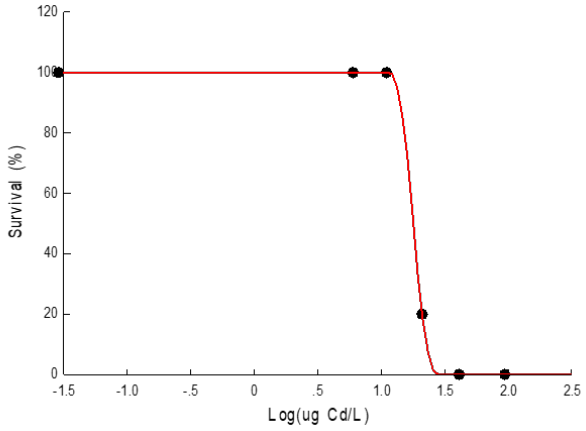
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.9	0.87943			
S	7	7.0379			
Y0	97	97			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	7.5759				0.87943
20	6.7175				0.82721
10	6.3225				0.80089
5	6.0573				0.78228
0	5.4619				0.73735

LC50:LC5 = 1.251

Notes: TRAP Flagged for IP (No Unique Solution).

Besser et al. 2007	
Species: *Cottus bairdii*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-96	
Test: Acute 2a - juvenile	
Cd, (µg/L)	**%Survival**
0.02	100
6	100
11	100
21	20
41	0
94	0

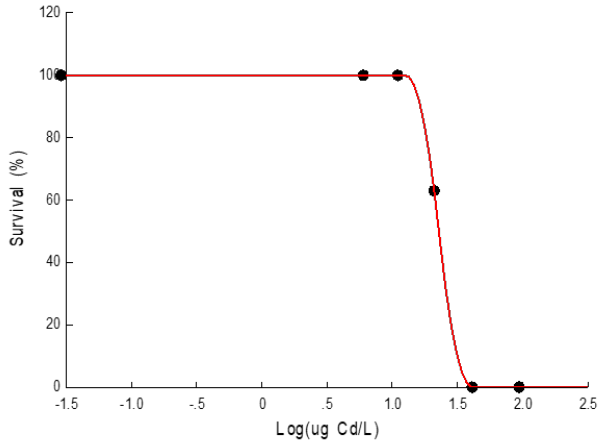


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.25	1.2537			
S	5	5.3649			
Y0	100	100			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	17.757				1.2494
20	15.014				1.1765
10	13.797				1.1398
5	12.996				1.1138
0	11.249				1.0511

LC50:LC5 = 1.366

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Besser et al. 2007	
Species: *Cottus bairdii*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-97	
Test: Acute 2b - juvenile	
Cd, (µg/L)	**%Survival**
0.02	100
6	100
11	100
21	63
41	0
94	0

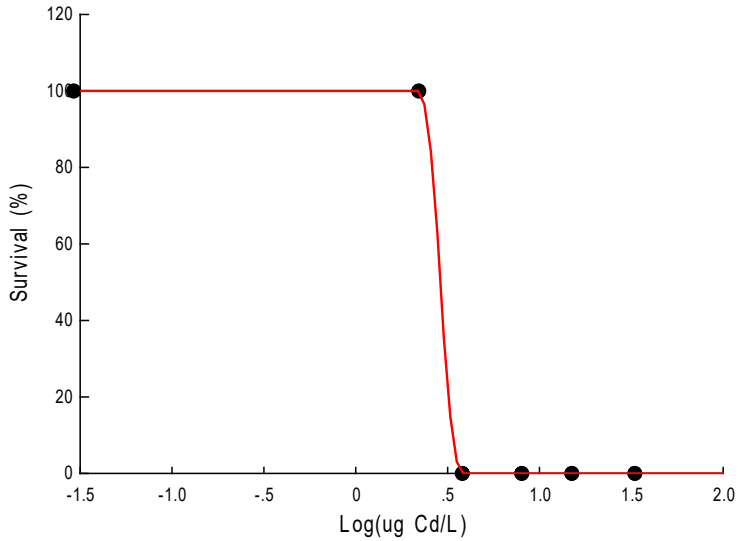


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.3	1.3578			
S	2.8	3.9267			
Y0	100	100			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	22.794				1.3578
20	18.374				1.2642
10	16.483				1.217
5	15.264				1.1837
0	12.681				1.1031

LC50:LC5 = 1.493

Notes: Not core data. TRAP Flagged for IP (No Unique Solution)

Besser et al. 2007	
Species: *Cottus bairdii*	
Test Hardness: 103 mg/L	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-98	
Test: Acute 2 - newly hatched	
Cd, (µg/L)	**%Survival**
0.02	100
2.2	100
3.8	0
8	0
15	0
33	0



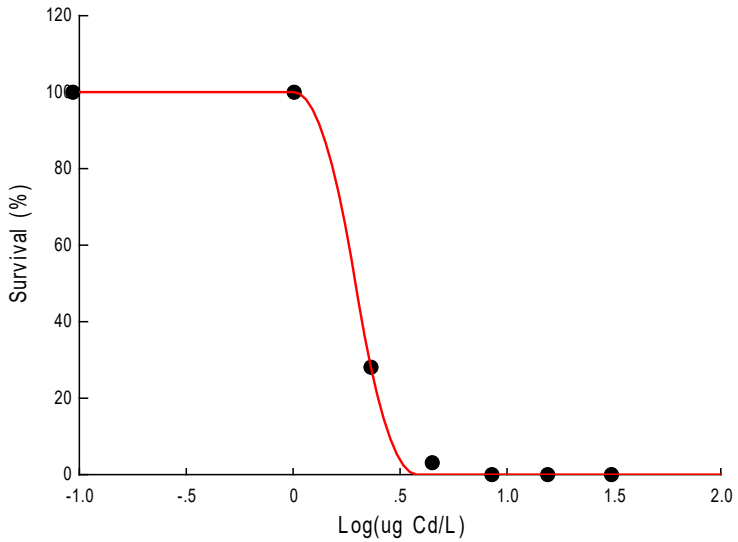
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.4611	0.4611	3.64E-08	0.4611	0.4611
S	8.1981	8.426	2.58E-06	8.426	8.426
Y0	100	100	3.31E-11	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.8914	2.8914	2.8914	3.64E-08	0.4611
20	2.6151	2.6151	2.6151	4.30E-08	0.41748
10	2.486	2.486	2.486	4.90E-08	0.3955
5	2.3986	2.3986	2.3986	5.31E-08	0.37995
0	2.2	2.2	2.2	6.30E-08	0.34242

LC50:LC5 = 1.205

Notes: TRAP Flagged for IP (No Unique Solution).

Brinkman and Vieira 2007	
Species: *Cottus bairdii* (fry)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-99	
Test: Single	
Cd, (µg/L)	**%Survival**
0.075	100
1.01	100
2.31	28
4.47	3
8.5	0
15.5	0
30.8	0



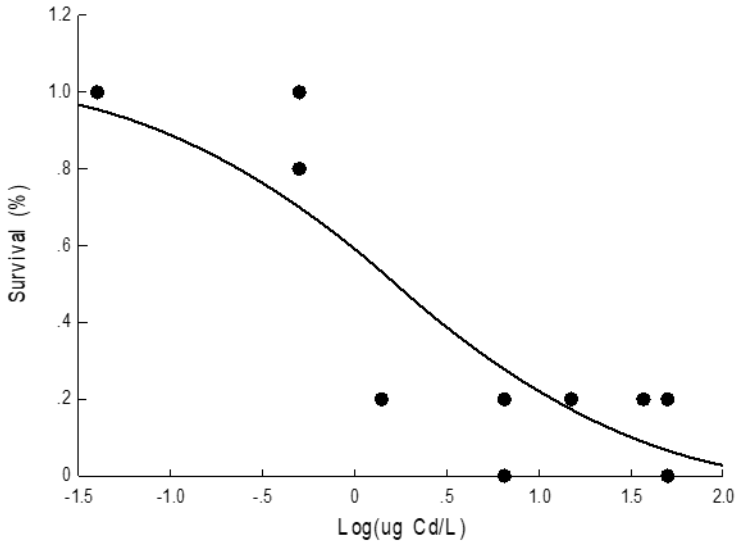
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.35953	0.29166	5.6618	-15.428	16.011
S	2.1498	3.4794	273.75	-756.56	763.52
Y0	100	100	1.55	95.697	104.3

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.9573			5.6618	0.29166
20	1.5347			13.973	0.18603
10	1.3577			18.161	0.13279
5	1.2449			21.123	0.095143
0	1.0099			28.274	0.0042573

LC50:LC5 = 1.572

Notes: TRAP Flagged for IP (No Unique Solution).

Mebane et al. 2012	
Species: *Cottus confusus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-100	
Test: test 16, LNF, H14	
Cd, (µg/L)	**Survivors**
0.04	5
0.04	5
0.5	5
0.5	4
1.4	1
1.4	1
6.5	0
6.5	1
15	1
15	1
37	1
37	1
50	1
50	0



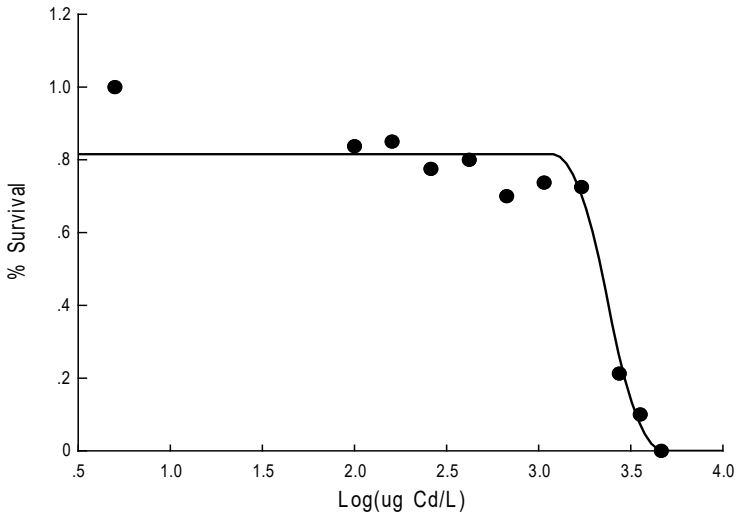
LC50:LC5 = 38.50

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.09555	0.22168	0.40629	-0.68358	1.1269
StDev	0.48219	0.94663	0.33075	0.66143	1.6613
Y0	1	0.9999	0.16127	0.69134	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.666	0.20721	13.395	0.40629	0.22168
20	0.23412	0.005604	9.7811	0.68777	-0.63057
10	0.087077	0.000577	13.137	0.85815	-1.0601
5	0.043269	8.21E-05	22.81	0.99548	-1.3638
0	0.007997	1.03E-07	620.55	1.3679	-2.0971

Notes: Poor model fit.

Gungordu et al. 2010	
Species: *Xenopus laevis*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-102	
Test: Single	
Cd, (µg/L)	**%Survival**
5	100
100	84
160	85
260	78
420	80
670	70
1070	74
1710	73
2740	21
3560	10
4630	0



	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.3	3.3764	0.018487	3.3392	3.4137
StDev	0.2	0.123	0.012479	0.10267	0.15344
Y0	0.896	0.81534	0.016331	0.78083	0.84651

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2379.3	2183.7	2592.4	0.018487	3.3764
20	1843.8	1620.6	2097.8	0.027526	3.2657
10	1621.4	1388.5	1893.5	0.032642	3.2099
5	1480.6	1242.9	1763.8	0.03637	3.1704
0	1189	947.02	1492.7	0.045288	3.0752

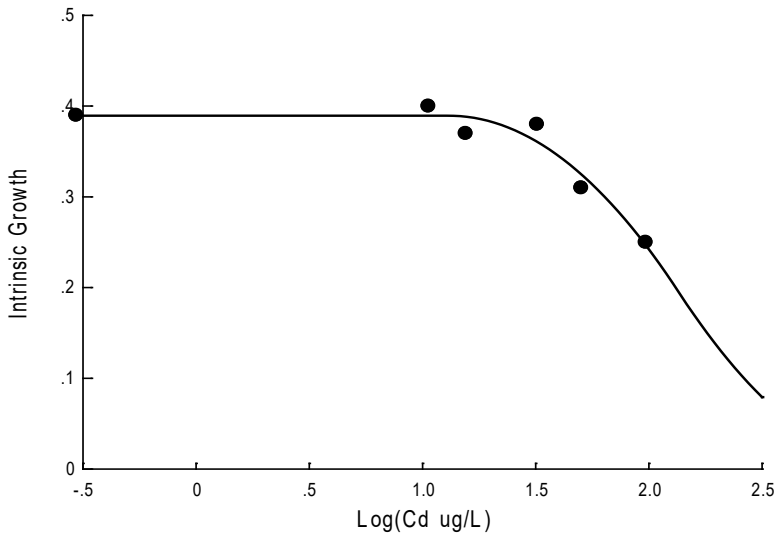
LC50:LC5 = 1.607

Notes: Poor model fit.

Appendix B.3

Test Information, C-R Data and Resulting TRAP models for Chronic Cadmium Toxicity Tests Acceptable for TAF and MAF Calculation

Niederlehner et al. 1984	
Species: *Aeolosoma headleyi*	
Test Endpoint: 14-d Intrinsic growth	
C-R Curve Label: Cd-Chronic-1	
Test: Single	
Cd, (µg/L)	**Intrinsic growth rate**
<0.5	0.39
10.6	0.40
15.5	0.37
32.0	0.38
50.2	0.31
96.7	0.25

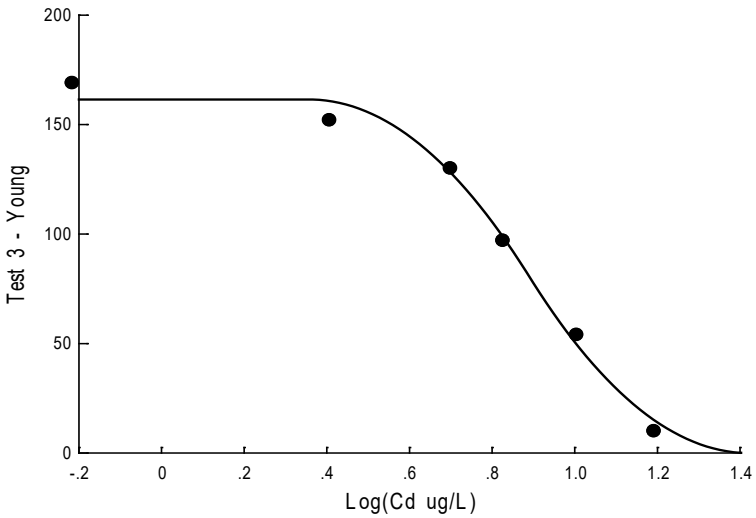


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	2.13	2.1324	0.082301	1.8705	2.3943
Slope	1	0.98324	0.26726	0.13271	1.8338
Y-intercept	0.395	0.38943	0.011694	0.35222	0.42665
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	135.64	74.208	247.91	0.082301	2.1324
20	**57.354**	34.803	94.518	0.068171	1.7586
10	37.168	16.996	81.278	0.10678	1.5702
5	**27.349**	9.8706	75.779	0.13908	1.4369
0	13.042	2.5619	66.39	0.22208	1.1153

EC20:EC5 = 2.097

Notes: Acceptable model fit.

Southwest Texas State University 2000	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 7-d Reproduction	
C-R Curve Label: Cd-Chronic-12	
Test: #3	
Cd, (µg/L)	**# Young**
0.5	169
2.55	152
5	130
6.7	97
10.1	54
15.55	10



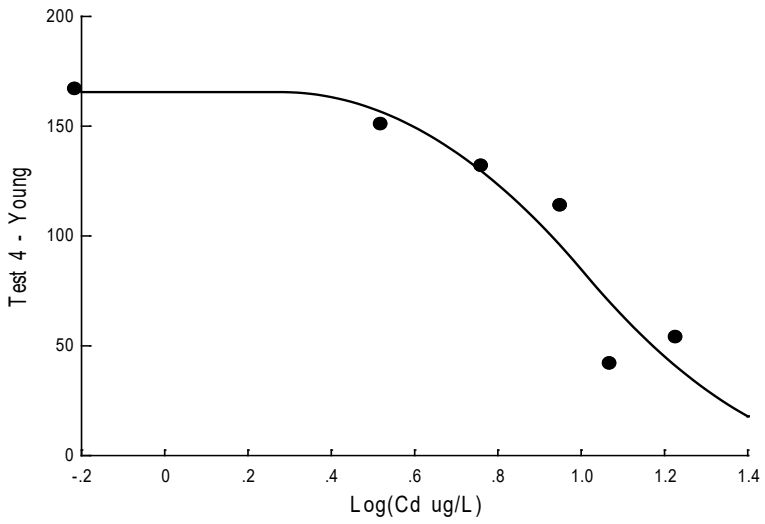
	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.9	0.88939	0.02306	0.816	0.96277
Slope	1.9	1.8781	0.25337	1.0717	2.6844
Y-intercept	169	161.48	6.0283	142.29	180.66

EC20:EC5 = 1.474

p	Xp	95% LCL	95% UCL	LogXp S.E.	LogXp
50	7.7515	6.5463	9.1785	0.02306	0.88939
20	**4.9395**	3.6743	6.6402	0.040378	0.69368
10	3.9359	2.5798	6.005	0.057649	0.59505
5	**3.352**	1.9064	5.8937	0.077012	0.5253
0	2.2747	0.87199	5.9338	0.13085	0.35692

Notes: Acceptable model fit.

Southwest Texas State University 2000	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 7-d Reproduction	
C-R Curve Label: Cd-Chronic-13	
Test: #4	
Cd, (µg/L)	**# Young**
0.5	167
3.3	151
5.75	132
8.9	114
11.7	42
16.85	54

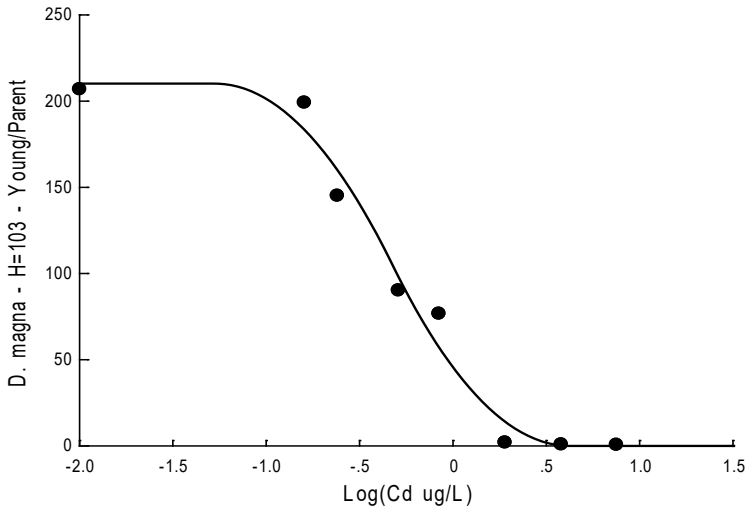


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	1	1.0092	0.079638	0.75576	1.2626
Slope	1.35	1.3692	0.54328	-0.35976	3.0981
Y-intercep	167	165.52	19.469	103.56	227.48
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	10.214	5.6985	18.308	0.079638	1.0092
20	**5.5051**	1.76	17.219	0.15562	0.74076
10	4.0315	0.83424	19.483	0.21498	0.60547
5	**3.2345**	0.45548	22.969	0.26751	0.5098
0	1.9004	0.068578	52.663	0.45332	0.27884

EC20:EC5 = 1.702

Notes: Acceptable model fit.

Chapman et al. Manuscript	
Species: *Daphnia magna*	
Test Endpoint: 21-d Reproduction	
C-R Curve Label: Cd-Chronic-15	
Test: Hardness = 103 mg/L	
Cd, (µg/L)	**Young/parent**
-	207
0.16	199.2
0.24	145.2
0.51	90.3
0.84	76.8
1.90	2.1
3.80	1
7.50	0.8

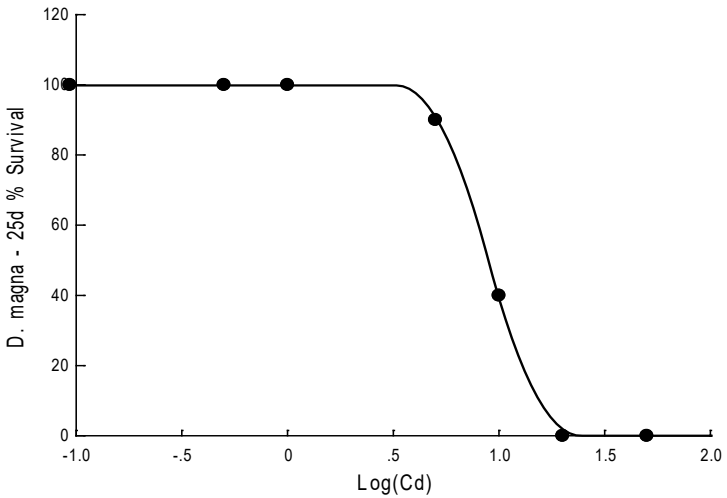


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	-0.325	-0.32427	0.061864	-0.48329	-0.16524
Slope	1.1	1.0504	0.19094	0.5596	1.5412
Y-intercept	207	210.17	14.098	173.93	246.41
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	0.47395	0.32863	0.68353	0.061864	-0.32427
20	**0.21175**	0.11276	0.39764	0.10646	-0.67417
10	0.14109	0.06259	0.31802	0.13731	-0.85052
5	**0.10587**	0.042666	0.26271	0.15354	-0.97522
0	0.052934	0.018215	0.15383	0.18023	-1.2763

EC20:EC5 = 2.000

Notes: Acceptable model fit. Large SE (x50).

Bodar et al. 1988b	
Species: *Daphnia magna*	
Test Endpoint: 25-d Survival	
C-R Curve Label: Cd-Chronic-17	
Test: Single	
Cd, (µg/L)	**% Survival**
control	100
0.5	100
1	100
5	90
10	40
20	0
50	0

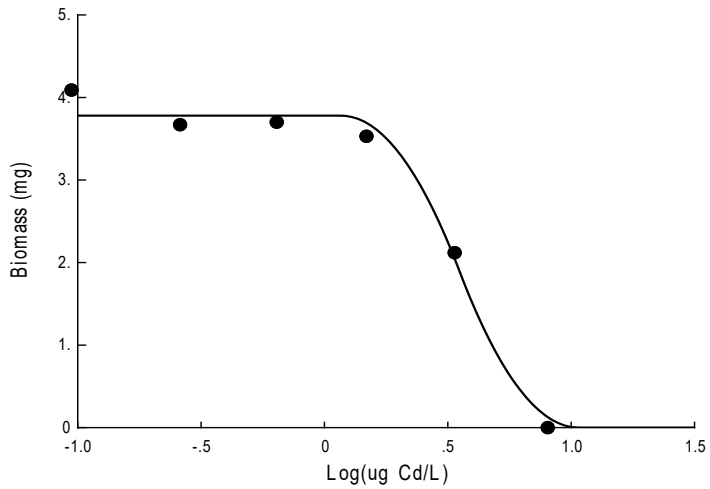


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.85036	0.95019	0.005423	0.93513	0.96525
Slope	1.121	2.2941	0.090326	2.0433	2.5449
Y-intercept	100	99.833	0.65055	98.027	101.64
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	8.9164	8.6126	9.231	0.005423	0.95019
20	**6.1656**	5.8041	6.5496	0.009451	0.78998
10	5.1195	4.7177	5.5555	0.012785	0.70923
5	**4.4888**	4.0867	4.9305	0.014681	0.65213
0	3.268	2.9273	3.6484	0.017224	0.51428

EC20:EC5 = 1.374

Notes: Acceptable model fit.

Brinkman 2012	
Species: *Oncorhynchus clarkii virginalis*	
Test Endpoint: ELS Biomass	
C-R Curve Label: Cd-Chronic-24	
Test: Single	
Cd, (µg/L)	**Biomass (g)**
<0.10 (0.05)	4.09
0.26	3.67
0.64	3.70
1.48	3.53
3.37	2.12
8.03	0.00



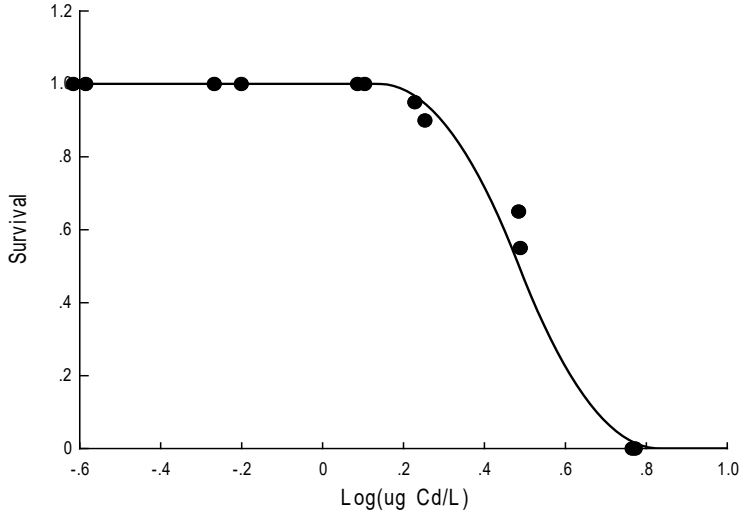
	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.5	0.54847	0.031212	0.44914	0.6478
Slope	2	2.0799	0.52697	0.40282	3.7569
Y-intercept	3.82	3.7784	0.12755	3.3725	4.1843

EC20:EC5 = 1.419

p	Xp	95% LCL	95% UCL	LogXp S.E.	LogXp
50	3.5357	2.8128	4.4443	0.031212	0.54847
20	**2.3537**	1.4878	3.7237	0.062599	0.37176
10	1.9173	0.86897	4.2304	0.10799	0.28269
5	**1.6585**	0.6207	4.4315	0.13412	0.21971
0	1.1686	0.50516	2.7034	0.11445	0.067672

Notes: Acceptable noise at low level effects.

Davies et al. 1993	
Species: *Oncorhynchus mykiss*	
Test Endpoint: LC Survival	
C-R Curve Label: Cd-Chronic-26	
Test: Hardness = 46 mg/L	
Cd, (µg/L)	**Proportion Surviving**
0.22	1.0
0.26	1.0
0.63	1.0
0.54	1.0
1.27	1.0
1.22	1.0
1.69	1.0
1.79	0.9
3.05	0.7
3.08	0.6
5.92	0.0
5.82	0.0

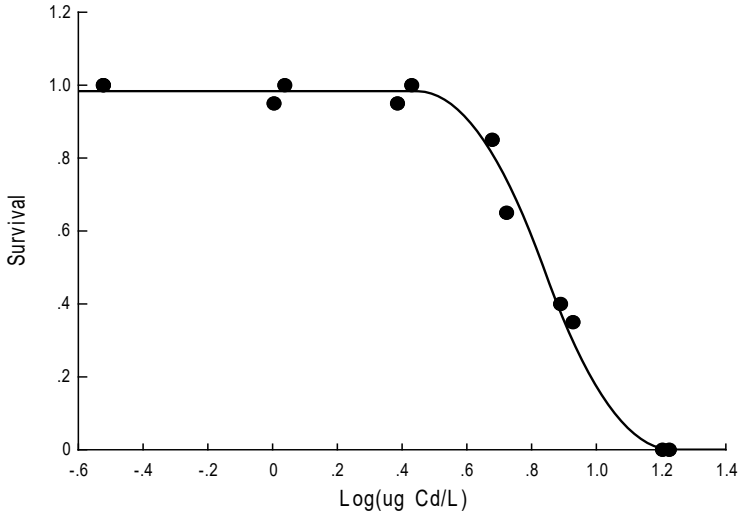


EC20:EC5 = 1.287

	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.5	0.48576	0.01931	0.44704	0.52449
StDev	0.15	0.14137	0.014451	0.11787	0.17668
Y-intercept	1	0.9999	0.00091277	0.96953	1
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	3.0603	2.7993	3.3457	0.01931	0.48576
20	**2.2829**	2.0405	2.5541	0.024059	0.35849
10	1.9694	1.7197	2.2553	0.028665	0.29434
5	**1.7741**	1.5208	2.0696	0.032161	0.24898
0	1.3787	1.1206	1.6963	0.041426	0.13947

Notes: Acceptable model fit.

Davies et al. 1993	
Species: *Oncorhynchus mykiss*	
Test Endpoint: LC Survival	
C-R Curve Label: Cd-Chronic-27	
Test: Hardness = 200 mg/L	
Cd, (µg/L)	**Proportion Surviving**
0.30	1.0
0.30	1.0
1.01	1.0
1.09	1.0
2.69	1.0
2.43	1.0
5.28	0.7
4.77	0.9
8.47	0.4
7.75	0.4
16.8	0.0
16.0	0.0

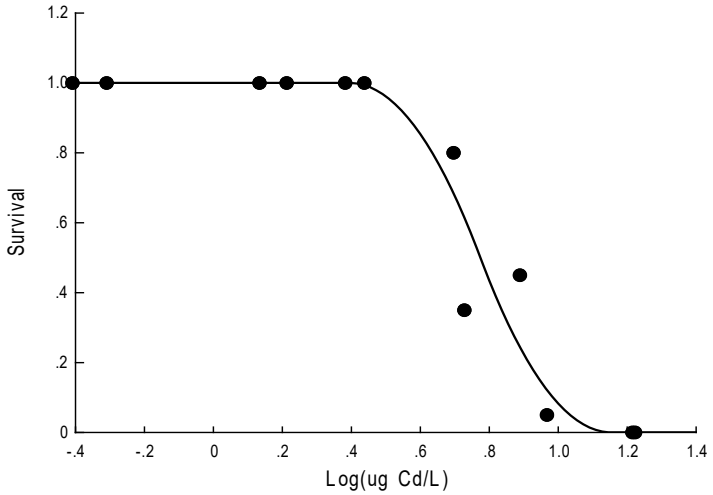


EC20:EC5 = 1.333

	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.85	0.84004	0.025422	0.78867	0.89142
StDev	0.16	0.16098	0.019872	0.12977	0.21208
Y-intercept	0.98	0.98323	0.011716	0.94097	0.99794
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	6.919	6.147	7.7878	0.025422	0.84004
20	**4.9558**	4.1756	5.8818	0.036247	0.69511
10	4.1886	3.4002	5.1599	0.04326	0.62207
5	**3.719**	2.9301	4.7202	0.04851	0.57042
0	2.7908	2.0257	3.8449	0.061068	0.44573

Notes: Acceptable model fit.

Davies et al. 1993	
Species: *Oncorhynchus mykiss*	
Test Endpoint: LC Survival	
C-R Curve Label: Cd-Chronic-28	
Test: Hardness = 400 mg/L	
Cd, (µg/L)	**Proportion Surviving**
0.49	1.0
0.39	1.0
1.63	1.0
1.36	1.0
2.41	1.0
2.74	1.0
4.97	0.8
5.34	0.4
7.74	0.5
9.27	0.1
16.4	0.0
16.7	0.0



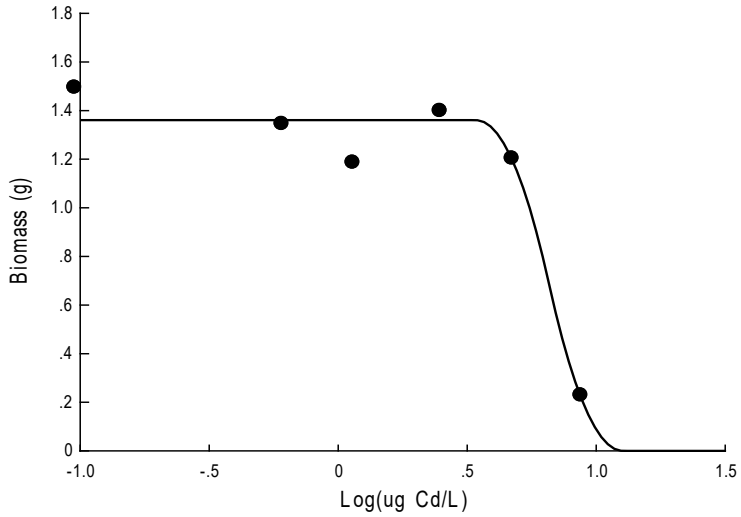
EC20:EC5 = 1.319

	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.75	0.77453	0.023732	0.72666	0.8224
StDev	0.15	0.15503	0.021917	0.12159	0.21398
Y-intercept	1	0.9999	0.00099961	0.9636	1

p	Xp	95% LCL	95% UCL	LogXp S.E.	LogXp
50	5.9501	5.3291	6.6435	0.023732	0.77453
20	**4.3147**	3.7659	4.9436	0.028703	0.63495
10	3.6695	3.0896	4.3583	0.035351	0.56461
5	**3.2724**	2.6674	4.0146	0.040953	0.51487
0	2.4819	1.8272	3.3711	0.056206	0.39478

Notes: Acceptable model fit.

Brinkman and Hansen 2004a; 2007	
Species: *Salmo trutta*	
Test Endpoint: ELS Biomass	
C-R Curve Label: Cd-Chronic-42	
Test: Hardness = 75 mg/L	
Dissolved Cd, (µg/L)	**Biomass (g)**
<0.1 (0.05)	1.499
0.60	1.349
1.13	1.190
2.46	1.403
4.68	1.207
8.64	0.233

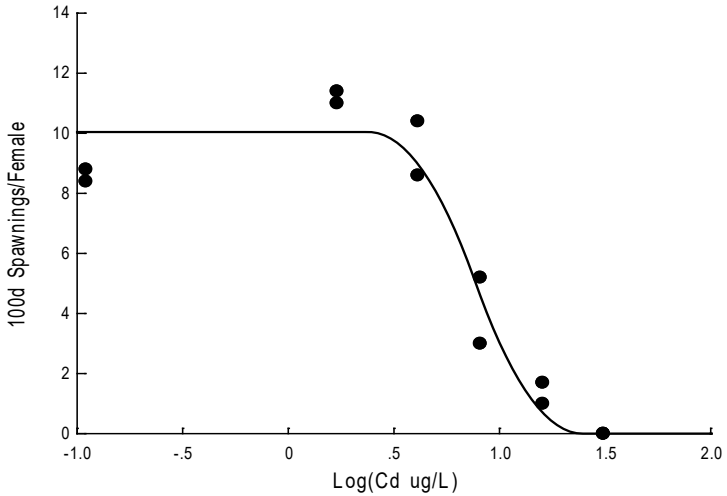


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.82	0.81905	0.038277	0.69723	0.94086
Slope	3.5	3.5303	1.0087	0.32009	6.7405
Y-intercep	1.37	1.3602	0.064673	1.1544	1.5661
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	6.5925	4.98	8.7269	0.038277	0.81905
20	**5.1872**	3.525	7.6334	0.052721	0.71494
10	4.5969	2.8782	7.3419	0.063896	0.66246
5	**4.2205**	2.4502	7.2698	0.074208	0.62536
0	3.4339	0	Infinity	28.36	0.53579

EC20:EC5 = 1.229

Notes: Acceptable noise at low level effects.

Spehar 1976	
Species: *Jordanella floridae*	
Test Endpoint: LC Reproduction	
C-R Curve Label: Cd-Chronic-48	
Test: Single	
Cd, (µg/L)	**Spawnings/female (100 d)**
0.11	8.8
0.11	8.4
1.7	11
1.7	11.4
4.1	10.4
4.1	8.6
8.1	5.2
8.1	3.0
16	1.7
16	1.0
31	0
31	0



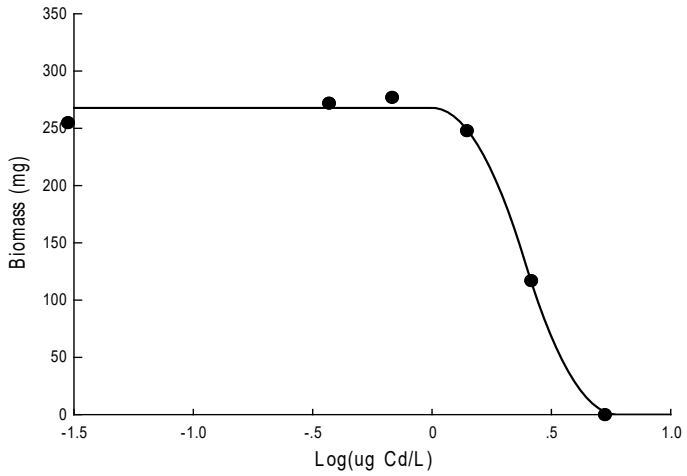
	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.9	0.88684	0.043807	0.78774	0.98594
Slope	2	1.9731	0.52585	0.78358	3.1627
Y-intercept	10	10.041	0.59217	8.701	11.38

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	7.7062	6.134	9.6814	0.043807	0.88684
20	**5.0184**	3.3774	7.4568	0.076028	0.70056
10	4.0428	2.3157	7.0582	0.10698	0.60668
5	**3.4697**	1.7093	7.0432	0.13592	0.5403
0	2.399	0.96362	5.9725	0.17511	0.38003

EC20:EC5 = 1.446

Notes: Acceptable noise at low level effects.

Besser et al. 2007	
Species: *Cottus bairdii*	
Test Endpoint: ELS Biomass	
C-R Curve Label: Cd-Chronic-52	
Test: 28-d	
Cd, (µg/L)	**Biomass (mg)**
<0.04 (0.02)	255
0.37	272
0.68	277
1.4	248
2.6	117
5.3	0

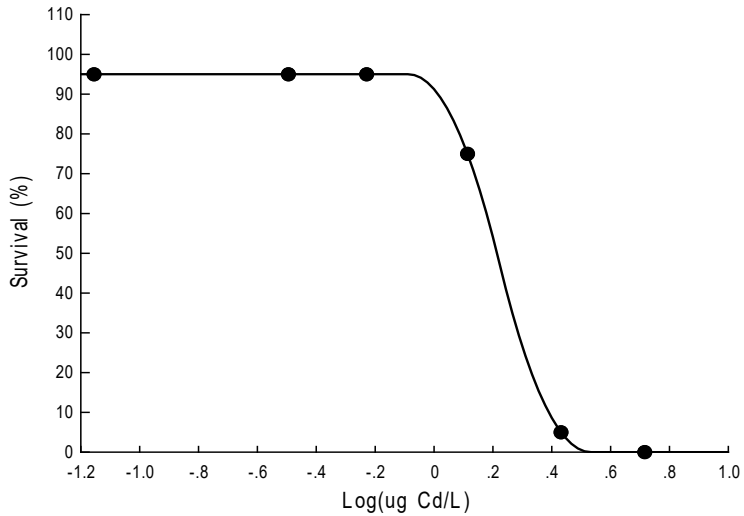


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.4	0.38853	0.014746	0.34161	0.43546
Slope	2.5	2.5793	0.3663	1.4136	3.7451
Y-intercept	268	267.79	5.4646	250.4	285.18
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	2.4464	2.1959	2.7256	0.014746	0.38853
20	**1.7621**	1.4403	2.1559	0.027523	0.24604
10	1.4935	1.1413	1.9545	0.036708	0.17422
5	**1.3287**	0.98826	1.7865	0.040399	0.12344
0	1.0019	0.70124	1.4316	0.048696	0.000837

EC20:EC5 = 1.326

Notes: Acceptable model fit.

Besser et al. 2007	
Species: *Cottus bairdii*	
Test Endpoint: ELS Survival	
C-R Curve Label: Cd-Chronic-53	
Test: 21-d	
Cd, (µg/L)	**% Survival**
0.07	95
0.32	95
0.59	95
1.3	75
2.7	5
5.2	0



	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.2	0.2225	0	0.2225	0.2225
Slope	3	3.2344	0	3.2344	3.2344
Y-intercept	95	95	0	95	95
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	1.6692	1.6692	1.6692	0	0.2225
20	**1.2849**	1.2849	1.2849	0	0.10886
10	1.1261	1.1261	1.1261	0	0.051592
5	**1.0259**	1.0259	1.0259	0	0.011094
0	0.81908	0.81908	0.81908	0	-0.08668

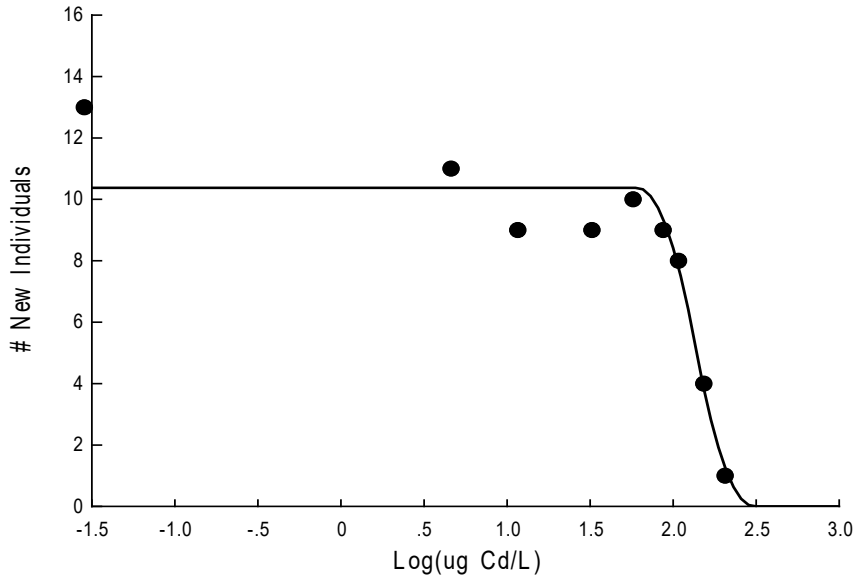
EC20:EC5 = 1.252

Notes: Acceptable model fit.

Appendix B.4

Test Information, C-R Data and Resulting TRAP models for Chronic Cadmium Toxicity Tests Unacceptable for TAF and MAF Calculation

Straus 2011	
Species: *Lumbriculus variegatus*	
Test Endpoint: 28-d LC Reproduction	
C-R Curve Label: Cd-Chronic-2	
Test: Single	
Cd, (µg/L)	**# of new individuals**
Control	13
4.6	11
11.6	9
32.4	9
57.4	10
86.9	9
107.6	8
153	4
205.3	1



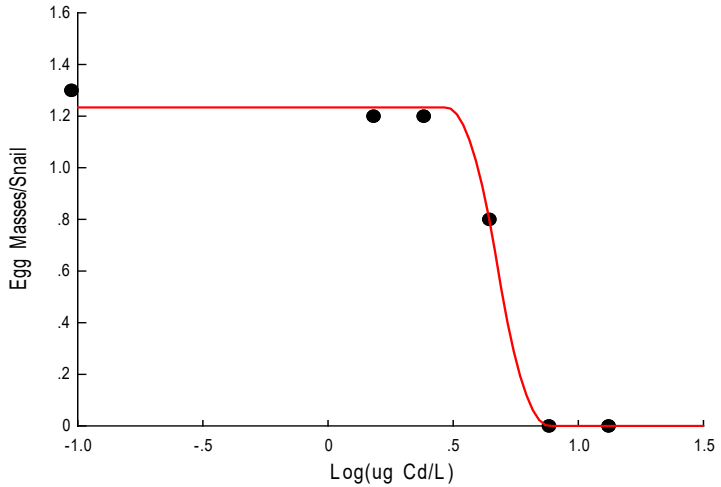
	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	2.1	2.1352	3.95E-02	2.0387	2.2318
Slope	2.8	2.8505	0.93253	0.56869	5.1323
Y-intercept	10.4	10.371	0.61422	8.8685	11.874

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	136.54	109.32	170.52	0.03945	2.1352
20	**101.46**	72.204	142.58	0.06038	2.0063
10	87.362	55.342	137.91	0.081028	1.9413
5	**78.59**	44.228	139.65	0.10204	1.8954
0	60.874	20.152	183.88	0.19621	1.7844

EC20:EC5 = 1.291

Notes: No effect within area of concern.

Holcombe et al. 1984	
Species: *Aplexa hypnorum*	
Test Endpoint: 26-d LC Reproduction	
C-R Curve Label: Cd-Chronic-3	
Test: Single (Tanks A&B)	
Cd, (µg/L)	**#egg masses/#snails**
<0.1	1.3
1.52	1.2
2.41	1.2
4.41	0.8
7.63	0
13.2	0

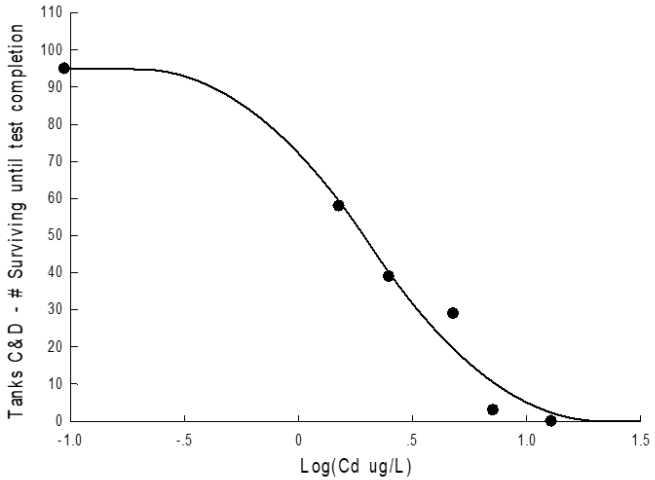


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.64316	0.67759	3.1227	-9.2602	10.615
Slope	1.7	4.878	459.43	-1457.2	1467
Y-intercept	1.2333	1.2333	0.027217	1.1467	1.3199
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	4.7598	5.4932E-10	41244000000	3.1227	0.67759
20	**4.0017**	3.5081	4.5647	0.017964	0.60225
10	3.6667	3.2057	4.1939	0.018336	0.56427
5	**3.4468**	3.0077	3.9501	0.018599	0.53742
0	2.9689	2.5636	3.4382	0.020028	0.47259

EC20:EC5 = 1.161

Notes: TRAP flagged for IP (No Unique Solution). Large SE for X50 and slope.

Holcombe et al. 1984	
Species: *Aplexa hypnorum*	
Test Endpoint: 26-d LC Reproduction	
C-R Curve Label: Cd-Chronic-4	
Test: Single (Tanks C&D)	
Cd, (µg/L)	**Total # of survivors**
<0.1	95
1.51	58
2.50	39
4.79	29
7.17	3
12.9	0

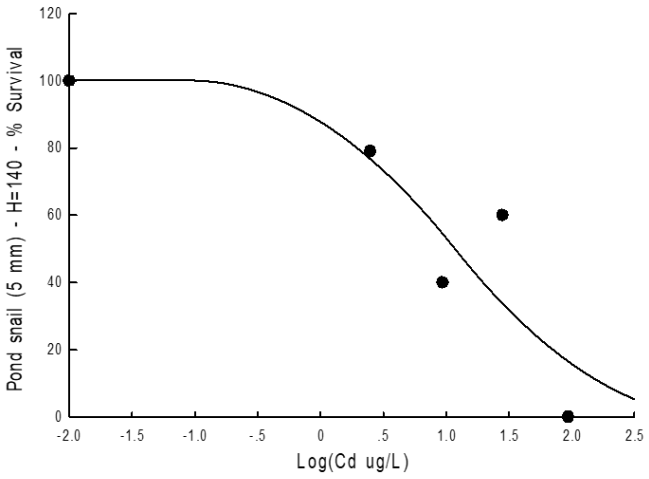


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.32	0.31565	0.07197	0.086613	0.54469
Slope	1	0.98192	0.21124	0.30965	1.6542
Y-intercept	95	94.825	7.1302	72.133	117.52
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	2.0685	1.2207	3.505	0.07197	0.31565
20	**0.87365**	0.30703	2.486	0.14271	-0.05866
10	0.56583	0.11887	2.6934	0.21292	-0.24731
5	**0.41619**	0.053424	3.2422	0.28015	-0.38071
0	0.19826	0.024346	1.6145	0.2862	-0.70276

EC20:EC5 = 2.099

Notes: No effect within area of concern.

Pais 2012	
Species: *Lymnaea stagnalis*	
Test Endpoint: 31-d Growth	
C-R Curve Label: Cd-Chronic-5	
Test: 5 mm snails	
Cd, (µg/L)	**% Survival**
0.00	100
2.50	79
9.43	40
28.3	60
94.3	0

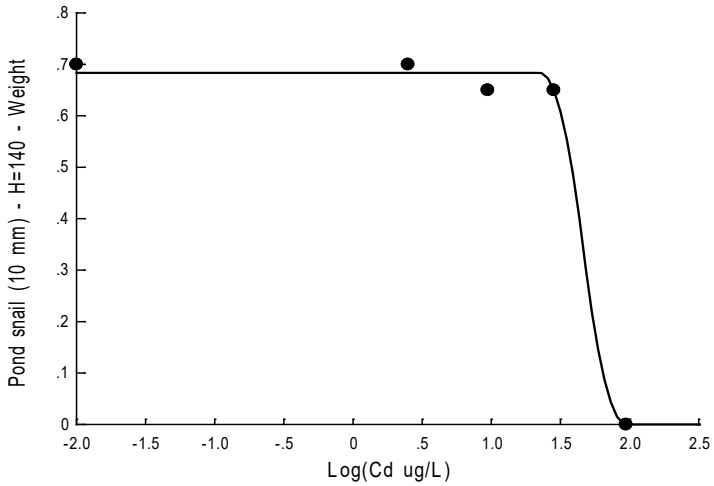


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	1.1	1.0697	0.46395	-0.92648	3.0659
Slope	0.5	0.47055	0.34276	-1.0042	1.9453
Y-intercept	100	100.14	23.973	-3.0072	203.28
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	11.741	0.11845	1163.9	0.46395	1.0697
20	**1.9437**	0.00034597	10920	0.87146	0.28863
10	0.78515	4.3007E-06	143340	1.2228	-0.10505
5	**0.4136**	7.0398E-08	2430000	1.5732	-0.38341
0	0.088013	9.2686E-15	8.3576E+11	3.0162	-1.0555

EC20:EC5 = 4.699

Notes: No effect within area of concern. Large SE for X50 and slope.

Pais 2012	
Species: *Lymnaea stagnalis*	
Test Endpoint: 31-d Growth	
C-R Curve Label: Cd-Chronic-6	
Test: 10 mm snails	
Cd, (µg/L)	**Weight (g)**
0.00	0.7
2.50	0.7
9.43	0.65
28.3	0.65
94.3	- (0)



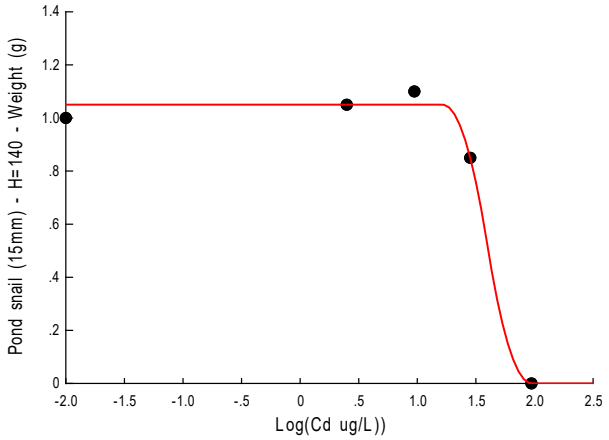
	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	1.7	1.6649	7.03E+00	-2.86E+01	31.914
Slope	2.6	3.2271	1.06E+02	-4.55E+02	4.61E+02
Y-intercept	0.7	0.68333	1.67E-02	6.12E-01	7.55E-01

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	46.23	0.00	8.E+31	7.03	1.66
20	**35.56**	22.60	55.95	0.05	1.55
10	31.16	20.10	48.30	0.04	1.49
5	**28.38**	17.69	45.52	0.05	1.45
0	22.65	12.87	39.84	0.06	1.36

EC20:EC5 = 1.253

Notes: Poor model fit at low level effects and lack of necessary partials to further evaluate acceptance of model fit.

Pais 2012	
Species: *Lymnaea stagnalis*	
Test Endpoint: 31-d Growth	
C-R Curve Label: Cd-Chronic-7	
Test: 15 mm snails	
Cd, (µg/L)	**Weight (g)**
0.00	1.00
2.50	1.05
9.43	1.10
28.3	0.85
94.3	- (0)

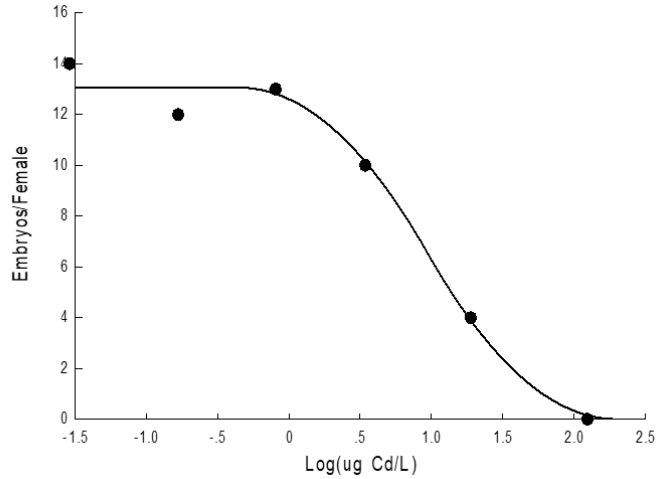


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	1.6	1.5966	4.5275	-17.883	21.077
Slope	2.5	2.6432	82.635	-352.91	358.19
Y-intercept	1.05	1.05	0.028868	0.92579	1.1742
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	39.501	1.3077E-18	1.1931E+21	4.5275	1.5966
20	**28.678**	20.903	39.346	0.031921	1.4576
10	24.405	16.791	35.471	0.037746	1.3875
5	**21.773**	14.441	32.827	0.041443	1.3379
0	16.53	10.156	26.905	0.049169	1.2183

EC20:EC5 = 1.317

Notes: TRAP flagged for IP (No unique solution); large SE for X50 and slope.

Pais 2012	
Species: *Potamopyrgus antipodarum*	
Test Endpoint: 28-d Reproduction	
C-R Curve Label: Cd-Chronic-8	
Test: Single	
Cd, (µg/L)	**Total embryos/female**
0.017	14
0.167	12
0.806	13
3.44	10
18.9	4
125.0	0

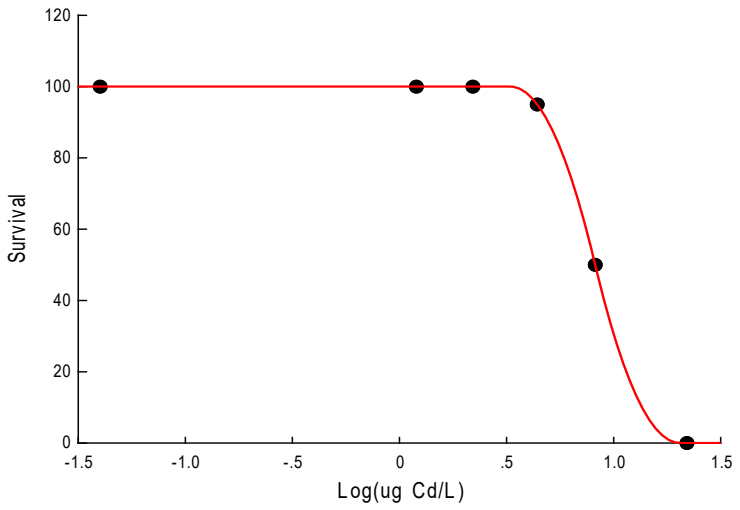


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.95	0.97564	0.092418	0.68152	1.2698
Slope	0.7	0.75559	0.1543	0.26452	1.2467
Y-intercept	15	13.053	0.54729	11.311	14.795
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	9.4545	4.8031	18.61	0.092418	0.97564
20	**3.0846**	1.0331	9.2103	0.14928	0.4892
10	1.7541	0.41306	7.4486	0.19734	0.24404
5	**1.1768**	0.22673	6.1075	0.22473	0.070686
0	0.44892	0.070714	2.8499	0.25222	-0.34783

EC20:EC5 = 2621

Notes: Not core data.

Wang et al. 2010d	
Species: *Lampsilis siliquoidea*	
Test Endpoint: 28-d juvenile survival	
C-R Curve Label: Cd-Chronic-9	
Test: single	
Cd, (µg/L)	**% Survival**
0.04	100
1.2	100
2.2	100
4.4	95
8.2	50
22	0

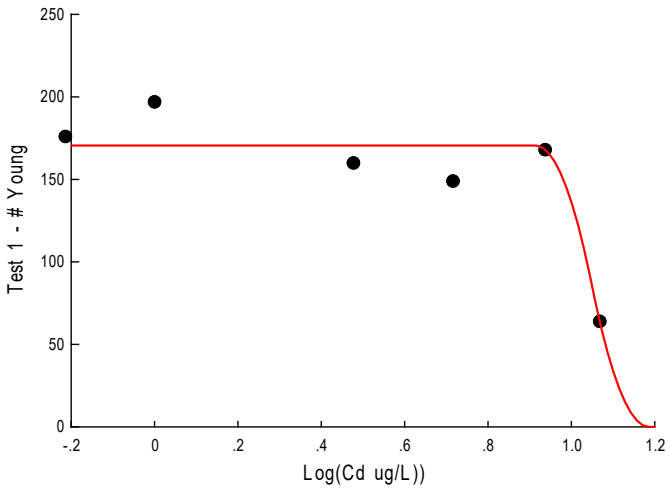


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.94562	0.91381	0	0.91381	0.91381
Slope	2.5241	2.5291	0	2.5291	2.5291
Y-intercept	98.75	100	0	100	100
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E**	**LogXp**
50	8.2	8.2	8.2	0	0.91381
20	**5.868**				0.76849
10	4.9573				0.69524
5	**4.4**				0.64345
0	3.2993				0.51842

EC20:EC5 = 1.334

Notes: TRAP flagged for IP (No Unique Solution).

Southwest Texas State University 2000	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 7-d Reproduction	
C-R Curve Label: Cd-Chronic-10	
Test: #1	
Cd, (µg/L)	**# Young**
0.5	176
1	197
3	160
5.2	149
8.65	168
11.7	64

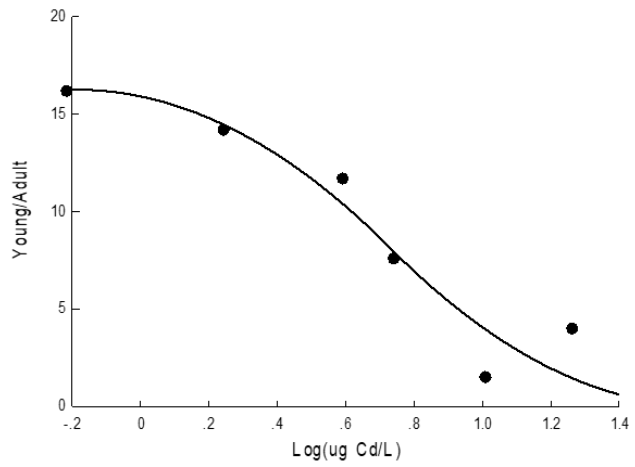


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	1	1.05	0.023475	0.97525	1.1247
Slope	7	7.3275	6.0398	-11.894	26.549
Y-intercept	170	170.51	10.428	137.32	203.7
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	11.219	9.4461	13.325	0.023475	1.05
20	**9.9954**	6.5386	15.28	0.057915	0.9998
10	9.4302	5.3338	16.673	0.077765	0.97452
5	**9.0499**	4.6101	17.766	0.092047	0.95664
0	8.1939	3.2155	20.88	0.12765	0.91349

EC20:EC5 = 1.104

Notes: TRAP flagged – IP (No unique solution); large SE for slope.

Southwest Texas State University 2000	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 7-d Reproduction	
C-R Curve Label: Cd-Chronic-11	
Test: #2	
Cd, (µg/L)	**# Young**
0.5	162
1.75	142
3.9	117
5.5	68
10.2	6
18.3	4

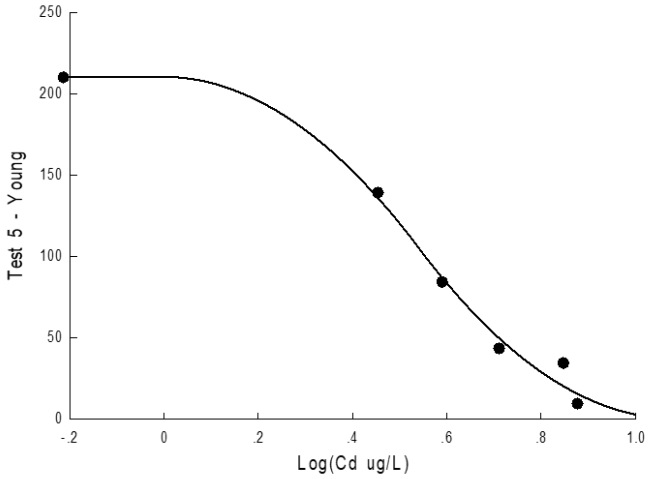


	Initial Guess	Final Est.	Standard I	95% LCL	95% HCL
Log X50	0.66893	0.73017	0.10933	0.38224	1.0781
Slope	1.3747	1.0872	0.39203	-0.16045	2.3348
Y-intercept	16.2	16.259	2.0781	9.6452	22.872
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	5.3724	2.4112	11.97	0.10933	0.73017
20	**2.4666**	0.57323	10.614	0.19914	0.39209
10	1.6661	0.21447	12.943	0.27977	0.2217
5	**1.2625**	0.088843	17.94	0.36217	0.10122
0	0.64616	0.0093279	44.761	0.57835	-0.18966

EC20:EC5 = 1.954

Notes: No effect within area of concern.

Southwest Texas State University 2000	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 7-d Reproduction	
C-R Curve Label: Cd-Chronic-14	
Test: #5	
Cd, (µg/L)	**# Young**
0.5	210
2.85	139
3.9	84
5.15	43
7.05	34
7.55	9

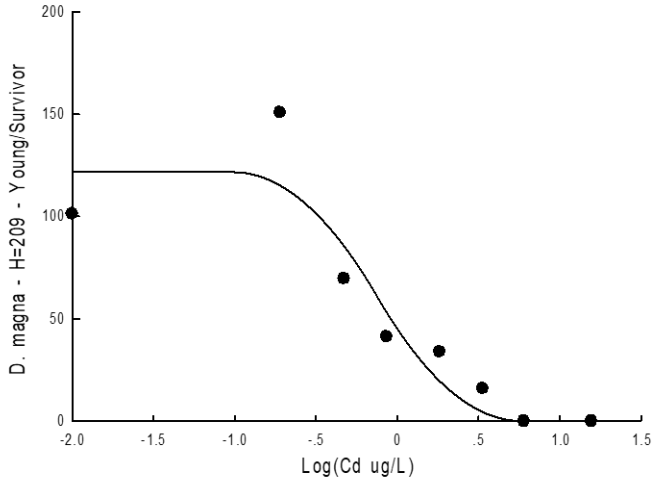


	Initial Guess	Final Est.	Standard I	95% LCL	95% HCL
Log X50	0.55	0.54004	0.024311	0.46267	0.61741
Slope	1.8	1.8368	0.23609	1.0854	2.5881
Y-intercept	210	210.66	9.9033	179.14	242.18
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	3.4677	2.9018	4.1439	0.024311	0.54004
20	**2.1874**	1.5563	3.0745	0.046456	0.33994
10	1.7341	1.0562	2.8473	0.067666	0.23909
5	**1.4715**	0.73805	2.934	0.094169	0.16777
0	0.98994	0.3746	2.6161	0.13261	-0.00439

EC20:EC5 = 1.487

Notes: No effect within area of concern.

Chapman et al. Manuscript	
Species: *Daphnia magna*	
Test Endpoint: 21-d Reproduction	
C-R Curve Label: Cd-Chronic-16	
Test: Hardness = 209 mg/L	
Cd, (µg/L)	**Young/parent**
-	82.2
0.19	134.2
0.47	22.6
0.86	34.2
1.82	4.3
3.35	2.9
6.00	1.2
15.60	0.0

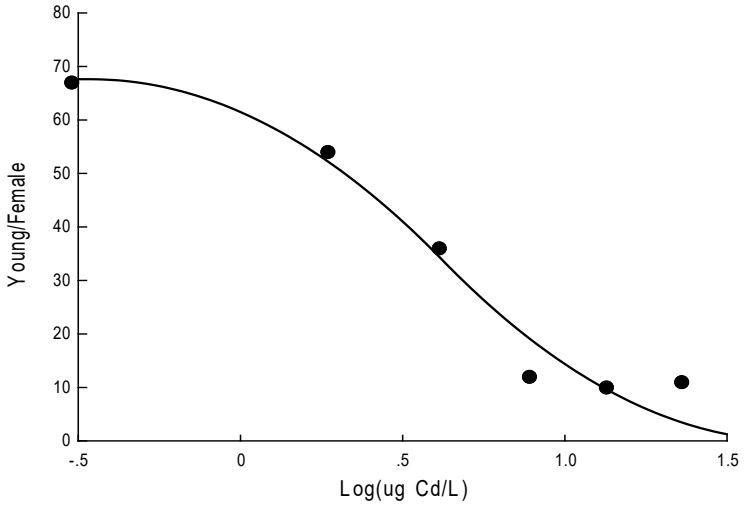


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	-0.12	-0.12416	0.15621	-0.52572	0.2774
Slope	1.1	1.1266	0.56177	-0.31751	2.5707
Y-intercep	126.2	121.71	20.027	70.229	173.19
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	0.75134	0.29804	1.8941	0.15621	-0.12416
20	**0.35448**	0.068002	1.8478	0.27895	-0.45041
10	0.24275	0.02393	2.4625	0.39144	-0.61484
5	**0.18574**	0.0098186	3.5135	0.49671	-0.73111
0	0.097319	0.0030566	3.0985	0.58467	-1.0118

EC20:EC5 = 1.909

Notes: Unacceptable noise at low level effects. Large SE for X50 and slope.

Borgmann et al. 1989a; b	
Species: *Daphnia magna*	
Test Endpoint: 21-d Reproduction	
C-R Curve Label: Cd-Chronic-18	
Test: Single	
Cd, (µg/L)	**Young/female**
0.22	67
1.86	54
4.1	36
7.78	12
13.43	10
22.92	11



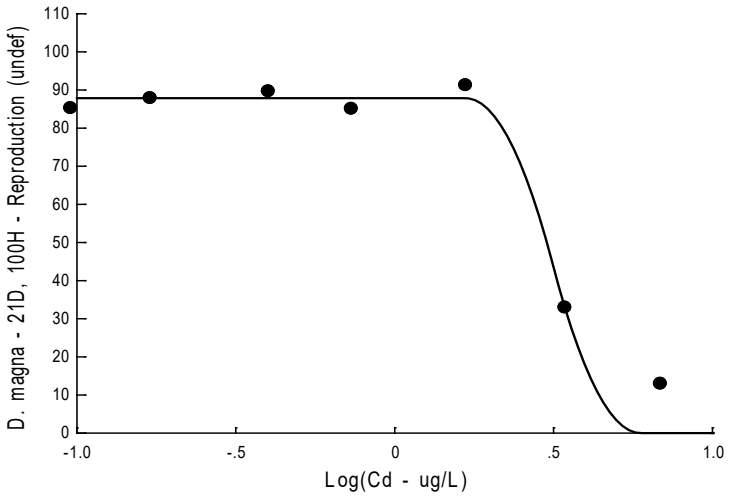
	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.6	0.62274	0.090629	0.33432	0.91116
Slope	0.9	0.92243	0.216	0.23501	1.6099
Y-intercept	67	67.591	6.0477	48.345	86.837

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	4.1951	2.1593	8.1501	0.090629	0.62274
20	**1.6761**	0.50741	5.5363	0.16306	0.22429
10	1.0555	0.19586	5.6885	0.22986	0.023472
5	**0.76115**	0.084645	6.8445	0.29973	-0.11853
0	0.34566	0.018815	6.3506	0.39723	-0.46135

EC20:EC5 = 2.202

Notes: No effect within area of concern.

Chadwick Ecological Consultants 2003	
Species: *Daphnia magna*	
Test Endpoint: 21-d Reproduction	
C-R Curve Label: Cd-Chronic-19	
Test: Hardness = 100 mg/L	
Cd, (µg/L)	**Undefined**
0.07	85.3
0.17	87.9
0.4	89.7
0.73	85.1
1.67	91.3
3.43	33
6.85	13

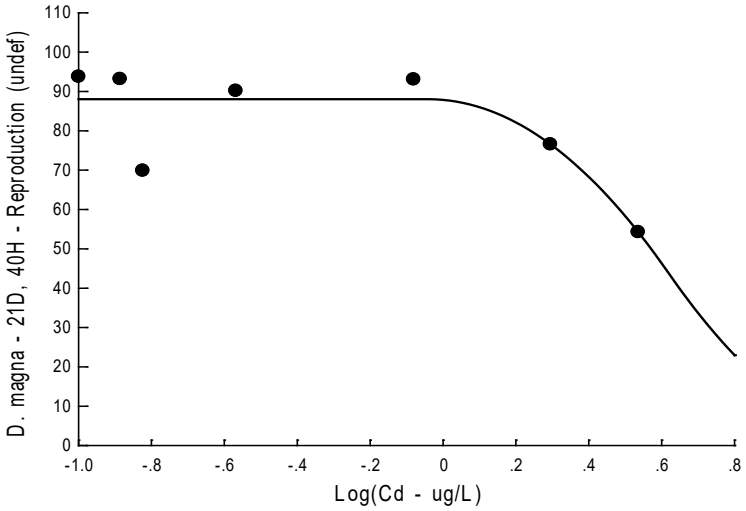


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	1	0.99662	0.12882	0.63896	1.3543
Slope	0.7	0.71766	0.27003	-0.032073	1.4674
Y-intercept	54	53.318	4.45	40.963	65.673
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	9.9224	4.3547	22.609	0.12882	0.99662
20	**3.0512**	0.69454	13.405	0.23151	0.48448
10	1.6841	0.2083	13.615	0.32692	0.22636
5	**1.1062**	0.081801	14.96	0.40738	0.043839
0	0.40105	0.0060252	26.695	0.65668	-0.3968

EC20:EC5 = 1.222

Notes: Poor model fit at high effect concentrations and lack of partials around area of concern.

Chadwick Ecological Consultants 2003	
Species: *Daphnia magna*	
Test Endpoint: 21-d Reproduction	
C-R Curve Label: Cd-Chronic-20	
Test: Hardness = 50 mg/L	
Cd, (µg/L)	**Undefined**
0.1	93.8
0.13	93.2
0.15	69.9
0.27	90.2
0.83	93.1
1.97	76.6
3.43	54.3

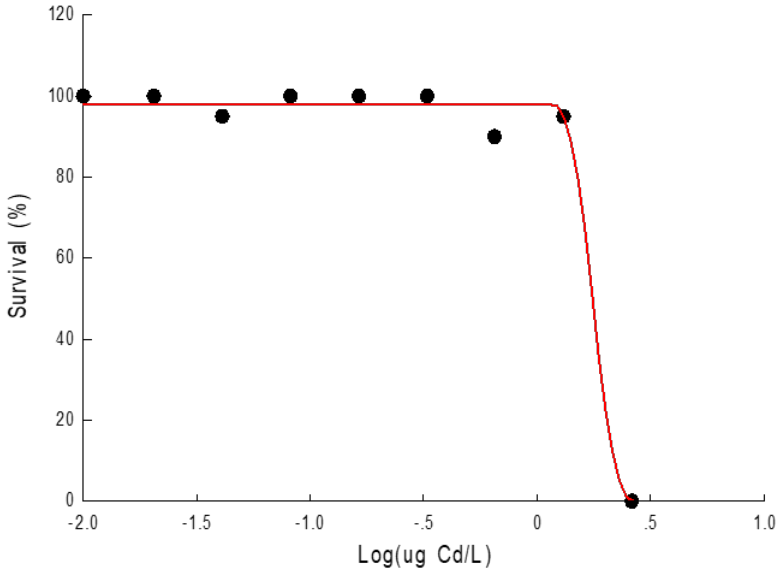


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.62	0.6173	1.29E-01	2.60E-01	0.97413
Slope	1.5	1.5183	1.12E+00	-1.58E+00	4.62E+00
Y-intercept	88.04	88.04	4.5778	75.33	100.75
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	4.1428	1.82E+00	9.42E+00	1.29E-01	0.6173
20	**2.3726**	1.1437	4.922	1.14E-01	3.75E-01
10	1.7915	0.53889	5.9558	1.88E-01	2.53E-01
5	**1.4688**	0.30368	7.1038	2.47E-01	1.67E-01
0	0.90924	7.31E-02	11.311	3.94E-01	-4.13E-02

EC20:EC5 = 1.615

Notes: Unacceptable noise at low level effects. Large SE for slope.

Jemec et al 2008	
Species: *Daphnia magna*	
Test Endpoint: 21-d Survival	
C-R Curve Label: Cd-Chronic-21	
Test: Single	
Cd, (µg/L)	**% Survival**
0	100
0.0205	100
0.041	95
0.082	100
0.164	100
0.328	100
0.65	90
1.31	95
2.62	0



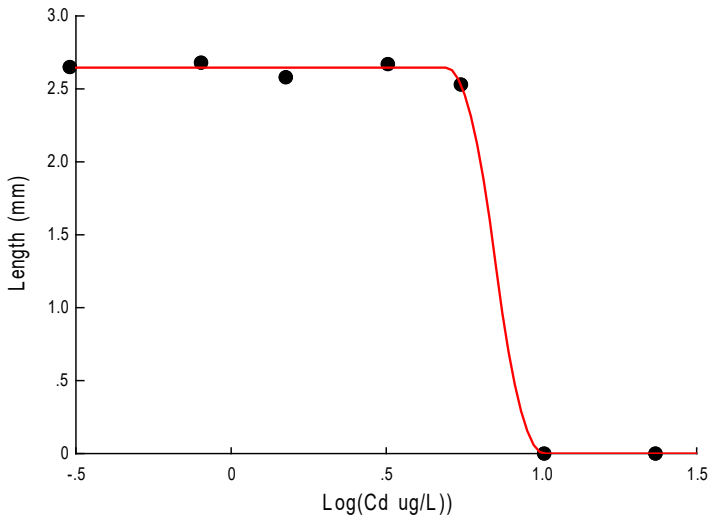
	Initial Guess	Final Est.	Standard Err	95% LCL	95% HCL
Log X50	0.25	0.24723	1.6804	-3.8645	4.359
Slope	5	5.8352	75.447	-178.78	190.45
Y-intercept	97.5	97.857	1.4869	94.219	101.5

p	Xp	95% LCL	95% UCL	LogXp S.E.	LogXp
50	1.767	0.00013662	22854	1.6804	0.24723
20	**1.5284**	1.3048	1.7903	0.028071	0.18425
10	1.4207	1.2197	1.6549	0.027079	0.1525
5	**1.3491**	1.1452	1.5894	0.02909	0.13005
0	1.1909	0.97982	1.4473	0.034621	0.07586

EC20:EC5 = 1.133

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

Niederlehner 1984	
Species: *Daphnia pulex*	
Test Endpoint: 21-d Growth	
C-R Curve Label: Cd-Chronic-22	
Test: Single	
Cd, (µg/L)	**Mean Length (mm)**
0.2	2.65
0.8	2.68
1.5	2.58
3.2	2.67
5.5	2.53
10.2	- (0)
23.3	- (0)

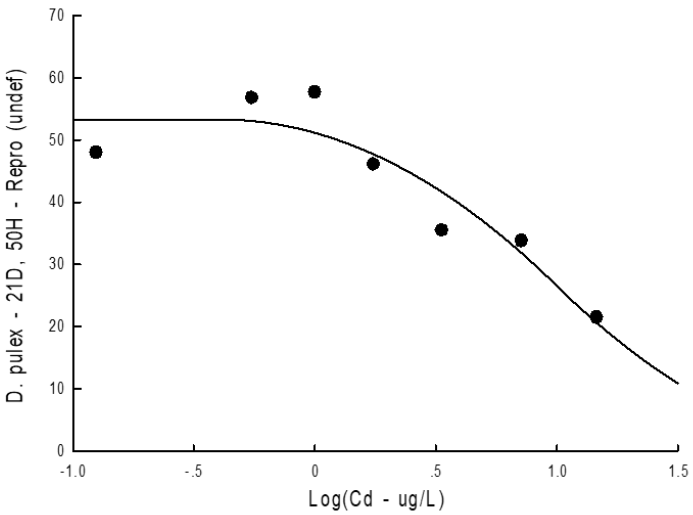


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.85	0.85113			
Slope	6.3	6.3647			
Y-intercept	2.645	2.6451			
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	7.0978			0.010292	0.85113
20	**6.2141**			0.010292	0.79338
10	5.8113			0.010292	0.76427
5	**5.5424**			0.010292	0.74369
0	4.9432			0.010292	0.69401

EC20:EC5 = 1.121

Notes: TRAP flagged for IP (No unique solution).

Chadwick Ecological Consultants 2003	
Species: *Daphnia pulex*	
Test Endpoint: 18-d Reproduction	
C-R Curve Label: Cd-Chronic-23	
Test: Table 7	
Cd, (µg/L)	**Reproduction**
0.125	48
0.55	56.8
1	57.7
1.75	46.1
3.35	35.5
7.15	33.8
14.6	21.5

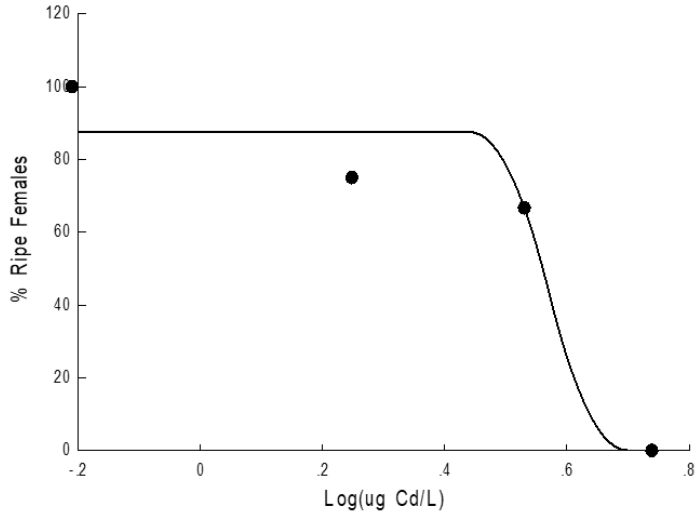


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	1	0.99662	0.12882	0.63896	1.3543
Slope	0.7	0.71766	0.27003	-0.032073	1.4674
Y-intercept	54	53.318	4.45	40.963	65.673
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	9.9224	4.3547	22.609	0.12882	0.99662
20	**3.0512**	0.69454	13.405	0.23151	0.48448
10	1.6841	0.2083	13.615	0.32692	0.22636
5	**1.1062**	0.081801	14.96	0.40738	0.043839
0	0.40105	0.0060252	26.695	0.65668	-0.3968

EC20:EC5 = 2.758

Notes: Unacceptable noise at low level effects.

Brown et al 1994	
Species: *Oncorhynchus mykiss*	
Test Endpoint: LC Reproduction	
C-R Curve Label: Cd-Chronic-25	
Test: (2 yr old) 95 week	
Cd, (µg/L)	**% Ripe Females**
0.47	100
1.77	75
3.39	66.66
5.48	0

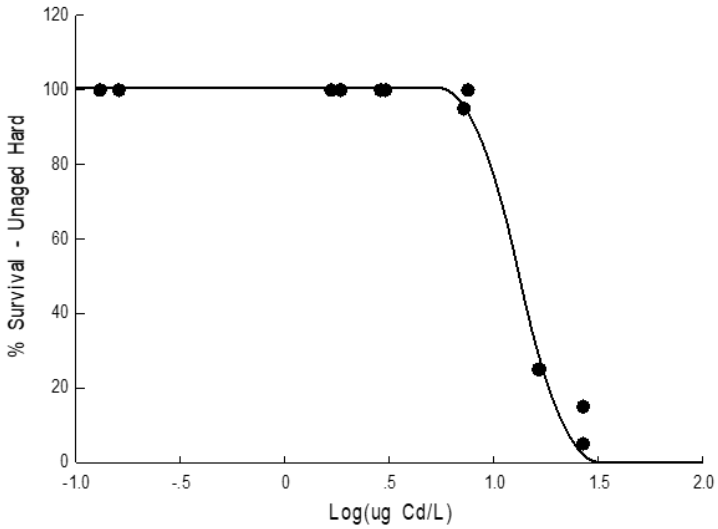


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.5	0.56993			
Slope	6	7.7976			
Y-intercept	100	87.5			
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	3.7148				0.56993
20	**3.3327**				0.5228
10	3.1553				0.49904
5	**3.0356**				0.48224
0	2.765				0.44169

EC20:EC5 = 1.098

Notes: Poor model fit.

Davies and Brinkman 1994b	
Species: *Oncorhynchus mykiss*	
Test Endpoint: ELS Survival	
C-R Curve Label: Cd-Chronic-29	
Test: 100-d; Unaged hard water (301 mg/L)	
Cd, (µg/L)	**% Survival**
0.16	100.0
0.13	100.0
1.66	100.0
1.84	100.0
2.86	100.0
3.02	100.0
7.17	95.0
7.49	100.0
16.5	25.0
16.3	25.0
26.7	15.0
26.6	5.0



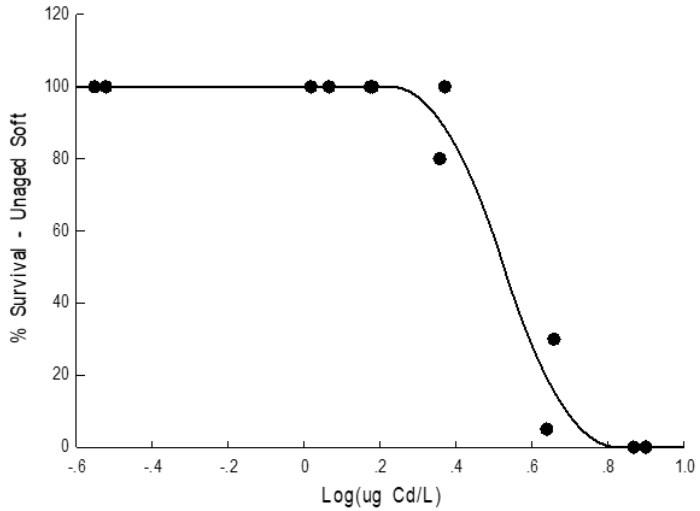
EC20:EC5 = 1.323

	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	1.2	1.1195	0.055	0.717	0.964
Slope	2.6	2.5986	2.897	-3.853	9.253
Y-intercept	99	100.57	1.268	96.628	102.370

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	13.168	11.902	14.568	0.019	1.120
20	**9.508**	8.022	11.268	0.033	0.978
10	8.068	6.498	10.018	0.042	0.907
5	**7.184**	5.617	9.188	0.047	0.856
0	5.429	4.015	7.339	0.058	0.735

Notes: Not core data.

Davies and Brinkman 1994b	
Species: *Oncorhynchus mykiss*	
Test Endpoint: ELS Survival	
C-R Curve Label: Cd-Chronic-30	
Test: 100-d; unaged soft water (29 mg/L)	
Cd, (µg/L)	**% Survival**
0.30	100.0
0.28	100.0
1.04	100.0
1.16	100.0
1.51	100.0
1.49	100.0
2.34	100.0
2.27	80.0
4.54	30.0
4.34	5.0
7.35	0.0
7.92	0.0



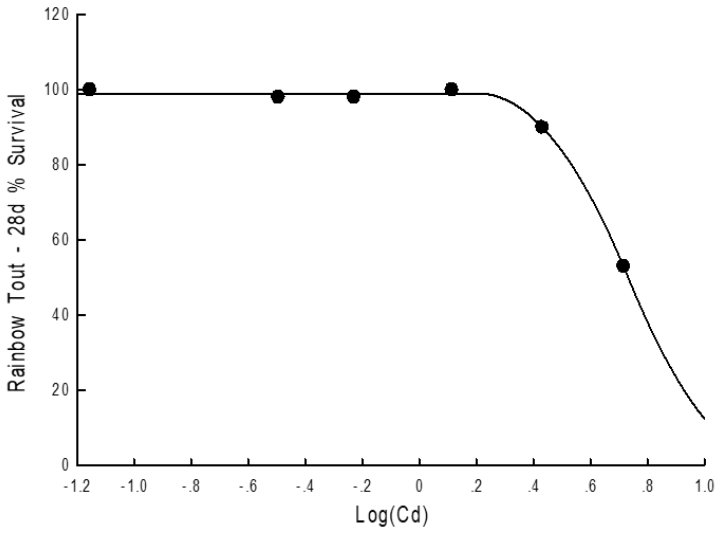
EC20:EC5 = 1.242

	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.55	0.52495	0.027	0.465	0.585
Slope	3.5	3.3613	0.628	1.941	4.781
Y-intercept	100	99.984	3.493	92.082	107.890

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	3.349	2.917	3.845	0.027	0.525
20	**2.604**	2.146	3.160	0.037	0.416
10	2.294	1.815	2.899	0.045	0.360
5	**2.097**	1.600	2.747	0.052	0.322
0	1.688	0.440	6.477	0.258	0.227

Notes: Not Core data.

Besser et al. 2007	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 28-d ELS Survival	
C-R Curve Label: Cd-Chronic-31	
Test: Single	
Cd, (µg/L)	**% Survival**
0.07	100
0.32	98
0.59	98
1.3	100
2.7	90
5.2	53

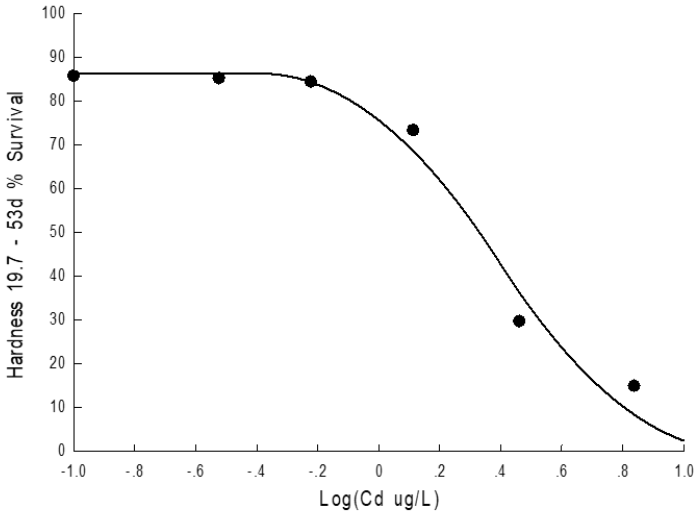


	Initial Gue	Final Est.	Standard I	95% LCL	95% UCL
Log X50	0.75	0.735	0.007039	0.7126	0.7574
Slope	1.9	1.8887	0.10991	1.539	2.2385
Y-intercept	99	99.003	0.57736	97.165	100.84
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	5.4325	5.1594	5.7201	0.007039	0.735
20	**3.4706**	3.216	3.7453	0.010395	0.5404
10	2.769	2.475	3.098	0.015321	0.44233
5	**2.3603**	2.0525	2.7143	0.019069	0.37297
0	1.6053	1.3032	1.9773	0.028444	0.20555

EC20:EC5 = 1.470

Notes: Not core data

Mebane et al. 2008	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 53-d ELS Survival	
C-R Curve Label: Cd-Chronic-32	
Test: Hardness: 19.7 mg/L	
Cd, (µg/L)	**% Survival**
<0.2	85.7
0.30	85.2
0.60	84.4
1.30	73.3
2.90	29.6
6.9	14.8



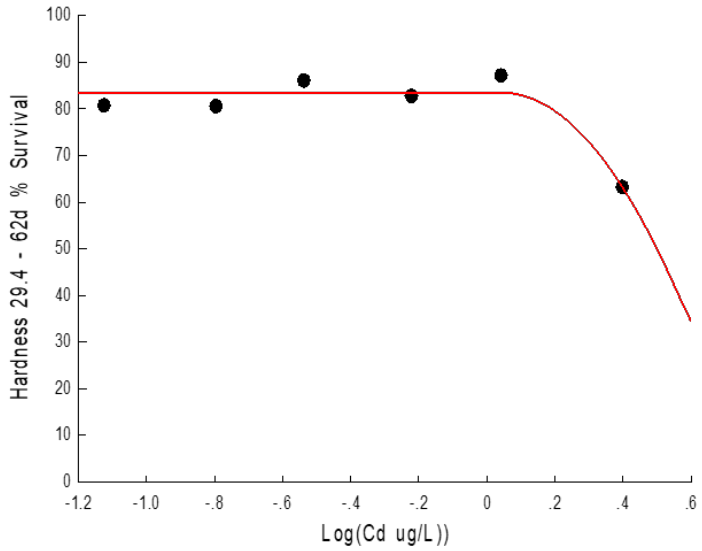
	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.4	0.39531	0.053133	0.22622	0.5644
Slope	1.25	1.2701	0.25826	0.44821	2.092
Y-intercept	85	86.34	3.9762	73.686	98.993

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	2.4849	1.6835	3.6678	0.053133	0.39531
20	**1.2762**	0.65987	2.4684	0.090018	0.10593
10	0.9122	0.36789	2.2618	0.12392	-0.039911
5	**0.71938**	0.22637	2.2862	0.15779	-0.14304
0	0.4055	0.068174	2.4119	0.24332	-0.39201

EC20:EC5 = 1.774

Notes: Not core data.

Mebane et al. 2008	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 62-d ELS Survival	
C-R Curve Label: Cd-Chronic-33	
Test: Hardness: 29.4 mg/L	
Cd, (µg/L)	**% Survival**
<0.15	80.8
0.16	80.6
0.29	86.1
0.6	82.8
1.1	87.2
2.5	63.3

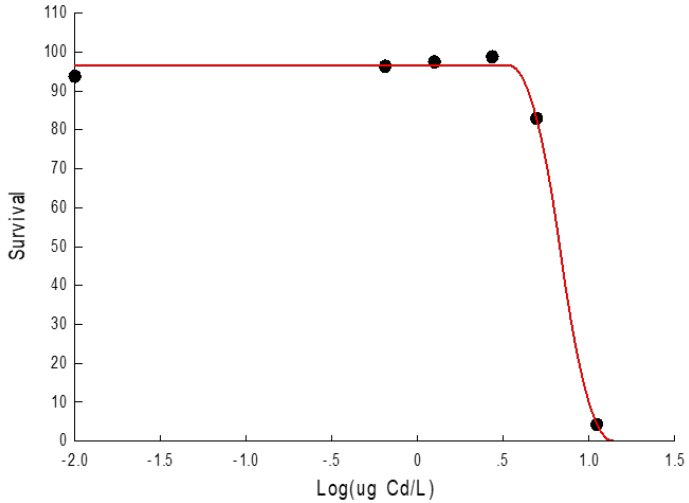


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.71943	0.55329			
Slope	1.2042	1.9588			
Y-intercept	83.5	83.486			
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	3.5751			0.29242	0.55329
20	**2.3209**			0.29242	0.36566
10	1.8668			0.29242	0.27109
5	**1.6004**			0.29242	0.20422
0	1.1035			0.29242	0.042784

EC20:EC5 = 1.450

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

Wang et al. 2014	
Species: *Oncorhynchus mykiss*	
Test Endpoint: ELS Survival	
C-R Curve Label: Cd-Chronic-34	
Test: Single	
Cd, (µg/L)	**% Survival**
<0.02	93.8
0.65	96.4
1.26	97.5
2.74	98.8
4.98	83
11.2	4.3

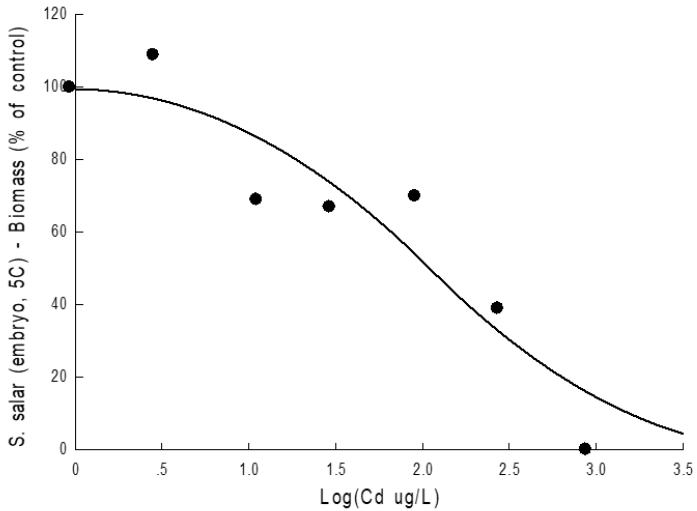


	Initial Gue	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.8	0.83824	1.21E-02	0.79979	0.87668
Slope	3	3.3257	0.24438	2.548	4.1034
Y-intercept	96.625	96.625	1.0617	93.246	100
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	6.8903	6.3065	7.528	1.21E-02	0.83824
20	**5.3422**	4.8667	5.8641	1.27E-02	0.72772
10	4.6992	4.1949	5.264	1.55E-02	0.67202
5	**4.2917**	1.2063	15.269	0.17319	0.63263
0	3.4478	2.9269	4.0615	2.24E-02	0.53755

EC20:EC5 = 1.245

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Rombough and Garside 1982	
Species: *Salmo salar*	
Test Endpoint: ELS Biomass	
C-R Curve Label: Cd-Chronic-35	
Test: (embryo, exposed from fert) - 5C	
Cd, (µg/L)	**Total Biomass (% Control)**
<1.0	100
2.8	109
11	69
29	67
90	70
270	39
870	-

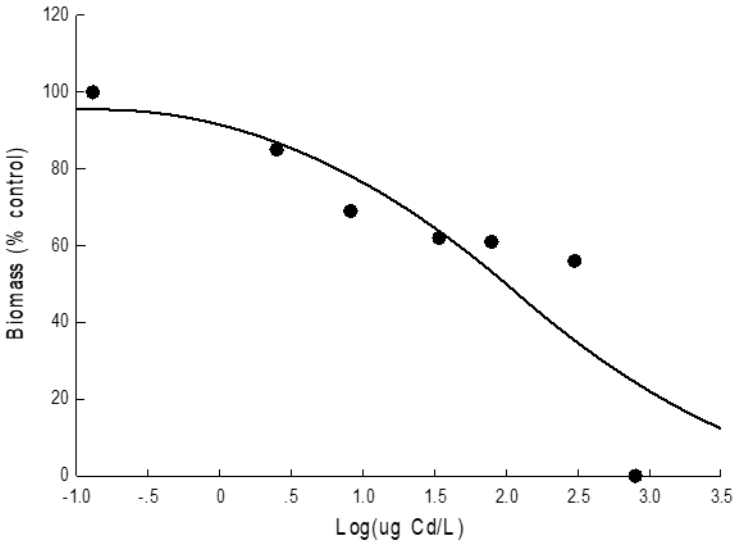


	Initial Gues	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	2.4	2.046	0.28723	1.2485	2.8434
Slope	1	0.48428	0.21063	-0.10053	1.0691
Y-intercept	80	99.415	13.868	60.912	137.92
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	111.17	17.721	697.34	0.28723	2.046
20	**19.365**	0.70155	534.55	0.519	1.287
10	8.0263	0.085062	757.35	0.71126	0.90452
5	**4.3057**	0.014297	1296.7	0.8928	0.63404
0	0.95733	5.92E-05	15487	1.5159	-0.018938

EC20:EC5 = 4.498

Notes: Not Core data. No effect within area of concern.

Rombough and Garside 1982	
Species: *Salmo salar*	
Test Endpoint: ELS Biomass	
C-R Curve Label: Cd-Chronic-36	
Test: (embryo, fert) - 8.9C	
Cd, (µg/L)	**Total Biomass (% Control)**
0.13	100
2.5	85
8.2	69
34	62
79	61
300	56
800	0

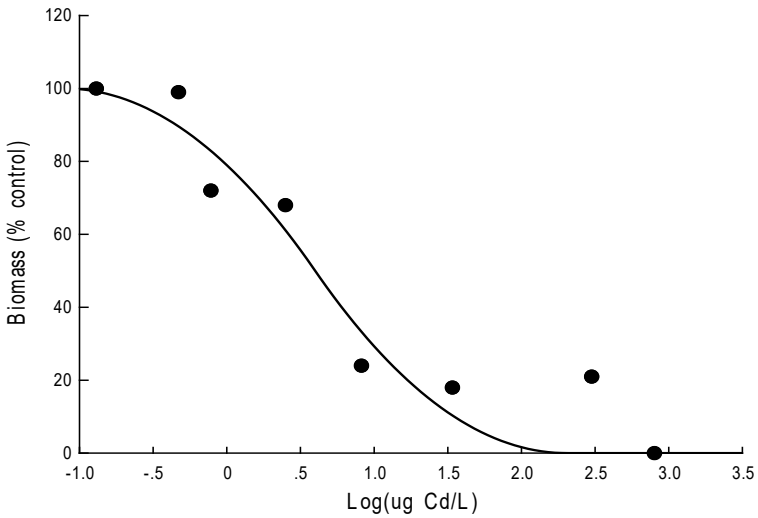


	Initial Gues	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	2	2.0712	0.43596	0.86083	3.2817
Slope	0.4	0.3442	0.17519	-0.1422	0.8306
Y-intercept	100	95.422	16.419	49.837	141.01
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	117.83	7.2582	1912.8	0.43596	2.0712
20	**10.079**	0.057509	1766.4	0.80811	1.0034
10	2.9189	0.002476	3441	1.1063	0.46523
5	**1.2153**	0.00019	7783.3	1.371	0.084671
0	0.14653	6.48E-08	331150	2.2886	-0.83407

EC20:EC5 = 8.293

Notes: Not core data. No effect within area of concern. Large SE for X50 and slope.

Rombough and Garside 1982	
Species: *Salmo salar*	
Test Endpoint: ELS Biomass	
C-R Curve Label: Cd-Chronic-37	
Test: 9.6°C	
Cd, (µg/L)	**Total Biomass (% control)**
0.13	100
0.47	99
0.78	72
2.5	68
8.2	24
34	18
79	Excluded
300	21
800	0

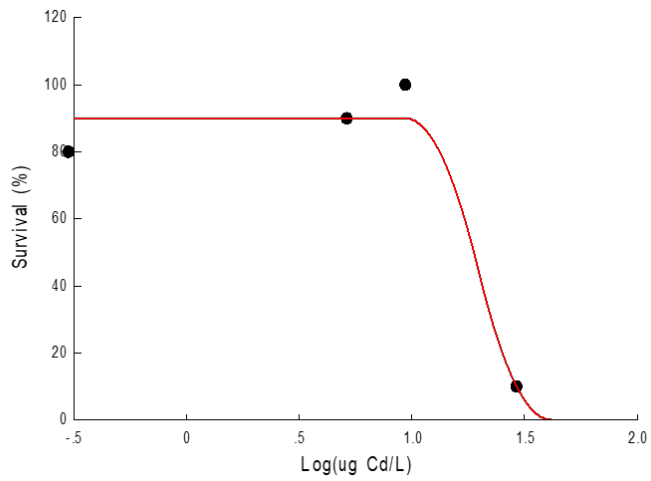


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.6	0.5999	0.13794	0.26238	0.93743
Slope	0.6	0.58586	0.14764	0.2246	0.94711
Y-intercept	100	100	0	1.00E+10	-1.00E+10
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	3.9802	1.8297	8.6582	0.13794	0.5999
20	**0.93872**	0.31795	2.7715	0.19215	-2.75E-02
10	0.45326	9.94E-02	2.0675	0.26936	-0.34365
5	**0.27087**	3.75E-02	1.9557	0.35087	-0.56723
0	7.82E-02	2.50E-03	2.4486	0.61135	-1.107

EC20:EC5 = 3.466

Notes: Poor model fit. Large SE (x50).

Brown et al 1994	
Species: *Salmo trutta*	
Test Endpoint: LC Survival	
C-R Curve Label: Cd-Chronic-38	
Test: (2 yr old) 95 week	
Cd, (µg/L)	**% Survival**
0.27	80
5.13	90
9.34	100
29.1	10

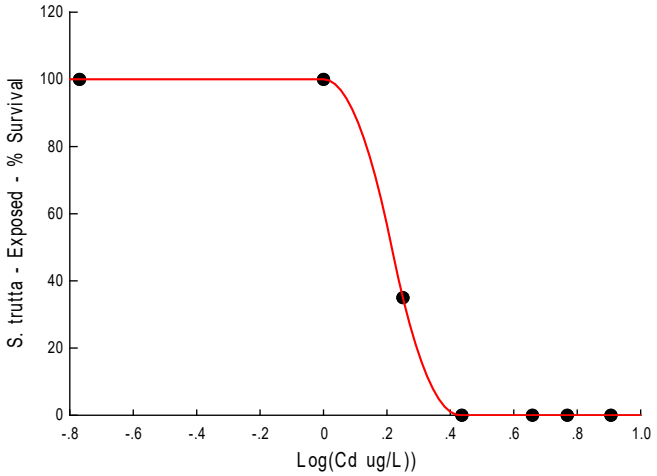


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	1.2	1.2934			
Slope	3	3.0997			
Y-intercept	90	90			
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	19.65				1.2934
20	**14.955**				1.1748
10	13.032				1.115
5	**11.824**				1.0728
0	9.3487				0.97075

EC20:EC5 = 1.265

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Davies and Brinkman 1994a	
Species: *Salmo trutta*	
Test Endpoint: ELS Survival	
C-R Curve Label: Cd-Chronic-39	
Test: Single	
Nominal Cd, (µg/L)	**% Survival (exposed)**
0.17	100
1.00	100
1.78	35
2.73	0
4.56	0
5.87	0
8.06	0

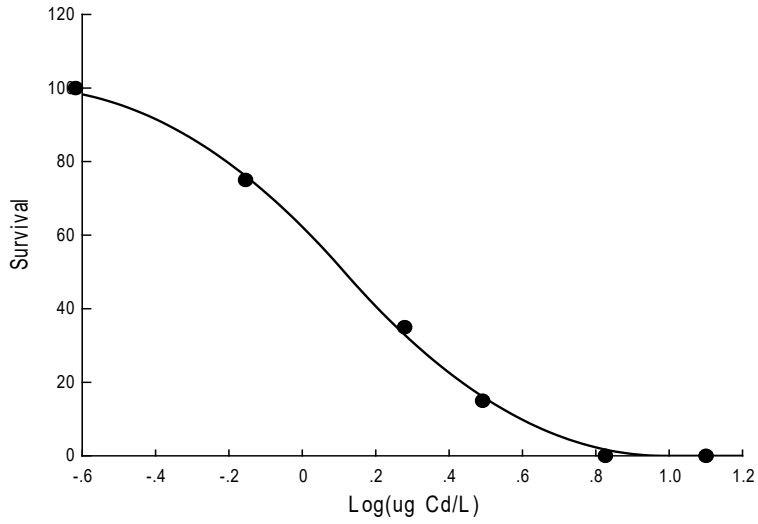


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.20721	0.21526			
Slope	3.4647	4.6457			
Y-intercept	100	100			
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	1.6416			4.1494	0.21526
20	**1.3682**			4.1494	0.13614
10	1.2482			4.1494	0.096271
5	**1.1697**			4.1494	0.068076
0	1			4.1494	6.267E-06

EC20:EC5 = 1.170

Notes: TRAP flagged for IP (No unique solution).

Davies and Brinkman 1994c	
Species: *Salmo trutta*	
Test Endpoint: 12 wk Fingerling Survival	
C-R Curve Label: Cd-Chronic-40	
Test: Single	
Cd, (µg/L)	**% Survival**
0.2	100
0.7	75
1.9	35
3.1	15
6.7	0
12.6	0

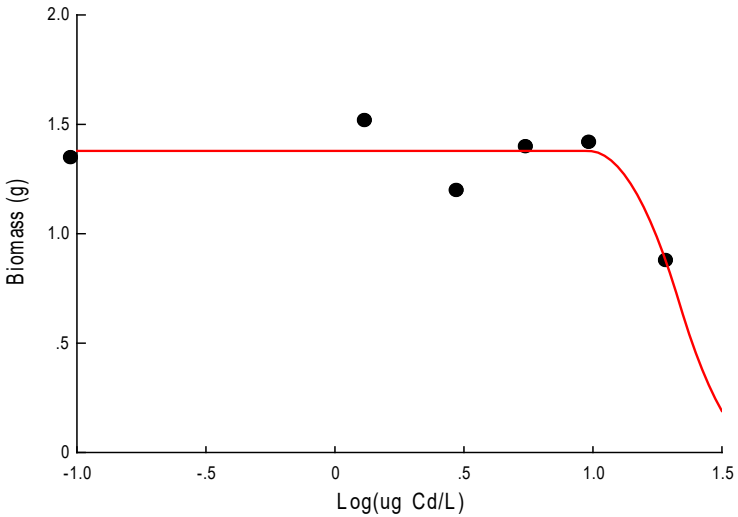


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.10544	0.11526	1.93E-02	5.37E-02	0.17682
Slope	1.2621	1.1483	6.57E-02	0.93911	1.3574
Y-intercept	100	99.848	2.0528	93.315	106.38
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	1.3039	1.1316	1.5025	1.93E-02	0.11526
20	**0.62399**	0.48398	0.80449	3.47E-02	-0.20483
10	0.43038	0.30691	0.60352	4.61E-02	-0.36615
5	**0.33096**	0.2227	0.49185	5.41E-02	-0.48022
0	0.17554	0.11327	0.27206	5.98E-02	-0.75562

EC20:EC5 = 1.885

Notes: No effect within area of concern.

Brinkman and Hansen 2004a; 2007	
Species: *Salmo trutta*	
Test Endpoint: ELS Biomass	
C-R Curve Label: Cd-Chronic-41	
Test: Hardness = 150 mg/L	
Dissolved Cd, (µg/L)	**Biomass (g)**
<0.1 (0.05)	1.35
1.30	1.52
2.95	1.20
5.47	1.40
9.62	1.42
19.1	0.88



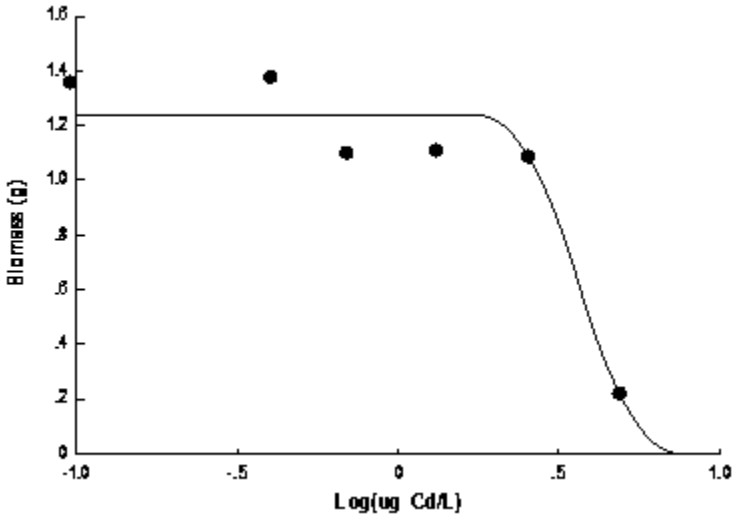
	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	1.3	1.3335	777.22	-2472.1	2474.8
Slope	2.2	2.8542	42260	-134490	134490
Y-intercep	1.4	1.378	0.067626	1.1628	1.5932

p	Xp	95% LCL	95% UCL	LogXp S.E.	LogXp
50	21.554	0	Infinity	777.22	1.3335
20	**16.023**	0	Infinity	1129.9	1.2048
10	13.799	0	Infinity	2090.5	1.1399
5	**12.415**	0	Infinity	2770.6	1.094
0	9.6199	0	Infinity	4412.2	0.98317

EC20:EC5 = 1.291

Notes: TRAP Flagged for IP (No Unique Solution).

Brinkman and Hansen 2004a; 2007	
Species: *Salmo trutta*	
Test Endpoint: ELS Biomass	
C-R Curve Label: Cd-Chronic-43	
Test: Hardness = 30 mg/L	
Dissolved Cd, (µg/L)	**Biomass (g)**
<0.1 (0.05)	1.360
0.40	1.378
0.69	1.101
1.31	1.111
2.54	1.087
4.87	0.222

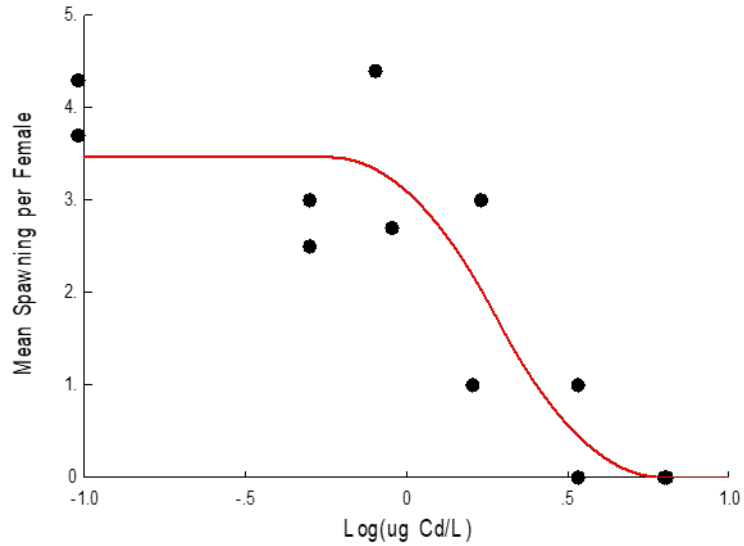


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.56	0.56265	0.052726	0.39486	0.73045
Slope	3	3.2113	1.1863	-0.564	6.9866
Y-intercep	1.4	1.2375	0.076038	0.99551	1.4795
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	3.653	2.4823	5.3759	0.052726	0.56265
20	**2.8067**	1.6439	4.7922	0.073006	0.4482
10	2.4576	1.2792	4.7215	0.089103	0.39052
5	**2.2373**	1.0427	4.8008	0.10419	0.34973
0	1.7834	1.6703E-05	190420	1.5801	0.25126

EC20:EC5 = 1.255

Notes: Poor model fit.

Benoit et al. 1976	
Species: *Salvelinus fontinalis*	
Test Endpoint: LC Reproduction	
C-R Curve Label: Cd-Chronic-44	
Test: First Generation	
Cd, (µg/L)	**Mean Spawning per Female**
Control (0.06)	4.3
Control (0.06)	3.7
0.5	2.5
0.5	3
0.9	2.7
0.8	4.4
1.7	3
1.6	1
3.4	-
3.4	1
6.3	-
6.4	-



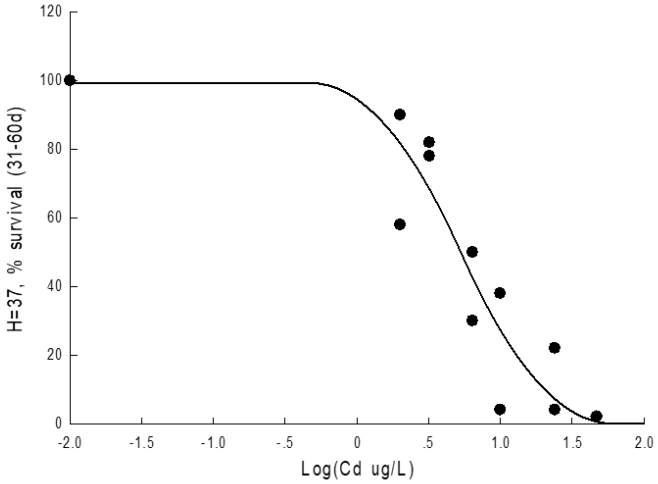
	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.3	0.27802	0.092816	0.068059	0.48799
Slope	3	1.9328	1.018	-0.37011	4.2357
Y-intercept	4	3.4658	0.39461	2.5731	4.3584

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	1.8968	1.1697	3.076	0.092816	0.27802
20	**1.2242**	0.57196	2.6203	0.1461	0.08786
10	0.98179	0.33446	2.882	0.20674	-0.00798
5	**0.83994**	0.19901	3.5451	0.27645	-0.07575
0	0.57628	0.046378	7.1606	0.48375	-0.23937

EC20:EC5 = 1.457

Notes: TRAP Flagged for IP (No Unique Solution). Large SE for slope.

Sauter et al. 1976	
Species: *Salvelinus fontinalis*	
Test Endpoint: ELS Survival	
C-R Curve Label: Cd-Chronic-45	
Test: Hardness= 37 mg/L; 31-60-d	
Cd, (µg/L)	**% Survival**
-	100
-	100
2.0	90
2.0	58
3.2	82
3.2	78
6.4	50
6.4	30
10	4
10	38
24	4
24	22
47	2
47	2

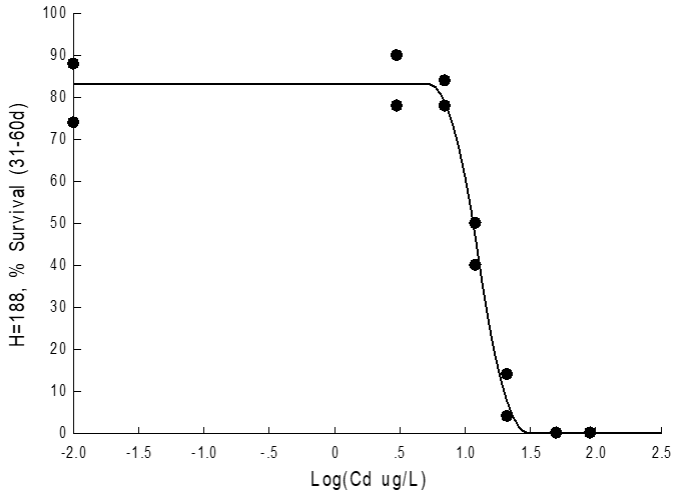


EC20:EC5 = 2.153

	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.75	0.72696	0.092068	0.52432	0.9296
Slope	0.95	0.94938	0.23593	0.43011	1.4687
Y-intercept	100	99.338	9.3625	78.731	119.94
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	5.3329	3.3444	8.5036	0.092068	0.72696
20	**2.1869**	0.96613	4.95	0.16119	0.33982
10	1.3954	0.46663	4.1728	0.21614	0.1447
5	**1.0156**	0.28847	3.5757	0.24836	0.0067307
0	0.47167	0.11639	1.9115	0.27612	-0.32636

Notes: Not core data.

Sauter et al. 1976	
Species: *Salvelinus fontinalis*	
Test Endpoint: ELS Survival	
C-R Curve Label: Cd-Chronic-46	
Test: Hardness= 188 mg/L; 31-60-d	
Cd, (µg/L)	**% Survival**
-	88
-	74
3	78
3	90
7	84
7	78
12	40
12	50
21	14
21	4
50	0
50	0
91	0
91	0

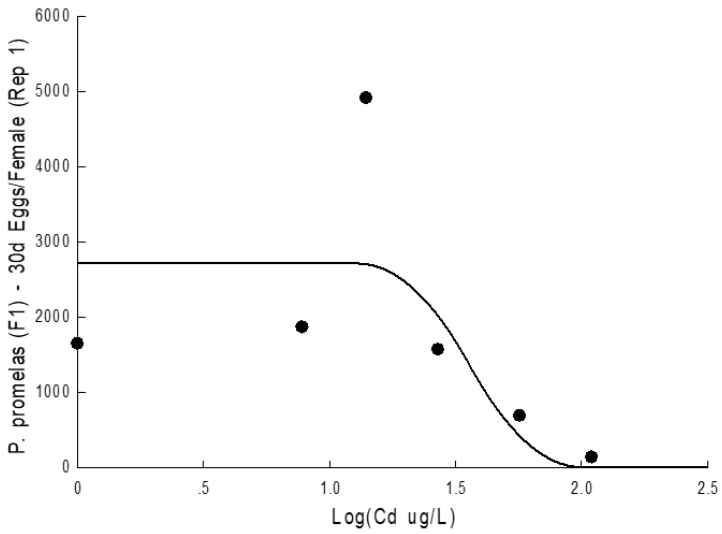


EC20:EC5 = 1.319

	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	1.1	1.1023	0.018162	1.0623	1.1422
Slope	2.6	2.6294	0.39099	1.7688	3.49
Y-intercept	82	83.184	2.5623	77.544	88.823
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	12.655	11.542	13.875	0.018162	1.1023
20	**9.1724**	7.8625	10.701	0.030408	0.96249
10	7.7989	6.2074	9.7986	0.045038	0.89204
5	**6.9538**	5.1042	9.4735	0.061015	0.84222
0	5.2717	3.4325	8.0966	0.084666	0.72195

Notes: Not core data.

Pickering and Gast 1972	
Species: *Pimephales promelas*	
Test Endpoint: LC Reproduction	
C-R Curve Label: Cd-Chronic-47	
Test: chronic test 2 (fry) - 30 d	
Cd, (µg/L)	**# of eggs per female - rep 1**
1.0	1645
7.8	1864
14	4916
27	1566
57	686
110	133

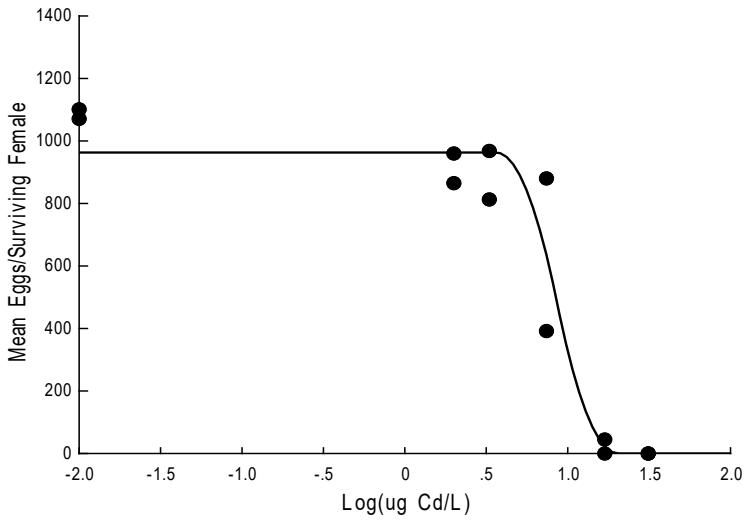


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	1.5	1.5565	0.30325	0.59142	2.5216
Slope	2.2	2.2461	4.0729	-10.716	15.208
Y-intercept	2800	2712.6	931.32	-251.25	5676.5
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	36.016	3.9032	332.34	0.30325	1.5565
20	**24.709**	0.95597	638.67	0.44381	1.3929
10	20.436	0.2458	1699	0.60325	1.3104
5	**17.868**	0.042657	7484.2	0.82392	1.2521
0	12.92	8.4342E-12	1.9793E+13	3.8289	1.1113

EC20:EC5 = 1.383

Notes: Unacceptable noise at low level effects; large SE for X50 and slope.

Carlson et al. 1982	
Species: *Jordanella floridae*	
Test Endpoint: LC Reproduction	
C-R Curve Label: Cd-Chronic-49	
Test: 0.004 mg/L taconite tailings	
Cd, (µg/L)	**Mean # eggs/Surviving female (adjusted)**
0	1101
0	1071
2.0	960
2.0	865
3.3	813
3.3	968
7.4	392
7.4	880
16.9	45
16.9	0
31.2	-
31.2	-

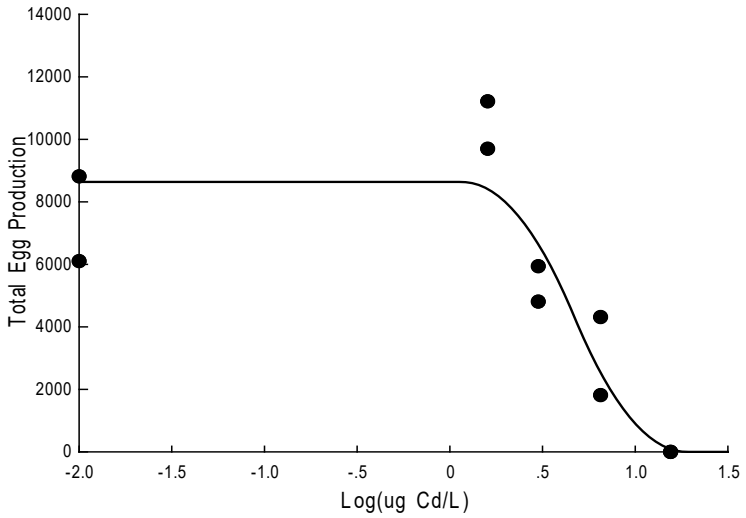


EC20:EC5 = 1.313

	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.9	0.93497	0.053248	0.81451	1.0554
Slope	2.5	2.6759	1.4008	-0.49289	5.8448
Y-intercept	1086	963	58.203	831.34	1094.7
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	8.6093	6.524	11.361	0.053248	0.93497
20	**6.275**	3.8889	10.125	0.091855	0.79762
10	5.3505	6.437E-07	44471000	3.0589	0.72839
5	**4.7802**	1.3356	17.109	0.2448	0.67944
0	3.6414	1.8307	7.2431	0.13202	0.56127

Notes: Poor model fit; large SE for slope.

Carlson et al. 1982	
Species: *Jordanella floridae*	
Test Endpoint: LC Reproduction	
C-R Curve Label: Cd-Chronic-50	
Test: 0.08 mg/L taconite tailings	
Cd, (µg/L)	**Total egg production**
0	8817
0	6106
1.6	11216
1.6	9699
3.0	4810
3.0	5941
6.5	1820
6.5	4314
15.5	0
15.5	0
29.9	-
29.9	-

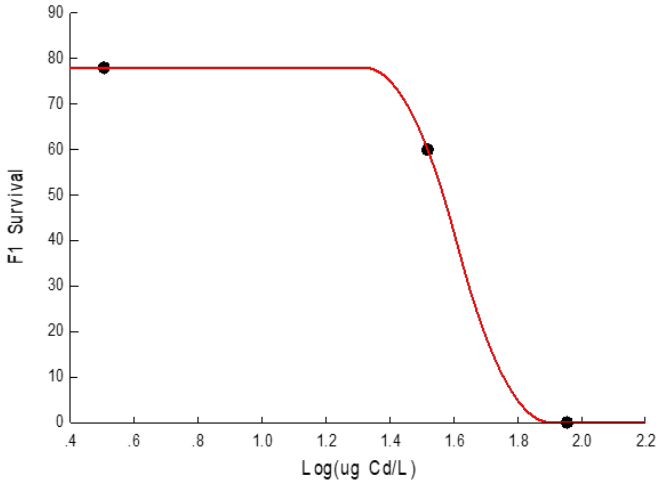


EC20:EC5 = 1.554

	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.65	0.67149	0.10809	0.41591	0.92707
Slope	1.6	1.6514	0.83649	-0.32661	3.6294
Y-intercept	8959.5	8634.7	1155.5	5902.3	11367
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	4.6934	2.6056	8.4541	0.10809	0.67149
20	**2.8114**	1.0547	7.4939	0.18006	0.44892
10	2.1714	0.60344	7.8138	0.23518	0.33675
5	**1.809**	0.42892	7.6292	0.26433	0.25743
0	1.164	0.23096	5.8659	0.29704	0.065935

Notes: Unacceptable noise at low level effects; large SE for slope.

Eaton 1974	
Species: *Lepomis macrochirus*	
Test Endpoint: Survival	
C-R Curve Label: Cd-Chronic-51	
Test: F-1 Generation	
Cd, (µg/L)	**F1 Survival**
3.2	78
33	60
90	0
239	-
757	-
2140	-



	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	1.6	1.6118			
Slope	3	3.4358			
Y-intercept	78	78			
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	40.911				1.6118
20	**31.979**				1.5049
10	28.245				1.4509
5	**25.871**				1.4128
0	20.931				1.3208

EC20:EC5 = 1.236

Notes: TRAP flagged for IP (No unique solution).

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

September 4, 2018

Jennifer Anderson
Acting Assistant Regional Administrator
Greater Atlantic Region Fisheries Office
National Marine Fisheries Service
55 Great Republic Drive
Gloucester, MA 01930

Dear Ms. Anderson:

This letter is to request the National Marine Fisheries Service (NMFS) concurrence under Section 7 of the Endangered Species Act that EPA's approval of Virginia's adoption of statewide amendments to the aquatic life water quality criteria for cadmium and ammonia under Section 303(c)(3) of the Clean Water Act (CWA) are not likely to adversely affect listed species in Virginia.

On September 18, 2017, the Virginia Department of Environmental Quality (VADEQ) announced for public review and comment proposed amendments to its cadmium and ammonia criteria. The comment period ended December 8, 2017. Virginia is expected to respond to public comments and publish the revised cadmium and ammonia criteria under Virginia's Water Quality Standards Title 9 VACS 25-260 Water Quality Standards Regulations, and submit to EPA within the coming months.

The enclosed Biological Evaluation documents EPA's analysis of the possible effects of our approval of the statewide cadmium and ammonia aquatic life water quality criteria on listed species and designated critical habitats under the NMFS jurisdictions. EPA concludes that the actions EPA intends to take are not likely to adversely affect threatened and endangered species and designated critical habitats. We ask that NMFS provide a letter indicating your concurrence with our findings within thirty (30) days of receipt of this letter. If you have any questions, please contact me at (215) 814-5717, or Cheryl Atkinson at (215) 814-3392.

Sincerely,

Evelyn S. MacKnight, Associate Director
Water Protection Division

Enclosure

Biological Evaluation

For the Approval of Virginia's Water Quality Standards Title 9 VACS 25-260 Water Quality Standards Regulations Adoption of Ammonia and Cadmium

Prepared by U.S. Environmental Protection Agency
for the U.S. Fish and Wildlife Service

9-4-2018

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Executive Summary

This biological evaluation (BE) assesses the potential effects which may occur to federally listed endangered or threatened species of fish, wildlife, or plants ("listed species") and habitat of such species that have been designated as critical ("critical habitat") under the jurisdiction U.S. Fish and Wildlife Service (FWS). The specific focus of this evaluation is the U.S. Environmental Protection Agency (EPA), Clean Water Act (CWA) approval of Virginia's proposed updates to its aquatic life criteria to be consistent with the EPA's recommended criteria for ammonia and cadmium. These criteria consider the best available science, including local and regional information, as well as applicable EPA policies, guidance, and legal requirements, to protect aquatic life including listed species. EPA finds that our approval of Virginia's acute and chronic ammonia and cadmium criteria is Not Likely to Adversely Affect (NLAA) aquatic and aquatic-dependent listed species through direct and indirect effects and is Not Likely to Adversely Modify the designated critical habitats.

EPA views the ammonia and cadmium criteria revisions as beneficial to the conservation and protection of aquatic life, including listed species and their food sources in Virginia. The revisions are expected to aid in the conservation role of critical habitat. Many of the listed species occurring in Virginia freshwaters are not sensitive to acute and chronic freshwater ammonia and cadmium exposures at the respective criteria magnitudes under conservative exposure conditions. For those listed species that are relatively sensitive to acute and/or chronic freshwater ammonia and cadmium exposures, aquatic life criteria are implemented conservatively and are based on the fifth centile of sensitive genera and will, therefore, protect listed species and the broader aquatic community, including prey items.

Introduction

Endangered Species Act

Federally protected species are listed as endangered or threatened under the Endangered Species Act (ESA) of 1973, as amended, 16 U.S.C. section 1536, and its implementing regulations, 50 CFR Part 402. Section 7(a) of the ESA grants authority to impose requirements upon Federal agencies regarding endangered or threatened species of fish, wildlife, or plants ("listed species") and habitat of such species that have been designated as critical ("critical habitat"). The ESA requires every Federal agency, in consultation with the Secretary of the Interior, to ensure that any action it authorizes, funds, or carries out, in the United States or upon the high seas, is not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat.

The United States Fish and Wildlife Service (FWS) administers Section 7 consultations for freshwater species, while United States National Marine Fisheries Service (NMFS) administers Section 7 consultations for marine species and anadromous fish. This biological evaluation (BE) represents an effort by the EPA to informally consult with FWS regarding the EPA approval action of Virginia WQS.

CWA Water Quality Standards Program

WQS defines the water quality goals for a waterbody by designating the use or uses of the water, by setting criteria necessary to protect the uses, and by preventing or limiting degradation of water quality through anti-degradation provisions. The CWA provides the statutory basis for the WQS program. Section 101(a)(2) of the CWA sets out a national goal that wherever attainable, waters achieve a level of quality that provides for the protection and propagation of fish, shellfish, and wildlife, and for recreation in and on the water ("fishable/swimmable").

Under Section 303(c) of the CWA and 40 CFR Part 131, states and authorized tribes (state) have the primary responsibility to develop and adopt WQS to protect their waters. Also under the CWA Section 303(c) and 40 CFR Part 131, the EPA is required to review and either approve or disapprove new and revised state WQS. New and revised state WQS are not considered effective for CWA purposes until approved by the EPA under CWA Section 303(c).

ESA Consultation for WQS

The EPA consults with the FWS and NMFS (Services) under Section 7 of ESA when approving certain changes to state WQS. The EPA must determine whether the proposed WQS may or may not affect listed species or their critical habitat. If the EPA determines that their action will have "no effect" on listed species or critical habitat, it is not required to consult with the Services. If the EPA determines that listed species and critical are not likely to be adversely affected, and the Service agrees with that determination, the Service provides concurrence in writing, and no further consultation is required. Finally, if the EPA determines that the WQS are likely to affect listed species adversely, it must initiate formal consultation with the Services.

Informal consultation includes a consultation in which the action agency determines that an action may affect, but is not likely to adversely affect listed species or critical habitat. An informal consultation generally involves the EPA developing a BE. To assist in evaluating the effect of approving a water quality criterion, the BE typically includes an evaluation of whether the presence of a pollutant at criterion magnitude, duration, and exceedance frequency is not likely to adversely affect any pertinent listed species or their critical habitat.

Description of the Proposed Federal Action

The Federal action being evaluated under ESA, Section 7 is the approval by the EPA of the new and revised provisions regarding Virginia's proposed updates to its cadmium and ammonia aquatic life water quality criteria. These criteria are adopted and implemented to maintain and protect the waters of Virginia, and they provide for the propagation and protection of aquatically-dependent listed species. The WQS revisions discussed below consider the best available science, including local and regional information, as well as the applicable EPA policies, guidance, and legal requirements, to protect aquatic life.

Purpose of the Proposed Federal Water Quality Criteria

Section 304(a) of the CWA authorizes the EPA to develop and revise recommended criteria for specific pollutants reflecting the latest scientific knowledge. These national recommended criteria do not themselves alter the applicable WQS of any state but serve as important scientific resources for states engaged in adopting new WQS or revising existing WQS. Water quality criteria adopted into state WQS could have the same numerical values as the national recommendation. However, states might want to adjust the water quality criteria developed under Section 304(a) to reflect local environmental conditions. Alternatively, states may use different data and assumptions than the EPA in deriving numeric criteria that are scientifically defensible and protective of designated uses.

In 2013, the EPA published revised recommended criteria for ammonia and in 2016, the EPA published revised recommended criteria for cadmium, both of which are for the protection of aquatic life. The updated criteria are reflective of new toxicity data, which were unavailable during past updates. The criteria are intended to be protective of aquatic life, including federally listed species. Virginia proposed updates to its aquatic life ammonia and cadmium criteria to be consistent with the EPA's recommended criteria for ammonia and cadmium; therefore, the EPA's criteria documents are used throughout this BE to evaluate the potential effects of Virginia's WQS revisions on listed species (Ammonia, USEPA 2013; Cadmium, USEPA 2016). These criteria documents provide justification for water quality criteria, including comprehensive literature reviews and toxicological analyses.

Virginia's Ammonia and Cadmium Aquatic Life Criteria Revisions

On September 18, 2017, the Virginia Department of Environmental Quality (VADEQ) announced for public review and comment its proposed amendments to its cadmium and ammonia aquatic life water quality criteria. The comment period ended December 8, 2017. Virginia is expected to respond to public comments and publish revised cadmium and ammonia aquatic life water quality criteria within the coming year. Pursuant to the EPA's authority outlined in CWA Section 303(c) and 40 CFR Part 131, the EPA must review and approve the final new or revised cadmium and ammonia aquatic life water quality criteria. If the revisions to the aquatic life criteria are consistent with the revisions submitted to the EPA during the public comment period and evaluated below, the EPA requests concurrence from the Services to confirm that the revisions are not likely to adversely affect listed species or their critical habitat. If revisions to the aquatic life criteria significantly differ from what was published during the public comment period and evaluated below, the EPA will resubmit another BE for informal consultation.

Virginia's amendment to its cadmium criteria for the protection of fresh and saltwater aquatic life is based on the EPA's national recommended water quality criteria issued in 2016. The EPA updated national recommended cadmium criteria account for many new laboratory toxicity tests for cadmium. In addition, the effect of total hardness on cadmium toxicity was also revised using the newly acquired data, including toxicity data for 75 new species and 49 new genera.

Virginia has proposed to amend its freshwater ammonia aquatic life criteria to be consistent with the EPA's 2013 nationally recommended freshwater ammonia aquatic life criteria. Like Virginia's current criteria, the proposed criteria are calculated as a function of temperature and pH and account for the presence or absence of trout and early life stages of fish. The recalculated ammonia criteria now incorporate toxicity data for freshwater mussels in the family unionidae, which are the most sensitive organisms in the recalculation data base. The new criteria are about twice as stringent as the existing criteria primarily because more recent toxicity data show that mussels and snails (including endangered species) are very sensitive to ammonia and the current ammonia criteria do not provide sufficient protection for these species. Site specific options to calculate criteria omitting mussel toxicity data are proposed to be used in waters where a demonstration has been made that mussels are absent; however, Virginia's consultation with FWS and the Virginia Department of Game and Inland Fisheries indicate freshwater mussels should be considered ubiquitous in Virginia and likely to be present in any perennial waterbody.

Action Area

The EPA's proposed approval of the Virginia revised ammonia and cadmium criteria applies to all waters of the United States (within the Commonwealth of Virginia) under Federal jurisdiction. Jurisdiction over non-navigable, isolated, and intrastate waters would likely have to be determined on a case-by-case basis. The area evaluated for action is the surface waters of the Commonwealth. Waters of the Commonwealth are defined in section Title 62.1 of the Waters of the State, Ports and Harbors Law as "water includes all waters, on the surface and under the ground, wholly or partially within or bordering the Commonwealth or within its jurisdiction and which affect the public welfare."

According to ESA. the action area is defined as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action" (50 CFR Part 402.02). This includes the project's footprint as well as the area beyond it that may experience direct or indirect effects that would not occur but for the action.

Listed Species and Critical Habitat within the Action Area

The EPA obtained a current list of species believed to or known to occur in Virginia from the FWS Information, Planning and Consultation system (IPaC) to determine if any listed, proposed or candidate species may be present in the action area. IPaC generated a letter dated February 13, 2018, that enclosed a list of endangered and threatened species believed to or known to occur in Virginia. This letter is included as an attachment to this BE.

1 Effects Assessment Methodologies

1.1 Acute Effect Assessment Methodology: Direct Effects

1.1.1 Direct Acute Effects to Freshwater Animals

The protectiveness of the freshwater acute ammonia and freshwater acute cadmium criteria magnitudes was assessed by identifying or estimating acute toxicity values (i.e., LC_{50}) for Virginia aquatic listed species that were then adjusted to represent protective low effect threshold concentrations as described below. Acute toxicity values used to develop the acute effects

assessments were obtained from Appendix A of their respective 304(a) aquatic life criteria documents (Ammonia, USEPA 2013; Cadmium, USEPA 2016) and were specifically used to derive the acute criterion (i.e., bold values in Appendix A of USEPA 2013 and underlined values in USEPA 2016). These data were identified from EPA's ECOTOX database, the open and grey literature, and have been subjected to extensive data quality review (see Stephan et al. 1985 for data quality objectives). Acute ammonia values have been normalized to a pH of 7 (all freshwater animals) and 20°C (freshwater invertebrates only), consistent with criteria derivation (USEPA 2013). Acute cadmium toxicity data have been normalized to a total hardness of 100 mg/L as $CaCO_3$ consistent with criteria derivation (USEPA 2016). Ideally, species-specific toxicity data for listed species of concern would be available to support an acute effects assessment; however, data limitations often required use of surrogate toxicity data.

EPA considered acute toxicity data at the closest taxonomic level possible to calculate geometric mean acute toxicity values for each species assessed (i.e., LC_{50}). Considering surrogate toxicity data at the most phylogenetically-related taxonomic level possible accounts for genetically-derived traits conserved across taxa that may directly influence sensitivity to a pollutant. Geometric mean acute toxicity values at the genus, family, and order-level were calculated as the geometric mean of lower taxonomic-level geometric mean values, since these mean values are meant to represent the sensitivity for a particular taxon. Species-specific and surrogate acute toxicity data obtained from Appendix A of USEPA (2013) and USEPA (2016) represent sensitivity expressed as a concentration that will acutely affect half of the species population. Acute toxicity data (expressed as LC_{50}) were transformed to an acute minimum effect threshold concentration (i.e., LC_5) which represents a concentration that is expected to affect 5% of the test population of a listed species under continuous exposure conditions in a 96-hour toxicity test for fish, or 48-hour toxicity test for most invertebrates. Representing acute minimum effect thresholds as an LC_5 value is conservative because high-quality toxicity tests are considered acceptable even when up to 10% mortality is observed in the control treatment (organisms not exposed to the pollutant). Moreover, the use of a five percent toxicity value to represent an acute minimum effect threshold to an individual is consistent with reasonable and prudent measures (RPMs) outlined in a recent biological opinion (NOAA 2012).

Raw empirical acute toxicity data may be used to calculate LC_5 values directly from the concentration-response (C-R) curves of the listed species-specific toxicity tests, when available. However, not all acute tests provide concentration-response data. Therefore, species-specific, or surrogate LC_{50} values (which represent listed species 50% effect level), were transformed to an acute minimum effect threshold concentration through an acute taxonomic adjustment factor (TAF) or an acute mean adjustment factor (MAF). An acute TAF was calculated by averaging (geometric mean) the ratios of LC_{50}:LC_5 from chemical-specific acute toxicity tests conducted using species in the closest possible phylogenetic proximity (same species, genus, family, or order) as the listed species that is being assessed (genus, family, and order-level acute TAFs were calculated as the geometric mean of lower taxonomic-level geometric mean acute TAFs to ensure adequate representation of all lower-level taxa for a particular taxon). When data availability did not allow for the development of an acute TAF within the same order as the species being assessed, EPA considered applying an acute invertebrate or vertebrate TAF

(depending on whether the listed species assessed was an invertebrate or vertebrate). The acute invertebrate TAF and the acute vertebrate TAF were calculated as the geometric mean of genus-level LC_{50}:LC_5 ratios of invertebrates and vertebrates, respectively. An acute MAF was used to adjust species effect concentrations (i.e., LC_{50}) to low effect threshold concentrations (i.e., LC_5) when; 1) an acute TAF was not available within the same order as the listed species being assessed and 2) when the acute invertebrate TAF and the acute vertebrate TAF were not significantly different via a two-sample t-test assuming unequal variances ($\alpha = 0.05$). The acute MAF was calculated as the geometric mean of all genus-level LC_{50}:LC_5 ratios available. Acute invertebrate and vertebrate TAFs and the acute MAF were calculated as the geometric mean of their respective genus-level LC_{50}:LC_5 ratios to limit the influence of LC_{50}:LC_5 ratios from species that are overly represented in a dataset, similar to criteria derivation (Stephan et al. 1985).

Listed species-specific or surrogate LC_{50} values were then divided by an appropriate adjustment factor (i.e., acute TAF or acute MAF depending on data availability) to derive an acute minimum effect threshold concentration. Dividing LC_{50} values by an adjustment factor to identify a minimum-level effect concentration is an approach that is fundamentally similar to acute criteria derivation[1], but is more specific to the chemical and species assessed. Acute minimum effect threshold concentrations were then compared to corresponding criteria magnitudes (i.e., criterion maximum concentration [CMC]) to assess potential direct adverse effects of ammonia or cadmium exposures at the acute criterion concentration over conservative exposure durations.

Vertebrate sensitivity to ammonia in freshwaters is dependent on pH, due to ammonia speciation differences, with tolerance decreasing as pH increases. Invertebrate sensitivity is influenced by both pH and temperature, with invertebrate tolerance increasing as temperature decreases (see USEPA 2013). When salmonids in the Genus *Oncorhynchus* are present, EPA's recommended acute freshwater ammonia criterion magnitude is limited to protect adult rainbow trout (a commercially and recreationally important species), which are the most sensitive species at lower temperatures (i.e., < 15.7°C). Thus, the CMC is both pH- and temperature-dependent. The CMC increases with decreasing temperature as a result of increased invertebrate insensitivity until it reaches a plateau of 24.10 mg total ammonia nitrogen (TAN)/L at 15.7°C and below, where the most sensitive taxon is the temperature-sensitivity-invariant rainbow trout. Unlike the criterion magnitude, however, invertebrate sensitivity to ammonia continues to decrease as temperature decreases. Figure 1-1 depicts the change in the ammonia CMC across water chemistries (i.e., the change in acute criterion magnitude with temperature at pH 6, 7, 8, and 9),

[1]The Final Acute Value (FAV; fifth centile of genus mean acute values) is divided by 2.0 to derive the Criterion Maximum Concentration (CMC). The FAV was divided by 2.0 to ensure the CMC is representative of a concentration that will not severely adversely affect too many organisms. To support the development of the 1985 Guidelines, a Federal Register notice published in 1978 (Vol 43, pp. 21506-21518; USEPA 1978) outlined the derivation of a generic LC_{50} to LC_{low} (i.e., 0-10% effect) adjustment factor of 0.44 (or divide by 2.27). The adjustment factor of 2.27 was derived as the "*geometric mean of the quotients of the highest concentration that killed 0-10% of the organisms divided by the LC_{50} in 219 acute toxicity tests*." The geometric mean adjustment factor (2.27) outlined in the 1978 Federal Register notice was subsequently rounded to 2.0 in the 1985 Guidelines (Stephan et al. 1985).

and how the acute minimum effect threshold for dwarf wedgemussel: Family Unionidae (from Section 2.6.1) changes with the criterion magnitude proportionally (factor difference of 2.664) until 15.7°C. The acute effects assessment was developed using toxicity data normalized to reference conditions (pH = 7, temperature = 20°C) and compared to the corresponding CMC in those same reference conditions. Because species sensitivity and the CMC both change similarly across water chemistries, conclusions based on reference conditions translate to other water chemistries.

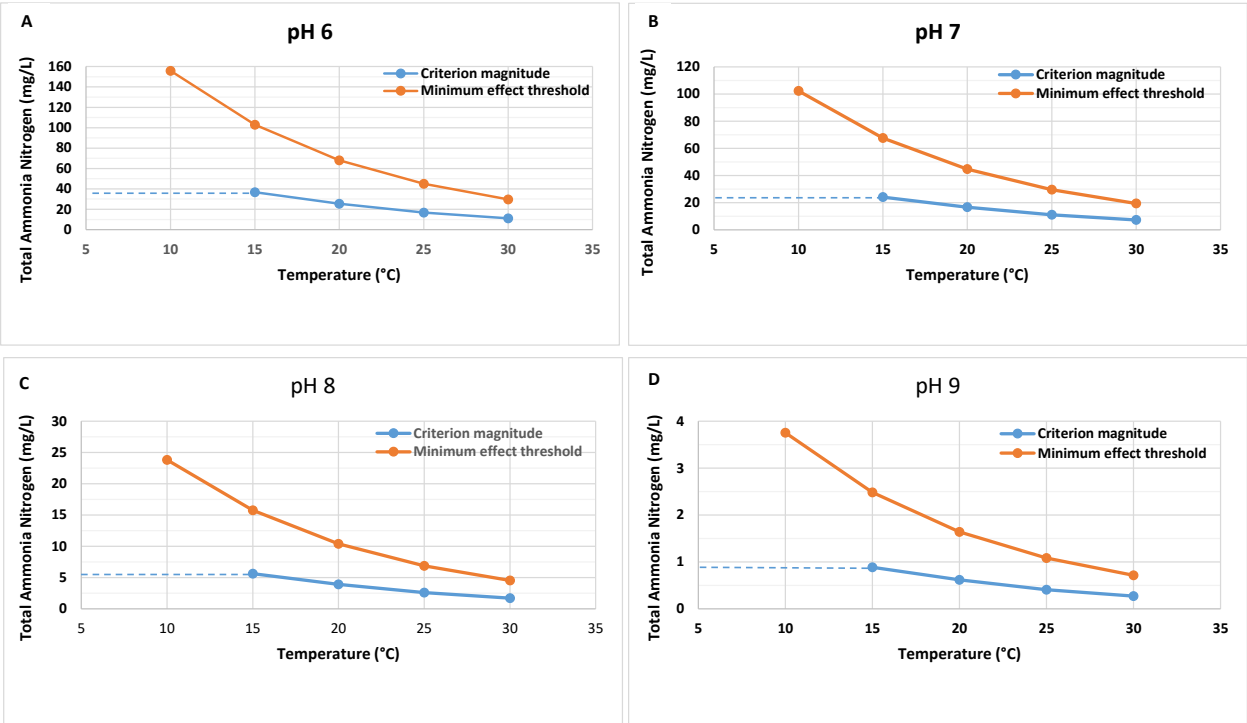

Figure 1-1. Acute ammonia criterion magnitudes extrapolated across a temperature gradient at pH 6, 7, 8 and 9 (Panels A-D). The acute minimum threshold concentration calculated for dwarf wedgemussel (per Section 2.6.1 of this document) is overlaid on the acute criterion magnitude. Using the depiction at pH 7 (Panel B) as the example, the criterion magnitude increases with decreasing temperature as a result of increased invertebrate tolerance until the CMC reaches a plateau of 24.10 mg TAN/L at 15.7°C and below, where the most sensitive taxa is the temperature-sensitivity-invariant rainbow trout. The criterion plateau (indicated by the dotted line) also changes with pH. The dwarf wedgemussel acute minimum effect threshold continues to decrease as temperature decreases. In waters warmer than 15.7°C, the factor difference between the acute criterion magnitude and acute minimum effect threshold for dwarf wedgemussel is 2.664.

In contrast to ammonia, species sensitivity to cadmium in freshwaters is only dependent on water hardness, with tolerance increasing as hardness increases (see USEPA 2016). The freshwater cadmium CMC increases with increasing hardness across the range of hardness in typical ambient surface water (acute toxicity hardness slope 0.9789). Figure 1-2 depicts the change in the cadmium CMC across water hardness of 25 to 400 mg/L as $CaCO_3$, and how the acute minimum effect threshold for dwarf wedgemussel (from Section 3.6.1) changes with the criterion

magnitude proportionally (factor difference of 14.94). The acute freshwater cadmium effects assessment was developed using toxicity data normalized to a reference condition (hardness = 100 mg/L) and compared to the corresponding CMC in those same reference conditions. Because species sensitivity to acute cadmium exposures in freshwater and the freshwater cadmium CMC both change similarly across water chemistries, conclusions based on reference conditions translate to other water chemistries.

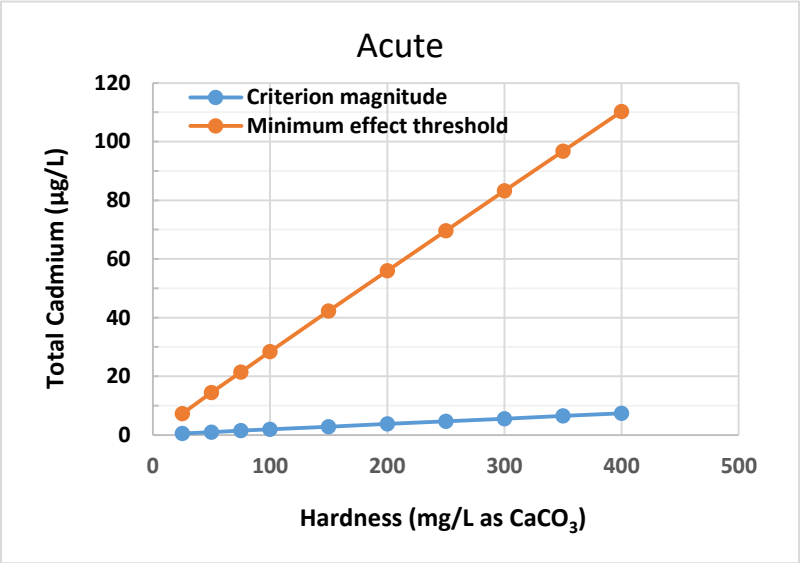

Figure 1-2. Acute cadmium criterion magnitudes extrapolated across a gradient of water hardness, overlaid with the dwarf wedgemussel acute minimum effect threshold concentration (Section 3.6.1 of this document). The freshwater acute cadmium criterion magnitude and the dwarf wedgemussel acute minimum effect threshold both increase with increasing water hardness. The factor difference between the acute criterion magnitude and acute minimum effect threshold for dwarf wedgemussel is 14.94.

Assessing an acute criterion magnitude alone does not consider the duration and frequency components of the criterion and represents an overly conservative exposure scenario that assumes a pollutant concentration in all Virginia freshwaters will be at the acute criterion magnitude indefinitely. If a listed species acute minimum effect threshold concentration is greater than the corresponding acute criterion magnitude, then a refined assessment and consideration of the criterion duration and realistic exposure is not necessary, and approval of the acute criterion is Not Likely to Adversely Affect (NLAA) that particular listed species through direct acute effects in freshwaters.

1.1.2 Direct Acute Effects to Freshwater Plants

Five listed aquatic/semi-aquatic plant species occur in Virginia freshwaters. Given limited plant toxicity data relative to animals, direct effects of EPA's approval of the acute ammonia and cadmium freshwater criteria to aquatic/semi-aquatic freshwater plants were evaluated through a qualitative approach by considering sensitivity of plants relative to most-sensitive taxa used to derive the acute ammonia and cadmium criteria for freshwaters.

1.1.3 Direct Acute Effects to Estuarine/Marine Animals

In additional to the freshwater cadmium criterion, Virginia has also proposed to adopt the estuarine/marine acute cadmium criterion (USEPA 2016). Virginia has not proposed to adopt any estuarine/marine ammonia criteria There are no animal species in Virginia under the jurisdiction of FWS that may be directly affected EPA's estuarine/marine acute cadmium criterion (USEPA 2016). Saltwater and anadromous species with range and/or critical habitat in Virginia are subject to consultation with NMFS.

1.1.4 Direct Acute Effects to Estuarine/Marine Plants

One listed aquatic/semi-aquatic plant occurs in Virginia estuarine/marine waters. Given limited saltwater toxicity data, direct effects of EPA's approval of the acute cadmium estuarine/marine criterion to an estuarine/marine plant was evaluated through a qualitative approach by considering sensitivity of plants relative to most-sensitive taxa used to derive the acute cadmium criterion for estuarine/marine waters.

1.2 Chronic Effect Assessment Methodology: Direct Effects

1.2.1 Direct Chronic Effects to Freshwater Animals

The protectiveness of the chronic freshwater ammonia and chronic freshwater cadmium criteria magnitudes was assessed by identifying or estimating chronic toxicity values (i.e., EC_{20}) for Virginia aquatic listed species that were then adjusted to represent protective low effect threshold concentrations as described below. Ammonia chronic toxicity values used to develop the chronic effects assessments were obtained from Appendix B of the ammonia 304(a) aquatic life criteria document (USEPA 2013), and cadmium chronic toxicity data were obtained from Appendix C of the cadmium criteria document (USEPA 2016). These data were specifically used to derive the ammonia and cadmium criteria (i.e., bold values in Appendix B or underlined values in Appendix C, respectively) and were identified from EPA's ECOTOX database, the open and grey literature, and have been subjected to extensive data quality review (see Stephan et al. 1985 for data quality objectives). Chronic ammonia toxicity data (i.e., EC_{20}) used to support the effects assessment have been normalized to a pH of 7 (all freshwater species) and 20°C (freshwater invertebrates only), consistent with criteria derivation (USEPA 2013), and chronic cadmium toxicity data have been normalized to a total hardness of 100 mg/L as $CaCO_3$, consistent with criteria derivation (USEPA 2016).

Ideally, species-specific toxicity data would be available to support a chronic effects assessment; however, data limitations often required use of surrogate toxicity data. EPA considered chronic toxicity data at the closest taxonomic level to calculate geometric mean chronic toxicity values for each species assessed (i.e., EC_{20}). Considering surrogate toxicity data at the most phylogenetically-related taxonomic level possible accounts for genetically-derived traits conserved across taxa that may directly influence sensitivity to a pollutant. Geometric mean chronic toxicity values at the genus, family, and order-level were calculated as the geometric mean of lower taxonomic-level geometric mean values, since these mean values are meant to represent the sensitivity for a particular taxon.

Unlike acute criteria derivation, which typically uses a generic LC_{50} to LC_{low} adjustment factor (i.e., 2.0, Stephan et al. 1985), chronic criteria are based directly on chronic effect concentrations (e.g., EC_{20}) and do not incorporate a generic EC_x to EC_{low} adjustment factor. However, a concentration that results in chronic effects to 20% of a listed species population may not be considered acceptable for listed species. Therefore, a similar convention used for the acute assessment methodology was applied to the chronic effects assessment methodology to determine a chronic minimum effect threshold concentration (i.e., EC_5) from chronic toxicity values.

Raw empirical chronic toxicity data may be used to calculate EC_5 values directly from the concentration-response (C-R) curves of the listed species-specific toxicity tests, when available. However, not all chronic tests provide concentration-response data. Therefore, species-specific, or surrogate EC_{20} values (which represent listed species 20% effect level), were transformed to a chronic minimum effect threshold concentration through the use of a chronic taxonomic adjustment factor (TAF) or a chronic mean adjustment factor (MAF), in the same manner as the acute adjustment factors were, as described above. Specifically, a chronic TAF was calculated by averaging (geometric mean) the ratios of EC_{20}:EC_5 from chemical specific chronic toxicity tests conducted using species in the closest possible phylogenetic proximity (same species, genus, family, or order) as the listed species that is being assessed (genus, family, and order-level chronic TAFs were calculated as the geometric mean of lower taxonomic-level geometric mean chronic TAFs to ensure adequate representation of all lower-level taxa for a particular taxon). When data availability did not allow for the development of a chronic TAF within the same order as the species being assessed, EPA considered applying a chronic invertebrate or vertebrate TAF (depending on whether the species assessed was an invertebrate or vertebrate). The chronic invertebrate TAF and the chronic vertebrate TAF were calculated as the geometric mean of genus-level EC_{20}:EC_5 ratios of invertebrates and vertebrates, respectively. A chronic MAF was used to adjust species effect concentrations (i.e., EC_{20}) to low effect threshold concentrations (i.e., EC_5) when; 1) a chronic TAF was not available within the same order as the listed species being assessed and 2) when the chronic invertebrate TAF and the chronic vertebrate TAF were not significantly different via a two-sample t-test assuming unequal variances ($\alpha = 0.05$). The chronic MAF was calculated as the geometric mean of all genus-level EC_{20}:EC_5 ratios available. Chronic invertebrate and vertebrate TAFs and the chronic MAF were calculated as the geometric mean of their respective genus-level EC_{20}:EC_5 ratios to limit the influence of EC_{20}:EC_5 ratios from species that are overly represented in a dataset, similar to criteria derivation (Stephan et al. 1985).

Listed species-specific or surrogate EC_{20} values were then divided by an appropriate adjustment factor (i.e., chronic TAF or chronic MAF depending on data availability) to derive a chronic minimum effect threshold concentration. Chronic minimum effect threshold concentrations were then compared to the corresponding criterion magnitude (i.e., criterion continuous concentration [CCC]) to assess potential adverse effects of ammonia or cadmium exposures at the chronic criterion concentration.

The freshwater ammonia CCC is both pH- and temperature-dependent. Chronic vertebrate sensitivity to ammonia in freshwater is affected by pH, while chronic invertebrate sensitivity to ammonia is influenced by temperature and pH. Figure 1-3 depicts the change in CCC across water chemistries and how the chronic minimum effect threshold for dwarf wedgemussel (from Section 2.6.2) changes proportionally with the criterion magnitude (factor difference of 1.024). Because species sensitivity and the CCC both change similarly across water chemistries, conclusions based on reference conditions translate to other water chemistries.

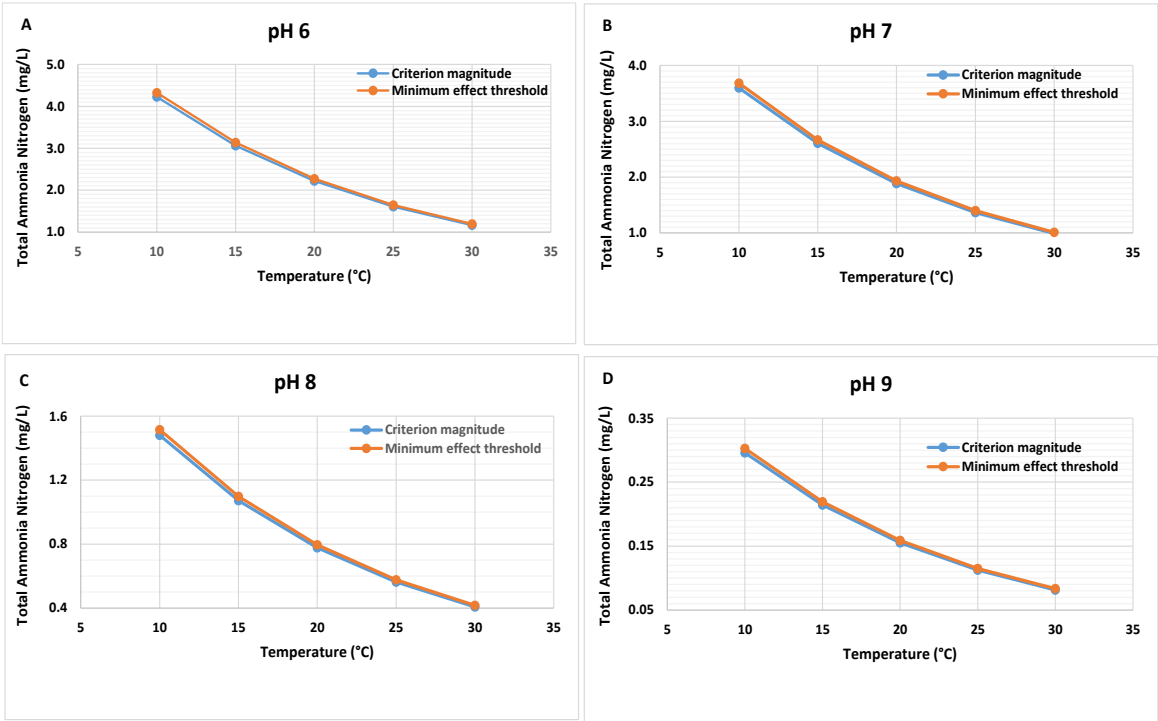

Figure 1-3. Chronic ammonia criterion magnitude extrapolated across a temperature gradient at pH 6, 7, 8 and 9 (Panels A-D) with the dwarf wedgemussel (per Section 2.6.2 of this document) chronic ammonia minimum effect threshold concentration overlaid. The factor difference between the chronic criterion magnitude and chronic minimum effect threshold for dwarf wedgemussel is 1.024.

In contrast to ammonia, species sensitivity to cadmium in freshwater is only dependent on water hardness, with tolerance increasing as hardness increases (see USEPA 2016). The CCC increases with increasing hardness across the range of hardness typical of natural ambient surface water, but with a slightly shallower slope than for the CMC (chronic toxicity hardness slope 0.7977). Figure 1-4 depicts the change in the cadmium CCC across water hardness of 25 to 400 mg/L as $CaCO_3$, and how the chronic minimum effect threshold for dwarf wedgemussel (from Section 3.6.2) changes with the chronic freshwater cadmium criterion magnitude proportionally (factor difference of 9.513). The chronic effects assessment was developed using toxicity data normalized to a reference condition (hardness = 100 mg/L) and compared to the corresponding CCC in those same reference conditions. Because species sensitivity and the CCC both change similarly across water chemistries, conclusions based on reference conditions translate to other water chemistries.

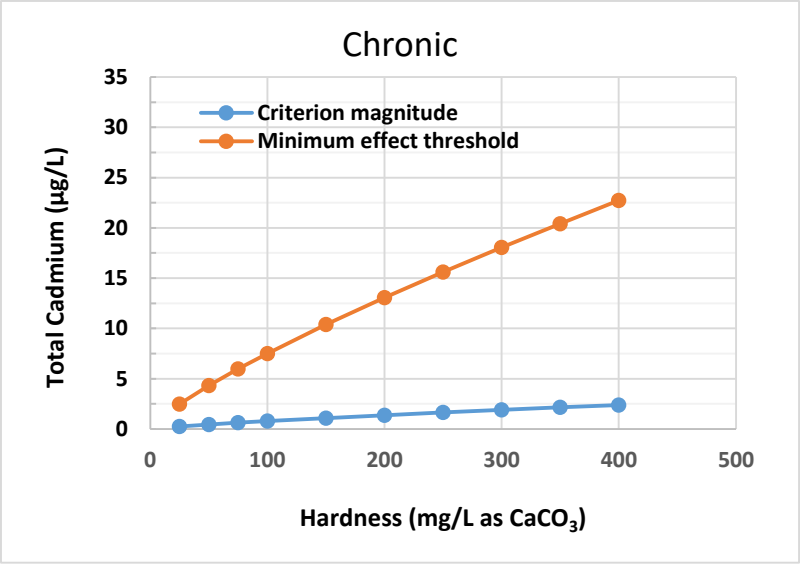

Figure 1-4. Chronic cadmium criterion magnitudes extrapolated across a gradient of water hardness overlaid with the dwarf wedgemussel chronic minimum effect threshold concentration (Section 3.6.2 of this document). The criterion magnitude increases and the dwarf wedgemussel chronic minimum effect threshold both increase with increasing water hardness. The factor difference between the chronic criterion magnitude and chronic minimum effect threshold for dwarf wedgemussel is 9.513.

Assessing a chronic criterion magnitude alone does not consider the duration and frequency components of the criterion and represents an overly conservative exposure scenario that assumes a pollutant concentration in all Virginia freshwaters will be at the chronic criterion magnitude indefinitely. If a listed species chronic minimum effect threshold concentration is greater than the corresponding chronic criterion magnitude, then a refined assessment and consideration of the criterion duration and realistic exposure is not necessary, and approval of the chronic criterion is Not Likely to Adversely Affect (NLAA) that particular listed species through direct chronic effects in freshwaters.

1.2.2 Direct Chronic Effects to Freshwater Plants

Five listed aquatic/semi-aquatic plant species occur in Virginia freshwaters. Given limited plant toxicity data, direct effects of EPA's approval of the chronic ammonia and cadmium freshwater criteria to aquatic/semi-aquatic freshwater plants were evaluated through a qualitative approach by considering sensitivity of plants relative to most-sensitive taxa used to derive the chronic ammonia and cadmium criterion for freshwaters.

1.2.3 Direct Chronic Effects to Estuarine/Marine Animals

In additional to the freshwater cadmium criterion, Virginia has also proposed to adopt the chronic cadmium criterion for estuarine/marine waters (USEPA 2016). Virginia has not proposed to adopt any estuarine/marine ammonia criteria. Under the jurisdiction of FWS, there are no animal species in Virginia that may be directly affected by approval of EPA's estuarine/marine chronic cadmium criterion (USEPA 2016). Saltwater and anadromous species with range or critical habitat in Virginia estuarine/marine waters are subject to consultation with NMFS.

1.2.4 Direct Chronic Effects to Estuarine/Marine Plants

One listed aquatic/semi-aquatic plant occurs in Virginia estuarine/marine waters. Given limited saltwater toxicity data, direct effects of EPA's approval of the chronic cadmium estuarine/marine criterion to an estuarine/marine plant was evaluated through a qualitative approach by considering sensitivity of plants relative to most-sensitive taxa used to derive the chronic cadmium criterion for estuarine/marine waters.

1.3 Indirect Effects: Assessment of Acute and Chronic Criteria

Following assessment of direct acute and chronic effects, EPA considered and assessed potential indirect effects of the water quality standard approval actions on aquatic organisms and aquatic-dependent animals (note, aquatic dependent species were not evaluated for potential direct effects given no meaningful exposure). To assess potential indirect effects, EPA considered potential effects to listed animal prey items. EPA did not include a full evaluation of indirect effects of the water quality standard approval actions on listed aquatic/semi-aquatic species, because indirect effects are not likely to adversely affect plants given their life histories and biology (i.e., assimilate nutrients from sediments and energy through photosynthesis).

1.4 Listed Species: Final Effects Determinations

Final effect determinations were based on direct and/or indirect effects of EPA's approval of the acute and chronic ammonia (freshwater) and cadmium (freshwater and estuarine/marine) water quality standards in Virginia. For aquatic listed species, EPA considered direct acute and chronic effects as well as indirect effects to make a final effects determination. For aquatic-dependent listed species, such as birds and mammals, EPA concludes there will be no direct effects of ammonia and cadmium in freshwater (as a result of no meaningful direct exposure) and made a final effects determination based on indirect effects only.

1.5 Critical Habitat: Effects Assessment and Final Critical Habitat Effects Determinations

Following listed species final effects determinations, EPA made a critical habitat effects assessment for designated critical habitat pertaining to aquatic and aquatic-dependent species in the action area. EPA considered Physical and Biological Features (PBFs, formally Primary Constituent Elements [PCEs]) essential to critical habitat and potential effects to listed species prey items (evaluated through the indirect effects assessment) to determine if the proposed action is *Likely to Adversely Modify* critical habitat or if the proposed action is *Not Likely to Adversely Modify* critical habitat.

2 Ammonia Effects Assessments

(*Note: For economy of space, the effects assessments of several species are grouped together when taxonomic relatedness and data availability result in redundant calculations of acute and chronic low effect threshold values for species within a particular taxonomic group)*

2.1 Spotfin Chub (*Erimonax monachus*), Slender Chub (*Erimystax cahni*), and Blackside Dace (*Chrosomus cumberlandensis*)

2.1.1 Chub and Dace Acute Ammonia Effects Assessment: Freshwater

2.1.1.1 Identifying Chub and Dace Acute Ammonia Data

High-quality species-level or genus-level acute toxicity data from Appendix A of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for spotfin chub, slender chub or blackside dace. Family-level acute toxicity data were, therefore, used to represent the sensitivity of the chubs and dace to acute ammonia exposures. The Cyprinidae family mean acute value (FMAV), 99.33 mg/L normalized to a pH of 7, is based on seven genus mean acute values (GMAVs), which all, except *Cyprinella*, are composed of a single species mean acute value (SMAV) – see Table 2-1.

Table 2-1. Data used to calculate the Cyprinidae FMAV representative of spotfin chub, slender chub and blackside dace acute sensitivity to ammonia.

Family	Species	SMAV (mg/L)[a]	GMAV (mg/L)[a]	FMAV (mg/L)[a]
Cyprinidae	Spotfin chub, *Erimonax monachus*	N/A	N/A	99.32
Cyprinidae	Slender chub, *Erimystax cahni*	N/A	N/A	
Cyprinidae	Blackside dace, *Chrosomus cumberlandensis*	N/A	N/A	
Cyprinidae	Central stoneroller, *Campostoma anomalum*	115.9	115.9	
Cyprinidae	Rainbow dace, *Cyprinella lutrensis*	196.1	110.0	
Cyprinidae	Spotfin shiner, *Cyprinella spiloptera*	83.80		
Cyprinidae	Steelcolor shiner, *Cyprinella whipplei*	80.94		
Cyprinidae	Common carp, *Cyprinus carpio*	106.3	106.3	
Cyprinidae	Rio Grande silvery minnow, *Hybognathus amarus*	72.55	72.55	
Cyprinidae	Golden shiner, *Notemigonus crysoleucas*	63.02	63.02	
Cyprinidae	Topeka shiner, *Notropis topeka*	96.72	96.72	
Cyprinidae	Fathead minnow, *Pimephales promelas*	159.2	159.2	

[a] Normalized to a pH 7 (USEPA 2013). N/A: not available.

2.1.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical acute toxicity data were not available for the spotfin chub, slender chub or blackside dace or surrogate species within the same genera: *Erimonax*, *Erimystax*, and *Chrosomus.* Therefore, no data are available to support the derivation of a taxonomic-specific LC_{50}:LC_5 adjustment factor at or below the genus-level. As a result, EPA obtained and analyzed

C-R data for 10 tests with closely-related surrogate species (i.e., other freshwater fishes within the Family Cyprinidae*)* to derive an acute Cyprinidae family-level TAF.

Raw empirical acute toxicity data were fit to C-R models using EPA's Toxicity Relationship Analysis Program (TRAP) software (version 1.30a) to calculate LC_{50} and corresponding LC_5 values for the 10 tests representing seven cyprinid fish species. Of the 10 C-R models available only six were used to calculate the Cyprinidae family-level TAF. Two C-R models were excluded because they did not exhibit a unique solution (inadequate partial effects) and two exhibited poor fit to key points reducing certainty in estimates. The remaining six ratios resulted in four genus-level LC_{50}:LC_5 ratios for cyprinid fish (Table 2-2). The overall variability in acute ammonia ratios among freshwater cyprinid fishes is low. Individual test ratios ranged from 1.034 to 1.406 (Table 2-2). The acute family-level TAF calculated as the geometric mean of all four genus-level LC_{50}:LC_5 ratios for freshwater cyprinids is 1.310 (see Appendix A.1 for raw empirical toxicity test data, TRAP models, and output for the six acute ammonia toxicity tests used to derive the acute Cyprinidae family-level TAF; Appendix A.2 includes the raw toxicity data, TRAP models, and output for the unacceptable and uncertain ammonia toxicity tests excluded from the acute family-level TAF).

2.1.1.3 Calculating Chub and Dace Acute Ammonia Minimum Effect Threshold

Dividing the estimated spotfin chub, slender chub and blackside dace FMAV (99.32 mg/L) by the acute Cyprinidae family-level TAF (1.310) results in an acute minimum effect threshold concentration of 75.82 mg/L (normalized to a pH 7).

2.1.1.4 Chub and Dace: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 (17 mg/L) is 4.5 times lower than the acute ammonia minimum effect threshold of 75.82 mg/L total ammonia calculated for the spotfin chub, slender chub and blackside dace. The spotfin chub, slender chub and blackside dace acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary and approval of the acute ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the spotfin chub, slender chub and blackside dace through direct acute effects.

Table 2-2. Acute LC_{50}:LC_5 ratios from analysis of six high-quality acute ammonia toxicity tests with freshwater cyprinid fish used to derive an acute Cyprinidae family taxonomic adjustment factor (TAF) representative of the spotfin chub, slender chub and blackside dace.

Family	Species	LC_{50} (mg TAN/L)	LC_{05} (mg TAN/L)	LC_{50}:LC_{05}	C-R Curve Label	Reference	Species-level TAF LC_{50}:LC_{05}	Genus-level TAF LC_{50}:LC_{05}	Family-level TAF LC_{50}:LC_{05}
Cyprinidae	Rainbow dace, *Cyprinella lutrensis*	21.14	15.04	1.406	Am-Acute-58	Hazel et al. 1979	1.387	1.387	1.310
Cyprinidae	Rainbow dace, *Cyprinella lutrensis*	7.040	5.144	1.369	Am-Acute-59	Hazel et al. 1979			
Cyprinidae	Common carp (299 mg), *Cyprinus carpio*	51.65	40.37	1.279	Am-Acute-62	Hasan and MacIntosh 1986	1.279	1.279	
Cyprinidae	Rio Grande silvery minnow (3-5 d old), *Hybognathus amarus*	17.52	12.52	1.399	Am-Acute-63	Buhl 2002	1.399	1.399	
Cyprinidae	Fathead minnow (0.2 g), *Pimephales promelas*	43.46	42.03	1.034	Am-Acute-69	Swigert and Spacie 1983	1.188	1.188	
Cyprinidae	Fathead minnow (0.5 g), *Pimephales promelas*	42.76	31.33	1.365	Am-Acute-70	Swigert and Spacie 1983			

2.1.2 Chub and Dace Chronic Ammonia Effects Assessment: Freshwater

2.1.2.1 Identifying Chub and Dace Chronic Ammonia Data

High-quality species-level or genus-level chronic toxicity data from Appendix B of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for the spotfin chub, slender chub, or blackside dace. Family-level chronic toxicity data were, therefore, used to determine a chronic toxicity value (i.e., EC_{20}) of 12.32 mg/L (pH 7) representative of the three species (Table 2-3). The Cyprinidae FMCV is based on chronic toxicity test results reported for two different freshwater cyprinid species, the fathead minnow (Genus *Pimephales*), and the common carp (Genus *Cyprinus*). The SMCV (and GMCV since no other *Pimephales* data were available) for fathead minnow is based on the geometric mean of four chronic toxicity tests, three of which were conducted as early-life stage exposures, with the test endpoint being either biomass (as reported by Adelman et al. [2009] and Swigert and Spacie [1983]) or survival (Mayes et al. 1986). The test endpoint reported for the fourth fathead minnow chronic test was based on embryo hatchability during a life-cycle test (Thurston et al. 1986). The SMCV (and GMCV since no other *Cyprinus* data were available) for common carp was based on the result of a single early-life stage test (Mallet and Sims 1994), and the test endpoint used for EC_{20} estimation was growth (wet weight). All EC_{20} values used to derive the cyprinid FMCV were used to derive the chronic criterion (bolded values in Appendix B of USEPA [2013]) and have been normalized to a pH of 7.

Table 2-3. Data used to calculate the FMCV representative of spotfin chub, slender chub and blackside dace chronic sensitivity to ammonia.

Family	Species	SMCV (mg/L)[a]	GMCV (mg/L)[a]	FMCV (mg/L)[a]
Cyprinidae	Spotfin chub, *Erimonax monachus*	N/A	N/A	12.32
Cyprinidae	Slender chub, *Erimystax cahni*	N/A	N/A	
Cyprinidae	Blackside dace, *Chrosomus cumberlandensis*	N/A	N/A	
Cyprinidae	Common carp, *Cyprinus carpio*	16.53	16.53	
Cyprinidae	Fathead minnow, *Pimephales promelas*	9.187	9.187	

[a] Normalized to pH 7 (USEPA 2013). N/A: not available

2.1.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

High-quality and relevant chronic toxicity data were not available for the spotfin chub, slender chub, or blackside dace at the species- or genus-level, and therefore, no raw empirical toxicity data are available to support the derivation of an EC_{20}:EC_5 adjustment factor for these genera. As a result, EPA analyzed C-R data for the same five chronic ammonia toxicity tests with surrogate species in the same family as the two chubs and dace (i.e., the same fathead minnow and common carp tests used to calculate the FMCV, all of which reported raw empirical data).

Raw empirical chronic toxicity data were fit to C-R models using EPA's TRAP software to calculate EC_{20} and corresponding EC_5 values for the five tests with freshwater cyprinid fishes

(Table 2-4). Ratios from the tests ranged from 1.330 to 1.881. The chronic Cyprinidae family-level TAF calculated as the geometric mean of the two genus-level EC_{20}:EC_5 ratios in the Family Cyprinidae (i.e., 1.469 and 1.565 for *Cyprinus* and *Pimephales*, respectively) is 1.516 (see Appendix A.3 for raw empirical toxicity data, TRAP models and outputs).

2.1.2.3 Calculating Chub and Dace Chronic Ammonia Minimum Effect Threshold

Dividing the estimated FMCV value (12.32 mg/L; family-level surrogate) by the chronic Cyprinidae family-level TAF (1.516) results in a chronic minimum effect threshold concentration of 8.127 mg/L (normalized to pH 7).

2.1.2.4 Chub and Dace: Chronic Ammonia Effect Determination

The chronic ammonia CCC at pH 7 (1.9 mg/L) is 4.3 times lower than the chronic minimum effect threshold concentration of 8.127 mg/L calculated for the spotfin chub, slender chub and blackside dace. When deriving criteria and developing effects assessments, EPA relies on the most relevant and high-quality data possible to inform scientifically-sound conclusions. In certain cases, EPA may consider other toxicity data of lower quality than the data used quantitatively to derive criteria, as supportive auxiliary information to inform effects determinations. Appendix C of the ammonia 304(a) Aquatic Life Criteria document (USEPA 2013) contains "Other Chronic Ammonia Toxicity Data" for freshwater species. The appendix consists of studies that do not meet the rigorous data quality, type and documentation requirements specified in the 1985 Guidelines, yet may contain quality portions that may be considered as supportive auxiliary data. For example, the 7-d IC25 of 15.80 mg/L (at pH 7) for growth of spotfin chub reported in Dwyer et al. (2005) was not used for criteria derivation because the test was not a true early-life stage test (i.e., the test was initiated with <24 hr old fish instead of embryos, and lasted only 7 days instead of 28 days), but provides supportive insight into spotfin chub tolerance to chronic ammonia exposures.

Spotfin chub larval sensitivity data suggest early life stages of spotfin chub and other closely related species may be insensitive to chronic ammonia exposure and would be adequately protected by the chronic criterion (CCC = 1.9 mg TAN/L, pH = 7.0). The spotfin chub, slender chub and blackside dace chronic minimum effect threshold concentration, based on the most relevant and highest quality data available from continuous laboratory exposures is greater than the corresponding criterion magnitude. Furthermore, supportive data from lower-quality chronic toxicity studies with the spotfin chub also suggest the chub (and other closely related) species is likely not sensitive to ammonia at the chronic criterion concentration. As a result, approval of the chronic ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the spotfin chub, slender chub or blackside dace through direct chronic effects.

2.1.3 Chub and Dace Ammonia Indirect Effects Assessment: Freshwater

Aquatic life criteria are based on the fifth centile of sensitive genera to protect aquatic communities, including listed species prey items. The spotfin and slender chubs are primarily benthic insectivores, while the blackside dace frequently consumes algae and plant matter and aquatic insects (USFWS 1983a, 1983b, 2014, 2015a). Aquatic insects ranked among the most tolerant taxa to acute ammonia exposures (see Table 3 of USEPA 2013; see Table 2-27 of this

assessment) while chronic toxicity data with emerging aquatic insects were relatively limited; however, the only insect genus represented is the most tolerant genus to chronic ammonia exposures (*Pteronarcella* genus mean chronic value [GMCV] = 73.74 mg/L, normalized to pH 7 and 20°C). Furthermore, plant matter consumed by the blackside dace is also tolerant to ammonia. For example, USEPA (2013) states, "*data available regarding the toxicity of ammonia to freshwater phytoplankton and vascular plants reported in the 1985 AWQC document indicate that aquatic plants appear to be two orders of magnitude less sensitive than the aquatic animals tested, it is assumed that any ammonia criterion appropriate for the protection of freshwater aquatic animals will also be protective of aquatic vegetation*." Spotfin chub, slender chub and blackside dace prey items are relatively insensitive overall to ammonia at magnitudes and exposure durations specified by the acute and chronic ammonia criteria. As a result, approval of the acute and chronic ammonia water quality standards is Not Likely to Adversely Affect (NLAA) the spotfin chub, slender chub or blackside dace through indirect effects.

Table 2-4. Chronic EC_{20}:EC_5 ratios from analysis of five high-quality chronic ammonia toxicity tests with freshwater cyprinid fishes used to derive a chronic family-level taxonomic adjustment factor (TAF) for the spotfin chub, slender chub, and blackside dace.

Family	Species	EC_{20} (mg/L)	EC_{05} (mg/L)	EC_{20}:EC_{05}	C-R Curve Label	Reference	Species-level TAF (EC_{20}:EC_{05})	Genus-level TAF (EC_{20}:EC_{05})	Family-level TAF (EC_{20}:EC_{05})
Cyprinidae	Common carp (fertilized), *Cyprinus carpio*	8.246	5.612	1.469	Am-Chronic-18	Mallet and Sims 1994	1.469	1.469	1.516
Cyprinidae	Fathead minnow (embryo-larvae), *Pimephales promelas*	4.656	3.361	1.385	Am-Chronic-19	Mayes et al. 1986	1.565	1.565	
Cyprinidae	Fathead minnow (embryo-larvae), *Pimephales promelas*	7.396	5.561	1.330	Am-Chronic-20	Adelman et al. 2009			
Cyprinidae	Fathead minnow, *Pimephales promelas*	5.795	3.081	1.881	Am-Chronic-21	Swigert and Spacie 1983			
Cyprinidae	Fathead minnow, *Pimephales promelas*	1.903	1.099	1.732	Am-Chronic-22	Thurston et al. 1986			

2.2 Duskytail Darter (*Etheostoma percnurum*) and Candy Darter (*Etheostoma osburni*)

2.2.1 Darter Acute Ammonia Effects Assessment: Freshwater

2.2.1.1 Identifying Darter Acute Ammonia Data

High-quality species-level acute toxicity data from Appendix A of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for the duskytail or candy darter. Genus-level acute toxicity data were, therefore, used to determine an acute toxicity value (i.e., LC_{50}) of 74.25 mg/L (normalized to pH 7) representative of the darter species (Table 2-5). The *Etheostoma* GMAV is based on the Johnny darter SMAV (71.45 mg/) and the orangethroat darter SMAV (77.17 mg/L). The SMAV for Johnny darter is represented by six LC_{50} values ranging from 43.72 to 105.7 mg/L reported by Nimmo et al. (1989). The SMAV for orangethroat darter is based on two LC_{50} values reported by Hazel et al. (1979).

Table 2-5. Data used to calculate the *Etheostoma* GMAV representative of duskytail and candy darter acute sensitivity to ammonia.

Family	Species	SMAV (mg/L)[a]	GMAV (mg/L)[a]
Percidae	Duskytail darter, *Etheostoma percnurum*	N/A	74.25
Percidae	Candy darter, *Etheostoma osburni*	N/A	
Percidae	Johnny darter, *Etheostoma nigrum*	71.45	
Percidae	Orangethroat darter, *Etheostoma spectabile*	77.17	

[a] Normalized to pH 7 (USEPA 2013). N/A: not available.

2.2.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical toxicity data were only reported in one of the two published acute toxicity studies used to calculate the *Etheostoma* GMAV representative of duskytail and candy darters (Table 2-5). C-R data from the two orangethroat darter acute toxicity tests reported by Hazel et al (1979; see curves Am-Acute-85 and Am-Acute-86 in Appendix A.1) were used to calculate two LC_{50}:LC_5 ratios. Taken together, the geometric mean of the two orangethroat darter LC_{50}:LC_5 ratios is 1.620 and serves as an acute genus-level TAF representative of the duskytail and candy darters. (see in Appendix A.1 for raw empirical toxicity test data, TRAP models and outputs for the two acute ammonia toxicity tests from Hazel at al. (1979).

2.2.1.3 Calculating Darter Acute Ammonia Minimum Threshold

Dividing the *Etheostoma* GMAV (74.25 mg/L) by the acute *Etheostoma* genus-level TAF (1.620) results in an acute minimum effect threshold concentration of 45.83 mg/L (normalized to pH 7) that is representative of the duskytail and candy darters.

2.2.1.4 Darter: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 (17 mg/L) is 2.7 times lower than the acute ammonia minimum effect threshold of 45.83 mg/L total ammonia calculated for the duskytail and candy darters. The duskytail and candy darter acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a

result, refined assessment and consideration of the criterion duration is not necessary and approval of the acute ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the duskytail and candy darters.

2.2.2 Darter Chronic Ammonia Effects Assessment: Freshwater

2.2.2.1 Identifying Darter Chronic Ammonia Data

High-quality chronic toxicity data from Appendix B of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for the duskytail darter and candy darter or other species within the family Percidae. Order-level chronic toxicity data were, therefore, used to determine a chronic toxicity value (i.e., EC_{20}) of 8.752 mg/L (normalized to pH 7) representative of the two darters (Table 2-6). The Order Mean Chronic Value (OMCV) is based on a single FMCV (for Centrarchidae) which was calculated as the geometric mean of two GMCVs (for *Lepomis* and *Micropterus*). The *Lepomis* GMCV is based on three EC_{20} values (endpoint = biomass) from 30-day early-life stage (ELS) tests reported in three publications (McCormick et al. [1984] and Reinbold and Pescitelli [1982a] reported chronic effect concentrations [i.e., EC_{20}] of 11.85 and 18.06 mg/L for *L. cyanellus*, respectively; Smith et al. (1984) reported a chronic effect of 3.273 mg/L for *L. macrochirus*). The *Micropterus* SMCV (11.07 mg/L) is based on the geometric mean of four EC_{20} values (endpoint = biomass) from 32-day ELS tests reported by Broderius et al. (1985).

Table 2-6. Data used to calculate the Perciformes OMCV representative of duskytail and candy darters chronic sensitivity to ammonia.

<table>
<tr><th>Order</th><th>Family</th><th>Species</th><th>SMCV (mg/L)[a]</th><th>GMCV (mg/L)[a]</th><th>FMCV (mg/L)[a]</th><th>OMCV (mg/L)[a]</th></tr>
<tr><td>Perciformes</td><td>Percidae</td><td>Duskytail darter, Etheostoma percnurum</td><td>N/A</td><td rowspan="2">N/A</td><td rowspan="2">N/A</td><td rowspan="5">8.752</td></tr>
<tr><td>Perciformes</td><td>Percidae</td><td>Candy darter, Etheostoma osburni</td><td>N/A</td></tr>
<tr><td>Perciformes</td><td>Centrarchidae</td><td>Bluegill, Lepomis cyanellus</td><td>14.63</td><td rowspan="2">6.920</td><td rowspan="3">8.752</td></tr>
<tr><td>Perciformes</td><td>Centrarchidae</td><td>Bluegill, Lepomis macrochirus</td><td>3.273</td></tr>
<tr><td>Perciformes</td><td>Centrarchidae</td><td>Smallmouth bass, Micropterus dolomieu</td><td>11.07</td><td>11.07</td></tr>
</table>

[a] Normalized to pH 7 (USEPA 2013).N/A: not available.

2.2.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

High-quality and relevant chronic toxicity data were not available for the duskytail and candy darters at the species-, genus- or family-level, and therefore, no raw empirical toxicity data are available to support the derivation of an EC_{20}:EC_5 adjustment factor within the Family *Percidae*. As a result, EPA analyzed C-R data for the same seven chronic ammonia toxicity tests with surrogate species in the same order as the darters (i.e., the same tests used to calculate the OMCV [Table 2-6], all of which reported raw empirical data).

Raw empirical chronic toxicity data were fit to C-R models using EPA's TRAP software to calculate EC_{20} and corresponding EC_5 values for the seven tests with freshwater fishes in Order

Perciformes. Of these, one model did not exhibit a unique solution (inadequate partial effects; Am-Chronic-26), one model exhibited excessive noise in the C-R relationship (Am-Chronic-25), and two models did not include observations in the region of interest which did not allow TRAP to accurately model a no-response plateau (Am-Chronic-28; Am-Chronic-29). After exclusion of the four unacceptable EC_{20}:EC_5 ratios for use in calculating a chronic Perciformes order-level TAF, three EC_{20}:EC_5 ratios remained (Table 2-7). Ratios from the tests ranged from 1.323 to 1.503. The chronic Perciformes order-level TAF is based on a single Centrarchidae family-level TAF which is calculated as the geometric mean of the two genus-level EC_{20}:EC_5 ratios (i.e., 1.323 and 1.440 for *Lepomis* and *Micropterus*, respectively). The chronic Perciformes order-level TAF is 1.380 (see Appendix A.3 for raw empirical toxicity data, TRAP models and outputs).

2.2.2.3 Calculating Darter Chronic Ammonia Minimum Effect Threshold

Dividing the estimated duskytail and candy darter EC_{20} value (8.752 mg/L; order-level surrogate) by the Perciformes order-level TAF (1.380) results in a chronic minimum effect threshold concentration of 6.342 mg/L (normalized to pH 7).

2.2.2.4 Darter: Chronic Ammonia Effects Determination

The chronic ammonia CCC at pH 7 (1.9 mg/L) is 3.3 times lower than the chronic minimum effect threshold concentration of 6.342 mg/L estimated for the duskytail and candy darters. The duskytail and candy darter chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the chronic ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the duskytail and candy darter through direct chronic effects.

Table 2-7. Chronic EC_{20}:EC_5 ratios from analysis of three high-quality chronic ammonia toxicity tests with freshwater aquatic organisms used to derive a Perciformes order-level TAF representative of the duskytail and candy darters.

Order	Family	Species	EC_{20} (mg/L)	EC_{05} (mg/L)	EC_{20}: EC_{05}	C-R Curve Label	Reference	Species-level TAF (EC_{20}:EC_{05})	Genus-level TAF (EC_{20}:EC_{05})	Family-level TAF (EC_{20}:EC_{05})	Order-level TAF (EC_{20}:EC_{05})
Perciformes	Centrarchidae	Bluegill, *Lepomis macrochirus*	1.855	1.402	1.323	Am-Chronic-27	Smith et al. 1984	1.323	1.323	1.380	1.380
Perciformes	Centrarchidae	Smallmouth bass, *Micropterus dolomieu*	8.395	5.585	1.503	Am-Chronic-30	Broderius et al. 1985	1.440	1.440		
Perciformes	Centrarchidae	Smallmouth bass, *Micropterus dolomieu*	1.610	1.168	1.379	Am-Chronic-31	Broderius et al. 1985				

2.2.3 Darter Ammonia Indirect Effects Assessment: Freshwater

The duskytail darter and candy darter are primarily benthic insectivores (Layman 1991, USFWS 2017). Aquatic life criteria are based on the fifth centile of sensitive genera to ensure the broad aquatic community, including emerging aquatic insects, is adequately protected. Aquatic insects ranked among the most tolerant taxa to acute ammonia exposures (see Table 3 of USEPA 2013; see Table 2-27 of this assessment). For example, the most sensitive aquatic insect genera (*Enallagma* GMAV = 164 mg/L, normalized to pH 7 and 20°C) to acute ammonia exposure ranked in the 68th centile of sensitivity among all genera. Chronic toxicity data with emerging aquatic insects were relatively limited; however, the only chronic toxicity data with an insect genus represented is the most tolerant genus to chronic ammonia exposures (*Pteronarcella* GMCV = 73.74 mg/L, normalized to pH 7 and 20°C). Duskytail and candy darter prey items are relatively insensitive to ammonia at magnitudes and exposure durations specified by the acute and chronic ammonia criteria. As a result, approval of the acute and chronic ammonia water quality standards is Not Likely to Adversely Affect (NLAA) the duskytail and candy darters through indirect effects.

2.3 Roanoke Logperch (*Percina rex)*

2.3.1 Roanoke Logperch Acute Ammonia Effects Assessment: Freshwater

2.3.1.1 Identifying Roanoke Logperch Acute Ammonia Data

High-quality species- and genus-level acute toxicity data from Appendix A of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for the Roanoke logperch. Family-level acute toxicity data were, therefore, used to determine a Percidae FMAV (i.e., LC_{50}) of 93.25 mg/L (normalized to pH 7) representative of the logperch (Table 2-8). The Percidae FMAV is based on GMAVs of 74.25 mg/L for *Etheostoma* (as described in Section 2.2.1.1) and 117.1 mg/L for *Sander*. The *Sander* GMAV is based on a single SMAV represented by four LC_{50} values ranging from 46.87 to 224.8 mg/L reported by West (1985), Arthur et al. (1987) and Mayes et al. (1986).

Table 2-8. Data used to calculate the Percidae FMAV representative of Roanoke logperch acute sensitivity to ammonia.

Family	Species	SMAV (mg/L)[a]	GMAV (mg/L)[a]	FMAV (mg/L)[a]
Percidae	Roanoke logperch, *Percina rex*	N/A	N/A	93.25
Percidae	Johnny darter, *Etheostoma nigrum*	71.45	74.25	
Percidae	Orangethroat darter, *Etheostoma spectabile*	77.17		
Percidae	Walleye, *Sander vitreus*	117.1	117.1	

[a] Normalized to pH 7 (USEPA 2013). N/A: not available.

2.3.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical acute toxicity data were unavailable for deriving an LC_{50}:LC_5 ratio for Roanoke logperch, and because no other toxicity tests are available for the Genus *Percina*, a genus-level TAF could not be calculated. As a result, EPA analyzed C-R data from the two acute toxicity

tests with orangethroat darter that reported raw empirical data (see Section 2.2.1.2) to derive an acute Percidae family-level TAF (no other acute toxicity studies with members of the Family Percidae reported raw C-R data). Raw empirical acute toxicity data were fit to C-R models using EPA's TRAP software to calculate LC_{50} and corresponding LC_5 values for the two tests. The acute Percidae family-level TAF representative of the Roanoke logperch is 1.620 (see Section 2.2.1.2).

2.3.1.3 Calculating Roanoke Logperch Acute Ammonia Minimum Threshold

Dividing the estimated Roanoke logperch FMAV (93.25 mg/L) by the acute Percidae family-level TAF (1.620) results in an acute minimum effect threshold concentration of 57.56 mg/L (normalized to pH 7).

2.3.1.4 Roanoke Logperch: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 (17 mg/L) is 3.4 times lower than the acute ammonia minimum effect threshold of 57.56 mg/L total ammonia calculated for Roanoke logperch. The Roanoke logperch acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary and approval of the acute ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the Roanoke logperch through direct acute effects.

2.3.2 Roanoke Logperch Chronic Ammonia Effects Assessment: Freshwater

2.3.2.1 Identifying Roanoke Logperch Chronic Ammonia Data

High-quality acute toxicity data from Appendix B of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for the Roanoke logperch or other species within the Family Percidae. Order-level chronic toxicity data were, therefore, used to determine a Perciformes chronic toxicity value (i.e., EC_{20}) of 8.752 mg/L (normalized to pH 7) representative of the logperch (see Section 2.2.2.1 for derivation of the Perciformes OMCV).

2.3.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

High-quality and relevant chronic toxicity data were not available for the Roanoke logperch at the species-, genus- or family-level, and therefore, no raw empirical toxicity data are available to support the derivation of an EC_{20}:EC_5 adjustment factor within the Family Percidae. As a result, EPA analyzed C-R data for the same seven chronic ammonia toxicity tests with surrogate species in the same order as the logperch to determine a chronic Perciformes order-level TAF of 1.380 that is representative of the Roanoke logperch (see section 2.2.2.2 for derivation of the Perciformes acute TAF).

2.3.2.3 Calculating Roanoke Logperch Chronic Ammonia Minimum Effect Threshold

Dividing the estimated Roanoke logperch EC_{20} value (8.752 mg/L; order-level surrogate) by the Perciformes order-level TAF (1.380) results in a chronic minimum effect threshold concentration of 6.342 mg/L (normalized to pH 7).

2.3.2.4 Roanoke Logperch: Chronic Ammonia Effects Determination

The chronic ammonia CCC at pH 7 (1.9 mg/L) is 3.3 times lower than the chronic minimum effect threshold concentration of 6.342 mg/L estimated for the Roanoke logperch. The Roanoke logperch chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the chronic ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the Roanoke logperch through direct chronic effects.

2.3.3 Roanoke Logperch Ammonia Indirect Effects Assessment: Freshwater

The Roanoke logperch is primarily a benthic insectivore (USFWS 1992). Aquatic life criteria are based on the fifth centile of sensitive genera to ensure the broad aquatic community, including emerging aquatic insects, is adequately protected. Aquatic insects ranked among the most tolerant taxa to acute ammonia exposures (see Table 3 of USEPA 2013; see Table 2-27 of this assessment). For example, the most sensitive aquatic insect genera (*Enallagma* GMAV = 164 mg/L, normalized to pH 7 and 20°C) to acute ammonia exposure ranked in the 68th centile of sensitivity among all genera. Chronic toxicity data with emerging aquatic insects were relatively limited; however, the only chronic toxicity data with an insect genus represented is the most tolerant genus to chronic ammonia exposures (*Pteronarcella* GMCV = 73.74 mg/L, normalized to pH 7 and 20°C). Roanoke logperch prey items are relatively insensitive to ammonia at magnitudes and exposure durations specified by the acute and chronic ammonia criteria. As a result, approval of the acute and chronic ammonia water quality standards is Not Likely to Adversely Affect (NLAA) the Roanoke logperch through indirect effects.

2.4 Yellowfin Madtom (*Noturus flavipinnis*)

2.4.1 Yellowfin Madtom Acute Ammonia Effects Assessment

2.4.1.1 Identifying Yellow Madtom Acute Ammonia Data

High-quality species- and genus-level acute toxicity data from Appendix A of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for the yellowfin madtom. Family-level acute toxicity data were, therefore, used to determine an acute toxicity value (i.e., LC_{50}) of 142.4 mg/L (pH 7) representative of the Yellowfin madtom (Table 2-9). The Ictaluridae FMAV is based on single GMAV for the Genus *Ictalurus*, which is represented by a single SMAV of 142.4 mg/L (normalized to pH 7) for channel catfish. The SMAV for *Ictalurus punctatus* is based on the geometric mean of 20 definitive LC_{50} values ranging from 64.77 to 277.4 mg/L involving multiple fish sizes and ages.

Table 2-9. Data used to calculate the Ictaluridae FMAV representative of yellowfin madtom acute sensitivity to ammonia.

Family	Species	SMAV (mg/L)[a]	GMAV (mg/L)[a]	FMAV (mg/L)[a]
Ictaluridae	Yellowfin madtom, *Noturus flavipinnis*	N/A	N/A	142.4
Ictaluridae	Channel catfish, *Ictalurus punctatus*	142.4	142.4	

[a] Normalized to pH 7 (USEPA 2013). N/A: not available

2.4.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical acute toxicity data were unavailable for deriving an LC_{50}:LC_5 ratio for yellowfin madtom, and because no other toxicity tests are available for the Genus *Noturus*, a genus-level TAF could not be calculated. As a result, EPA analyzed C-R data from the three (of 20) acute toxicity tests with channel catfish that reported raw empirical data to derive an acute Ictaluridae family-level TAF. Of these, two models (Am-Acute-75; Am-Acute-76) did not exhibit a unique solution (inadequate partial effects). After exclusion of the two unacceptable LC_{50}:LC_5 ratios for use in calculating an acute Ictaluridae family-level acute TAF, a single ratio remained. The acute Ictaluridae family-level TAF (representative of yellowfin madtom) is 1.485 (see Am-Acute-74 in Appendix A.1 for the raw empirical toxicity test data, TRAP model and output for the single acute ammonia toxicity test).

2.4.1.3 Calculating Yellowfin Madtom Acute Ammonia Minimum Effect Threshold

Dividing the estimated yellowfin madtom LC_{50} value (142.4 mg/L; Family-level surrogate) by the acute Ictaluridae family-level TAF (1.485) results in an acute minimum effect threshold concentration of 95.89 mg/L (normalized to pH 7) representative of the yellowfin madtom.

2.4.1.4 Yellowfin Madtom: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 (17 mg/L), is 5.6 times lower than the yellowfin madtom acute minimum effect threshold of 95.89 mg/L. The yellowfin madtom acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary and approval of the acute ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the yellowfin madtom through direct acute effects.

2.4.2 Yellowfin Madtom Chronic Ammonia Effects Assessment

2.4.2.1 Identifying Yellowfin Madtom Chronic Ammonia Data

High-quality species- or genus-level chronic toxicity data from Appendix B of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for the yellowfin madtom or other species within the Genus *Noturus*. Family-level surrogate chronic toxicity data were, therefore, used to determine an Ictaluridae chronic toxicity value (i.e., EC_{20}) of 21.36 mg/L (pH 7) representative of the yellowfin madtom (Table 2-10). The FMCV is based on chronic toxicity tests results reported for the channel catfish (Genus *Ictalurus*). The SMCV for channel catfish was calculated as the geometric mean of three EC_{20} values from two ELS tests and one juvenile test. The EC_{20} values from the tests ranged from 20.35 to 22.66 mg/L (see Appendix B in

USEPA 2013). The channel catfish test endpoints used for EC_{20} estimation were growth (measured as weight), biomass, and juvenile survival.

Table 2-10. Data used to calculate the Ictaluridae FMCV representative of yellowfin madtom chronic sensitivity to ammonia.

Family	Species	SMCV (mg/L)[a]	GMCV (mg/L)[a]	FMCV (mg/L)[a]
Ictaluridae	Yellowfin madtom, *Noturus flavipinnis*	N/A	N/A	21.36
Ictaluridae	Channel catfish, *Ictalurus punctatus*	21.36	21.36	

[a] Normalized to pH 7 (USEPA 2013). N/A: not available

2.4.2.2 Deriving the EC_{20} to EC_5 Chronic Adjustment Factor

Raw empirical chronic toxicity data were only available for one of the three early-life stage tests with channel catfish to calculate a chronic Ictaluridae family-level TAF representative of the yellowfin madtom; however, the TRAP model poorly fitted low-level effects and likely underestimated the EC_{20}:EC_5 ratio (see Am-Chronic-24 in Appendix A.4; EC_{20}:EC_5 ratio = 1.207). The single *Ictaluridae* C-R model was, therefore, excluded from the analysis, leaving no C-R data within the Order Siluriformes. As a result, EPA obtained and analyzed C-R data for all tests used to derive the chronic criterion (USEPA 2013 Appendix B bolded values) where such data were reported or could be obtained to derive a chronic vertebrate-level TAF and a chronic MAF, if necessary (i.e., if the vertebrate and invertebrate-level chronic TAFs do not differ from one another).

Raw empirical chronic toxicity data were fit to C-R models using EPA's TRAP software to calculate EC_{20} and corresponding EC_5 values for 31 tests representing 20 species (10 invertebrate and 10 fish species). C-R models were excluded from TAF and MAF calculation if 1) models did not exhibit a unique solution and were flagged by TRAP as having inadequate partial effects; 2) models did not include observations in the region of interest which did not allow TRAP to accurately model a no-response plateau and; 3) models exhibited incongruities such as no or poor fit to key points (as was the case with the channel catfish TRAP model, see Am-Chronic-24) or excessive noise in the C-R relationship. After exclusion of unacceptable or uncertain EC_{20}:EC_5 ratios for use in calculating a chronic MAF, 20 ratios remained resulting in five genus-level EC_{20}:EC_5 ratios for invertebrate species (arithmetic mean = 1.341 mg/L, variance = 0.01208 mg/L) and seven genus-level EC_{20}:EC_5 ratios for vertebrate species (arithmetic mean = 1.472 mg/L, variance = 0.01326 mg/L). Analysis of the two means via a two-sample t-test assuming unequal variances ($\alpha = 0.05$) indicated that the means are the same (*t stat [-2.004] < t critical for two tail [2.262]*). As a result, the chronic MAF was used to transform the Ictaluridae FMCV applicable to the yellowfin madtom (21.36 mg/L) to a chronic minimum effect threshold concentration.

Table 2-11 provides the 12 genus-level EC_{20}:EC_5 ratios used to derive the chronic MAF. Individual test ratios ranged from 1.183 to 1.881. The chronic MAF calculated as the geometric mean of all genus-level EC_{20}:EC_5 ratios is 1.412 (see Appendix A.3 for raw empirical toxicity test data, TRAP models and outputs for the 20 chronic ammonia toxicity tests used to derive the chronic MAF; Appendix A.4 includes the raw empirical toxicity data, TRAP models and outputs for all unacceptable and uncertain ammonia toxicity tests).

Although the single Ictaluridae C-R model was excluded from the analysis, it can provide supportive insight into the appropriateness of the chronic MAF. For example, EPA noted the TRAP model (Am-Chronic-24 in Appendix A.4) poorly fitted low-level effects and underestimated the EC_{20}:EC_5 ratio (1.207), suggesting a slightly larger ratio is most appropriate for members of the Family Ictaluridae based on empirical observations. Accordingly, the chronic MAF of 1.412 is appropriate based on acceptable C-R data and supporting information from unacceptable/uncertain C-R data (i.e., Am-Chronic-24).

Table 2-11. Chronic EC_{20}:EC_5 ratios from analysis of 20 high-quality chronic ammonia toxicity tests with freshwater aquatic organisms used to derive a chronic ammonia MAF representative of the yellowfin madtom.
(Note: the chronic MAF is the geometric mean of all available genus-level EC_{20}:EC_5 ratios).

Order	Family	Species	EC_{20} (mg/L)	EC_{05} (mg/L)	EC_{20}: EC_{05}	C-R Curve Label	Reference	Species-level TAF (EC_{20}:EC_{05})	Genus-level TAF (EC_{20}:EC_{05})
Veneroida	Pisidiidae	Long fingernailclam, *Musculium transversum*	6.049	4.626	1.308	Am-Chronic-4	Anderson et al. 1978	1.308	1.308
Neotaenioglossa	Hydrobiidae	Pebblesnail (1.81 mm juvenile), *Fluminicola* sp.	2.269	1.559	1.455	Am-Chronic-6	Besser 2011	1.455	1.455
Diplostraca	Daphniidae	Water flea, *Ceriodaphnia acanthina*	49.59	41.21	1.203	Am-Chronic-7	Mount 1982	1.203	1.322
Diplostraca	Daphniidae	Water flea, *Ceriodaphnia dubia*	15.57	10.36	1.503	Am-Chronic-8	Nimmo et al. 1989	1.453	
Diplostraca	Daphniidae	Water flea, *Ceriodaphnia dubia*	5.720	4.072	1.405	Am-Chronic-9	Willingham 1987		
Diplostraca	Daphniidae	Water flea, *Daphnia magna*	8.265	5.026	1.645	Am-Chronic-10	Gersich et al. 1985	1.436	1.436
Diplostraca	Daphniidae	Water flea, *Daphnia magna*	20.86	16.64	1.254	Am-Chronic-11	Reinbold and Pescitelli 1982a		
Plecoptera	Pteronarcyidae	Stonefly, *Pteronarcella badia*	133.8	113.0	1.183	Am-Chronic-13	Thurston et al. 1984b	1.183	1.183
Salmoniformes	Salmonidae	Lahontan cutthroat trout (fertilized), *Oncorhynchus clarkii henshawi*	19.32	10.83	1.784	Am-Chronic-15	Koch et al. 1980	1.784	1.497
Salmoniformes	Salmonidae	Rainbow trout, *Oncorhynchus mykiss*	8.982	7.148	1.257	Am-Chronic-16	Brinkman et al. 2009	1.257	
Esociformes	Esocidae	Northern pike (fertilized), *Esox lucius*	14.81	10.91	1.357	Am-Chronic-17	Harrahy et al. 2004	1.357	1.357
Cypriniformes	Cyprinidae	Common carp (fertilized), *Cyprinus carpio*	8.246	5.612	1.469	Am-Chronic-18	Mallet and Sims 1994	1.469	1.469
Cypriniformes	Cyprinidae	Fathead minnow (embryo-larvae), *Pimephales promelas*	4.656	3.361	1.385	Am-Chronic-19	Mayes et al. 1986	1.565	1.565
Cypriniformes	Cyprinidae	Fathead minnow (embryo-larvae), *Pimephales promelas*	7.396	5.561	1.330	Am-Chronic-20	Adelman et al. 2009		
Cypriniformes	Cyprinidae	Fathead minnow, *Pimephales promelas*	5.795	3.081	1.881	Am-Chronic-21	Swigert and Spacie 1983		
Cypriniformes	Cyprinidae	Fathead minnow, *Pimephales promelas*	1.903	1.099	1.732	Am-Chronic-22	Thurston et al. 1986		
Cypriniformes	Catostomidae	White sucker (3 d old embryo), *Catostomus commersonii*	1.296	0.783	1.656	Am-Chronic-23	Reinbold and Pescitelli 1982a	1.656	1.656

Order	Family	Species	EC_{20} (mg/L)	EC_{05} (mg/L)	EC_{20}: EC_{05}	C-R Curve Label	Reference	Species-level TAF (EC_{20}:EC_{05})	Genus-level TAF (EC_{20}:EC_{05})
Perciformes	Centrarchidae	Bluegill, *Lepomis macrochirus*	1.855	1.402	1.323	Am-Chronic-27	Smith et al. 1984	1.323	1.323
Perciformes	Centrarchidae	Smallmouth bass, *Micropterus dolomieu*	8.395	5.585	1.503	Am-Chronic-30	Broderius et al. 1985	1.440	1.440
Perciformes	Centrarchidae	Smallmouth bass, *Micropterus dolomieu*	1.610	1.168	1.379	Am-Chronic-31	Broderius et al. 1985		

2.4.2.3 Calculating the Yellowfin madtom Chronic Ammonia Minimum Effect Threshold

Dividing the estimated yellowfin madtom EC_{20} value (21.36 mg/L; family-level surrogate) by the chronic MAF (1.412) results in a chronic minimum effect threshold concentration of 15.13 mg/L (normalized to pH 7) representative of the yellowfin madtom.

2.4.2.4 Yellowfin madtom: Chronic Ammonia Effect Determination

The chronic ammonia CCC at pH 7 (1.9 mg/L), is 7.9 times lower than the yellowfin madtom chronic minimum effect threshold concentration of 15.13 mg/L. The yellowfin madtom chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, approval of the chronic ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the yellowfin madtom through direct chronic effects.

2.4.3 Yellowfin Madtom Ammonia Indirect Effects Assessment

The yellowfin madtom feeds from dusk into night on aquatic insect larvae (USFWS 1983c). Aquatic life criteria are based on the fifth centile of sensitive genera to ensure the broad aquatic community, including emerging aquatic insects, is adequately protected. Aquatic insects ranked among the most tolerant taxa to acute ammonia exposures (see Table 3 of USEPA 2013; see Table 2-27 of this assessment). For example, the most sensitive aquatic insect genera (*Enallagma* GMAV = 164 mg/L, normalized to pH 7 and 20°C) to acute ammonia exposure ranked in the 68th centile of sensitivity among all genera. Chronic toxicity data with emerging aquatic insects were relatively limited; however, the only chronic toxicity data with an insect genus represented is the most tolerant genus to chronic ammonia exposures (*Pteronarcella* GMCV = 73.74 mg/L, normalized to pH 7 and 20°C). Yellowfin madtom prey items are relatively insensitive to ammonia at magnitudes and exposure durations specified by the acute and chronic ammonia criteria. As a result, approval of the acute and chronic ammonia water quality standards is Not Likely to Adversely Affect (NLAA) the yellowfin madtom through indirect effects.

2.5 Pink Mucket (*Lampsilis abrupta*)

2.5.1 Pink Mucket Acute Ammonia Effects Assessment

2.5.1.1 Identifying Pink Mucket Acute Ammonia Data

High-quality species-level acute toxicity data are available for the pink mucket (see Appendix A of USEPA 2013). The pink mucket SMAV (26.03 mg/L, normalized to pH 7 and 20°C) is based on a single definitive LC_{50} value reported for 2-month old juveniles via a 96-hr flow-through test by Wang et al. (2007a). The pink mucket SMAV is the lowest for the Genus *Lampsilis*, and indicates the possibility of greater sensitivity of the species to ammonia compared to other tested mussels in the Genus *Lampsilis*.

2.5.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical toxicity data were available from the acute toxicity test used to calculate the pink mucket SMAV (Wang et al. 2007a). The raw empirical acute toxicity data were fit to a C-R model using EPA's TRAP software to calculate an LC_{50} and corresponding LC_5 value. The acute

species-level TAF for the pink mucket is 1.687 (see Am-Acute-10 in Appendix A.1 for raw empirical toxicity test data, TRAP model and output for the single acute ammonia toxicity test).

2.5.1.3 Calculating Pink Mucket Acute Ammonia Minimum Effect Threshold

Dividing the pink mucket SMAV (26.03 mg/L) by the pink mucket species-level acute TAF (1.687) results in an acute minimum effect threshold concentration of 15.43 mg/L (normalized to pH 7 and 20°C).

2.5.1.4 Pink Mucket: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 and 20°C (17 mg/L) is greater than the pink mucket acute minimum effect threshold of 15.43 mg/L, suggesting the ammonia CMC may not be protective of pink mucket under continuous exposure conditions. Because pink mucket sensitivity to acute ammonia exposure under continuous laboratory exposure is based on a single acute toxicity test, EPA further considered available acute toxicity test data with other mussels in the same genus (*Lampsilis*) that were used to calculate the *Lampsilis* GMAV in criteria derivation (USEPA 2013).

The pink mucket acute minimum effect threshold concentration contains some underlying uncertainty because it's based on a single LC_{50} value transformed by a single LC_{50}:LC_5 ratio for the species. Table 2-12 provides the LC_{50} values and SMAVs used to derive the *Lampsilis* GMAV in EPA's 2013 Ammonia Aquatic Life Criteria document. The single LC_{50} value for pink mucket (26.03 mg/L at pH 7 and 20°C) is among the lowest for the genus. A second pink mucket LC_{50} value was available but was excluded from criteria derivation because ammonia concentrations in the test waters were not measured. The pink mucket LC_{50} reported in the test with unmeasured ammonia treatment concentrations is similar (14.71 mg/L; Wang et al. 2007b) to the pink mucket SMAV used in this assessment, providing evidence of repeatability of results (see USEPA 2013, Appendix A). Of the six *Lampsilis* sp. for which high-quality acute toxicity data exist, the SMAV for pink mucket is the lowest with SMAVs for *Lampsilis* sp. ranging from 26.03 mg/L for the pink mucket to 69.97 mg/L for the Neosho mucket (Table 2-12; *L. rafinesqueana*). Because all SMAVs for other *Lampsilis* sp. are greater than 26.03 mg/L at pH 7 and 20°C, uncertainty remains concerning the representativeness of the single LC_{50} value for *L. abrupta*; although the repeat of the test with the same life stage (2-month old juveniles) in a different study with unmeasured ammonia treatments concentrations supports the value.

The species-level TAFs for other lampsilid mussels range from a low of 1.687 for pink mucket to 2.725 for *L. fasciola* (wavy-rayed lampmussel) – see Table 2-13. The genus-level TAF for *Lampsilis*, based on nine LC_{50}:LC_5 ratios representing four species, is 2.102 (Table 2-13). Dividing the pink mucket LC_{50} value (26.03 mg/L) by the acute *Lampsilis* genus-level TAF (2.102) results in an estimated acute minimum effect threshold concentration of 12.38 mg/L (normalized to pH 7 and 20°C). This value is more conservative then the acute minimum effect threshold concentration of 15.43 mg/L calculated using the species-level TAF, and given that the species-level TAFs for three other *Lampsilis* sp. is greater than the pink mucket species-level TAF, the acute minimum effect threshold is likely representative of the species. Evaluation of the concentration-response relationship and LC_{50}:LC_5 ratio for the second (unused) LC_{50} value available for the same life stage (2-month-old juveniles) of pink mucket from the same

laboratory but different study (i.e., Wang et al. 2007b), indicates that the ratio could be as low as 1.465 (see Am-Acute-9 in Appendix A.2). The TRAP model for the test with unmeasured ammonia treatment concentrations, however, did not exhibit a unique solution (inadequate partial effects) and was not used. Nevertheless, the LC_{50}:LC_5 ratio from the test indicates that the species-level TAF of 1.687 is potentially conservative for the species given the steep C-R slope suggested by the pink mucket C-R curve from the test with unmeasured ammonia treatments (Wang et al. 2007b; see Am-Acute-9 in Appendix A.2).

Table 2-12. Data used to calculate the *Lampsilis* GMAV.

Species	Normalized LC_{50} (mg/L)[a]	SMAV (mg/L)[a]	GMAV (mg/L)[a]
Pink mucket (2 mo old juvenile), *Lampsilis abrupta*	26.03	26.03	46.63
Plain pocketbook (1-2 d old juvenile), *Lampsilis cardium*	54.07	50.51	
Plain pocketbook (1-2 d old juvenile), *Lampsilis cardium*	47.19		
Wavy-rayed lampmussel (2-5 d old juvenile), *Lampsilis fasciola*	25.31	48.11	
Wavy-rayed lampmussel (<5 d old juvenile), *Lampsilis fasciola*	69.63		
Wavy-rayed lampmussel (glochidia), *Lampsilis fasciola*	59.28		
Wavy-rayed lampmussel (glochidia), *Lampsilis fasciola*	51.30		
Higgin's eye (1-2 d old juvenile), *Lampsilis higginsii*	45.64	41.90	
Higgin's eye (1-2 d old juvenile), *Lampsilis higginsii*	38.46		
Neosho mucket (<5 d old juvenile), *Lampsilis rafinesqueana*	70.31	69.97	
Neosho mucket (<5 d old juvenile), *Lampsilis rafinesqueana*	86.17		
Neosho mucket (glochidia), *Lampsilis rafinesqueana*	56.55		
Fatmucket (3 mo old juvenile), *Lampsilis siliquoidea*	74.25	55.42	
Fatmucket (2 mo old juvenile), *Lampsilis siliquoidea*	28.99		
Fatmucket (7 d old juvenile), *Lampsilis siliquoidea*	24.30		
Fatmucket (7 d old juvenile), *Lampsilis siliquoidea*	28.39		
Fatmucket (7 d old juvenile), *Lampsilis siliquoidea*	40.27		
Fatmucket (7 d old juvenile), *Lampsilis siliquoidea*	27.51		
Fatmucket (7 d old juvenile), *Lampsilis siliquoidea*	65.59		
Fatmucket (7 d old juvenile), *Lampsilis siliquoidea*	54.37		
Fatmucket (glochidia), *Lampsilis siliquoidea*	91.01		

Species	Normalized LC_{50} (mg/L)[a]	SMAV (mg/L)[a]	GMAV (mg/L)[a]
Fatmucket (glochidia), *Lampsilis siliquoidea*	84.14		
Fatmucket (glochidia), *Lampsilis siliquoidea*	107.6		
Fatmucket (glochidia), *Lampsilis siliquoidea*	>160.5		
Fatmucket (glochidia), *Lampsilis siliquoidea*	49.74		
Fatmucket (glochidia), *Lampsilis siliquoidea*	66.77		

[a] Normalized to pH 7 and 20°C (USEPA 2013). N/A: not available.

Acute effect concentrations are inherently linked to exposure duration; the longer organisms are exposed to a particular pollutant, the lower the observed acute effect concentration is anticipated to be (down to an incipient lethal concentration; i.e., the point where the concentration that is lethal to the test organisms as a result of exposure for periods sufficiently long that acute lethal action has essentially ceased). The ammonia acute criterion magnitude is associated with a one-hour duration, which is a conservative approach, considering the pink mucket acute low effect threshold concentration is based on a 96-hour continuous exposure toxicity test. The pink mucket minimum effect threshold concentration may be lower than the criterion magnitude; however, the duration component of the acute criterion provides a level of protection that is not anticipated to result in adverse effects. For example, Table 4 of Wang et al. (2007a) reported a pink mucket 96-hr LC_{50} of 26.03 total mg ammonia/L (normalized to pH 7 and 20°C) and a 48-hr LC_{50} from the same acute toxicity test of 56.77 total mg ammonia/L (normalized to pH 7 and 20°C). The 48-hr LC_{50} is more than two times greater than the corresponding LC_{50} at 96 hours, indicating greater tolerance at shorter exposure durations.

Further, aquatic life criteria are conservatively implemented in National Pollution Discharge Elimination System (NPDES) permit limits by assuming receiving streams are continually at low-flow conditions which significantly limits the probability of *in situ* pollutant concentrations reaching criteria magnitudes and durations. NPDES permit limits based on the acute ammonia criterion typically assume a receiving stream is continually at 1Q10 low-flow conditions, while the probability of these low-flow conditions occurring is exceedingly rare (i.e., 1-day average lowest flow over the course of a 10-year period). Similarly, NPDES permit limits based on the chronic ammonia criterion typically assume receiving streams are continually at 30Q10 or 30Q5 low-flow conditions (i.e., 30-day average lowest flow over the course of a 5 or 10-year period). As a result, excess dilution limits instream ammonia concentrations and drastically decreases the probability *in situ* ammonia concentrations will reach criteria magnitudes and durations. Independent of assuming low flow conditions, NPDES permits also provide an additional level of protection by ensuring facilities discharge ammonia at Long Term Average concentrations (LTAs), which are based on Waste Load Allocations[2] (WLAs) set as the 99th centile of a log-

[2] A Waste Load Allocation (WLA) is the maximum allowable pollutant concentration in an effluent from a discharger that, after accounting for available dilution under critical low flow conditions (e.g., 1Q10, 30Q5, 30Q10), will meet an applicable water quality criterion (USEPA 1991).

normal distribution that describes effluent variability. Setting WLAs as the 99th centile of an effluent distribution ensures permitted facilitates discharge relatively low concentrations of ammonia so that the probability of in stream ammonia concentrations reaching criteria concentrations is 1% under the additional protective assumption that streams are always at critical low flow conditions. Setting WLAs as the 99th centile of an effluent distribution while independently assuming streams are continually at critical low flow conditions, compounds protective conservative assumptions to considerably reduce the probability that in stream ammonia concentrations reach criteria magnitudes. Thus, it is highly unlikely (e.g., 1% chance, even assuming streams are actually at 1Q10 low flow conditions; USEPA 1991) the pink mucket will be exposed to ammonia *in situ* at the acute criterion magnitude for continuous exposure durations. As a result, approval of the acute ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the pink mucket through direct acute effects.

Table 2-13. Comparison of acute LC_{50}:LC_5 ratios from analysis of nine high-quality acute ammonia toxicity tests with freshwater unionid mussels in Genus *Lampsilis*.

Family	Species	LC_{50} (mg/L)	LC_{05} (mg/L)	LC_{50}: LC_{05}	C-R Curve Label	Reference	Species-level TAF LC_{50}:LC_{05}	Genus-level TAF LC_{50}:LC_{05}
Unionidae	Pink mucket (2 mo old juvenile), *Lampsilis abrupta*	2.559	1.518	1.687	Am-Acute-10	Wang et al. 2007a	1.687	2.102
Unionidae	Wavy-rayed lampmussel (<5 d old juvenile), *Lampsilis fasciola*	7.896	2.476	3.189	Am-Acute-12	Wang et al. 2007b	2.725	
Unionidae	Wavy-rayed lampmussel (glochidia), *Lampsilis fasciola*	8.435	3.786	2.228	Am-Acute-13	Wang et al. 2007b		
Unionidae	Wavy-rayed lampmussel (glochidia), *Lampsilis fasciola*	6.133	2.153	2.849	Am-Acute-14	Wang et al. 2007b		
Unionidae	Neosho mucket (<5 d old juvenile), *Lampsilis rafinesqueana*	11.26	4.835	2.328	Am-Acute-16	Wang et al. 2007b	2.328	
Unionidae	Fatmucket (2 mo old juvenile), *Lampsilis siliquoidea*	3.959	2.010	1.970	Am-Acute-21	Wang et al. 2007a	1.825	
Unionidae	Fatmucket (7 d old juvenile), *Lampsilis siliquoidea*	10.75	5.677	1.894	Am-Acute-22	Wang et al. 2008		
Unionidae	Fatmucket (7 d old juvenile), *Lampsilis siliquoidea*	12.01	8.766	1.370	Am-Acute-27	Wang et al. 2008		
Unionidae	Fatmucket (glochidia), *Lampsilis siliquoidea*	7.537	3.469	2.173	Am-Acute-32	Wang et al. 2007b		

2.5.2 Pink Mucket Chronic Ammonia Effects Assessment

2.5.2.1 Identifying Pink Mucket Chronic Ammonia Data

High-quality species-level chronic toxicity data from Appendix B of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for the pink mucket. Genus-level chronic toxicity data were, therefore, used to determine a chronic toxicity value (i.e., EC_{20}) of 2.126 mg/L (pH 7 and 20°C) representative of the pink mucket (Table 2-14). The *Lampsilis* GMCV is based on chronic toxicity test results reported for two different lampsilid species, the fatmucket and wavy-rayed lamp mussel. The test endpoint measured in each test was juvenile survival. The values used to calculate the *Lampsilis* GMCV were used to derive the chronic ammonia criterion (bold values in Appendix B of USEPA [2013]) and have been normalized to a pH of 7 and water temperature of 20°C.

Table 2-14. Data used to calculate the *Lampsilis* GMCV representative of pink mucket chronic sensitivity to ammonia.

Family	Species	SMCV (mg/L)[a]	GMCV (mg/L)[a]
Unionidae	Pink mucket, *Lampsilis abrupta*	N/A	2.126
Unionidae	Wavy-rayed lamp mussel, *Lampsilis fasciola*	1.408	
Unionidae	Fatmucket, *Lampsilis siliquoidea*	3.211	

[a] Normalized to pH 7 and 20°C (USEPA 2013).N/A: not available.

2.5.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

EPA analyzed C-R data from the two surrogate species tests used to calculate the *Lampsilis* GMCV representative of the pink mucket (no species-level C-R data available). Both models (Am-Chronic-1 and Am-Chronic-2) were not used because of poor model fit, which missed the initial decline in response at low effect concentrations. No other acceptable chronic C-R data were available within the Order Unionoida, requiring the application of the chronic MAF (see previous analysis from Section 2.4.2.2 for chronic MAF derivation). The chronic MAF, calculated as the geometric mean of all acceptable genus-level EC_{20}:EC_5 ratios, is 1.412 (see Appendix A.3 for raw toxicity test data, TRAP models and outputs for the 20 chronic ammonia toxicity tests used to derive the chronic MAF).

2.5.2.3 Calculating Pink Mucket Chronic Ammonia Minimum Effect Threshold

Dividing the estimated pink mucket EC_{20} value (2.126 mg/L; genus-level surrogate) by the chronic MAF (1.412) results in a chronic minimum effect threshold concentration of 1.506 mg/L (normalized to pH 7 and 20°C).

2.5.2.4 Pink Mucket: Chronic Ammonia Effects Determination

The chronic ammonia CCC at pH 7 and 20°C (1.9 mg/L) is greater than the pink mucket chronic minimum effect threshold concentration of 1.506 mg/L, suggesting the ammonia CCC may not be protective of pink mucket under continuous exposure conditions. Due to the apparent pink mucket sensitivity to chronic ammonia exposure under continuous laboratory exposure, EPA further considered available chronic toxicity tests data used to support the chronic effects

assessment for the pink mucket. Specifically, EPA considered the two less-robust C-R models (see Appendix A; Am-Chronic-1; Am-Chronic-2) and relationships defined in the two 28-day juvenile chronic toxicity tests with wavy-rayed lamp mussel (*L. fasciola*) and fatmucket mussel (*L. siliquoidea*). These tests were used to calculate the *Lampsilis* GMCV (the tests used to calculate the genus-level surrogate value), but not used to determine a chronic *Lampsilis* genus-level TAF due to poor model fit.

The C-R data for the wavy-rayed lampmussel (Wang et al. 2007a) shows 100% control survival after 28 days, decreasing to 83, 77, 73, and 30% at the four lowest treatment levels before decreasing to 0% at the 1.98 mg/L treatment concentration (Table 2-15). The TRAP model fit (see Am-Chronic-1 in Appendix A.4) adequately characterizes the falling limb of the C-R curve, but misses the initial decline observed in the lowest treatment level, which has 17% lower survival than the control. The poor model fit in the lower concentration range increases the uncertainty in the EC_{20}:EC_5 ratio for this test by over estimating the EC_5. The EC_{20}:EC_5 ratio for this test is likely to be greater than the TRAP estimated ratio of 1.590.

The C-R data for the fatmucket (Wang et al. 2007a) shows 95% control survival after 28 days, increasing to 96% and then decreasing again to 95, 82, and 75% at the next four treatment levels before decreasing to 0% at the 2.02 mg/L treatment concentration (Table 2-15). The TRAP model fit (see Am-Chronic-2 in Appendix A.4) also appears to adequately characterize the falling limb of the C-R curve by transecting the observed survival at the fourth treatment (0.88 mg TAN/L), but also misses the initial 13% decline observed in the third lowest treatment level (0.49 mg TAN/L). Poor model fit in the lower concentration range increases the uncertainty in the EC_{20}:EC_5 ratio for this test by over estimating the EC_5. The EC_{20}:EC_5 ratio for this test is likely greater than the TRAP estimated ratio of 1.208.

Dividing the estimated pink mucket EC_{20} value (2.126 mg/L; genus-level surrogate) by the chronic *Lampsilis* genus-level TAF (1.386; geometric mean of 1.590 and 1.208) calculated from less-robust C-R curves (Am-Chronic-1; Am-Chronic-2) results in a chronic minimum effect threshold concentration of 1.534 mg/L (normalized to pH 7 and 20°C). This value is similar to the chronic minimum effect threshold concentration of 1.506 mg/L calculated using the chronic MAF.

Table 2-15. Chronic raw empirical data from 28-day ammonia toxicity tests with 2-month old juvenile wavy-rayed lamp mussel (*L. fasciola*) and fatmucket (*L. siliquoidea*) used to derive EC_{20}:EC_5 adjustment factors (based on TRAP) representative of the pink mucket.

Species	Measured Total Ammonia Nitrogen (mg/L)	Percent Survival (%)
L. fasciola	0.04 (control)	100
L. fasciola	0.13	83
L. fasciola	0.34	77
L. fasciola	0.44	73
L. fasciola	1.02	30
L. fasciola	1.98	0
L. siliquoidea	0.06 (control)	95
L. siliquoidea	0.16	96
L. siliquoidea	0.26	95
L. siliquoidea	0.49	82
L. siliquoidea	0.88	75
L. siliquoidea	2.02	0

The estimated pink mucket chronic minimum effect threshold concentration contains some underlying uncertainty that stems largely from the lack of a robust EC_{20}:EC_5 ratio for the species, but some additional uncertainty also exists with the use of a genus-level surrogate chronic value (i.e., genus-level EC_{20}). For example, the acute data indicate the pink mucket is likely the most sensitive species (based on available data) within the Genus *Lampsilis* to acute ammonia exposures (see Section 2.5.1.1 and 2.5.1.4). As a result, it is possible that the chronic minimum effect threshold concentration for the pink mucket underestimates sensitivity to chronic ammonia exposures.

However, it is highly unlikely the pink mucket will be exposed to ammonia *in situ* at the chronic criterion magnitude for continuous exposure durations because aquatic life criteria are conservatively implemented in National Pollution Discharge Elimination System (NPDES) permit limits by assuming receiving streams are continually at low-flow conditions which significantly limits the probability of *in situ* pollutant concentrations reaching criteria magnitudes and durations. NPDES permit limits based on the acute ammonia criterion typically assume a receiving stream is continually at 1Q10 low-flow conditions, while the probability of these low-flow conditions occurring is exceedingly rare (i.e., 1-day average lowest flow over the course of a 10-year period). Similarly, NPDES permit limits based on the chronic ammonia criterion typically assume receiving streams are continually at 30Q10 or 30Q5 low-flow conditions (i.e., 30-day average lowest flow over the course of a 5 or 10-year period). As a result, excess dilution limits instream ammonia concentrations and drastically decreases the probability *in situ* ammonia concentrations will reach criteria magnitudes and durations. Independent of assuming low flow conditions, NPDES permits also provide an additional level of protection by ensuring

facilities discharge ammonia at Long Term Average concentrations (LTAs), which are based on Waste Load Allocations[2] (WLAs) set as the 99th centile of a log-normal distribution that describes effluent variability. Setting WLAs as the 99th centile of an effluent distribution ensures permitted facilitates discharge relatively low concentrations of ammonia so that the probability of in stream ammonia concentrations reaching criteria concentrations is 1% under the additional protective assumption that streams are always at critical low flow conditions. Setting WLAs as the 99th centile of an effluent distribution while independently assuming streams are continually at critical low flow conditions, compounds protective conservative assumptions to considerably reduce the probability that in stream ammonia concentrations reach criteria magnitudes. Because the pink mucket chronic low effect is similar to the chronic criterion magnitude and the probability of pink mucket being exposed to ammonia at the chronic criterion magnitude and duration is highly unlikely (e.g., 1% chance, even assuming streams are at 30Q10 or 30Q5 low flow conditions; USEPA 1991), approval of the chronic ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the pink mucket through direct chronic effects.

2.5.3 Pink Mucket Ammonia Indirect Effects Assessment

The pink mucket filters phytoplankton and zooplankton from the water column as a primary food source, both of which are relatively insensitive to acute and chronic ammonia exposures. For example, USEPA (2013) states, plants (e.g., phytoplankton) were not used to derive the ammonia criteria because "*plants are substantially less sensitive than animals*." Moreover, the most sensitive daphnid genus (i.e., *Daphnia*) represents the 50th and 87th centile of the acute and chronic species sensitivity distributions (SSD), respectively (USEPA 2013). Because pink mucket food sources are insensitive to ammonia, EPA approval of Virginia acute and chronic ammonia standards is Not Likely to Adversely Affect (NLAA) the pink mucket through indirect effects.

2.6 Dwarf Wedgemussel (*Alasmidonta heterodon*)

2.6.1 Dwarf Wedgemussel Acute Ammonia Effects Assessment: Freshwater

2.6.1.1 Identifying Dwarf Wedgemussel Acute Ammonia Data

High-quality species-level acute toxicity data are available for the dwarf wedgemussel. The dwarf wedgemussel SMAV (>109.0 mg/L, normalized to pH 7 and 20°C; see Appendix A of USEPA 2013) is composed of a single, non-definitive LC_{50} value from a test with glochidia (Wang et al. 2007b). No other acute values are available for other species in the Genus *Alasmidonta*, therefore, the single dwarf wedgemussel LC_{50} value also served as the GMAV for ammonia criteria derivation. The *Alasmidonta* GMAV is among the highest for the Family Unionidae, and indicates greater tolerance of the dwarf wedgemussel to ammonia compared to other freshwater unionid mussels.

2.6.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical toxicity data from the published acute toxicity study (Wang et al. 2007b) used to calculate the dwarf wedgemussel SMAV are available; however, an LC_{50}:LC_5 adjustment factor for the species could not be derived because the LC_{50} could not be calculated because of a lack of

effects around the area of concern (see Am-Acute-93 in Appendix A.2). No other toxicity tests with raw C-R data are available for the Genus *Alasmidonta*. As a result, EPA obtained and analyzed C-R data for 45 tests with closely-related surrogate species (i.e., freshwater mussels within the Family Unionidae where raw empirical data were reported) to derive an acute family-level TAF. These tests were obtained from Appendix A of USEPA (2013) and were used to derive the acute ammonia criterion, and also include mussel toxicity data reported by Wang et al. (2017; this test was not included in EPA's 304(a) Aquatic Life Criteria for ammonia [USEP 2013] due to its later publication date; however, it meets the data quality objectives for deriving criteria as specified in the 1985 Guidelines [Stephan et al. 1985]).

Raw empirical acute toxicity data were fit to C-R models using EPA's TRAP software to calculate LC_{50} and corresponding LC_5 values for the 45 tests with freshwater mussels in the family Unionidae. Models were excluded if they did not exhibit a unique solution (inadequate partial effects), did not include observations in the region of interest (limiting accuracy in modeling a no-response plateau), or exhibited incongruities such as no or poor fit to key points or excessive noise in the empirical data themselves. After excluding unacceptable/uncertain LC_{50}:LC_5 ratios, 22 ratios remained resulting in six genus-level LC_{50}:LC_5 ratios to calculate a Unionidae family-level TAF representative of the dwarf wedgemussel (Table 2-16; Unionidae family-level acute TAF = 2.441; see Appendix A.1 for raw empirical toxicity data, TRAP models and outputs for the 22 acute ammonia toxicity tests used to derive the acute Unionidae family-level TAF; Appendix A.2 includes the raw empirical toxicity data, TRAP models and outputs for the unacceptable and uncertain ammonia toxicity tests excluded from the acute family-level TAF).

Table 2-16. Acute LC_{50}:LC_5 ratios from analysis of 22 high-quality acute ammonia toxicity tests with freshwater unionid mussels used to derive an acute Unionidae family-level taxonomic adjustment factor (TAF) for the dwarf wedgemussel.

Family	Species	LC_{50} (mg/L)	LC_{05} (mg/L)	LC_{50}: LC_{05}	C-R Curve Label	Reference	Species-level TAF LC_{50}:LC_{05}	Genus-level TAF LC_{50}:LC_{05}	Family-level TAF LC_{50}:LC_{05}
Unionidae	Mucket (glochidia), *Actinonaias ligamentina*	8.681	4.250	2.043	Am-Acute-2	Wang et al. 2007b	2.258	2.258	2.441
Unionidae	Mucket (glochidia), *Actinonaias ligamentina*	5.634	2.256	2.497	Am-Acute-3	Wang et al. 2007b			
Unionidae	Oyster mussel (<5 d old juvenile), *Epioblasma capsaeformis*	5.657	3.651	1.549	Am-Acute-6	Wang et al. 2007b	2.110	2.110	
Unionidae	Oyster mussel (glochidia), *Epioblasma capsaeformis*	6.165	2.992	2.060	Am-Acute-7	Wang et al. 2007b			
Unionidae	Oyster mussel (glochidia), *Epioblasma capsaeformis*	3.215	1.092	2.944	Am-Acute-8	Wang et al. 2007b			
Unionidae	Pink mucket (2 mo old juvenile), *Lampsilis abrupta*	2.559	1.518	1.687	Am-Acute-10	Wang et al. 2007a	1.687	2.102	
Unionidae	Wavy-rayed lampmussel (<5 d old juvenile), *Lampsilis fasciola*	7.896	2.476	3.189	Am-Acute-12	Wang et al. 2007b	2.725		
Unionidae	Wavy-rayed lampmussel (glochidia), *Lampsilis fasciola*	8.435	3.786	2.228	Am-Acute-13	Wang et al. 2007b			
Unionidae	Wavy-rayed lampmussel (glochidia), *Lampsilis fasciola*	6.133	2.153	2.849	Am-Acute-14	Wang et al. 2007b			
Unionidae	Neosho mucket (<5 d old juvenile), *Lampsilis rafinesqueana*	11.26	4.835	2.328	Am-Acute-16	Wang et al. 2007b	2.328		
Unionidae	Fatmucket (2 mo old juvenile), *Lampsilis siliquoidea*	3.959	2.010	1.970	Am-Acute-21	Wang et al. 2007a	1.825		
Unionidae	Fatmucket (7 d old juvenile), *Lampsilis siliquoidea*	10.75	5.677	1.894	Am-Acute-22	Wang et al. 2008			
Unionidae	Fatmucket (7 d old juvenile), *Lampsilis siliquoidea*	12.01	8.766	1.370	Am-Acute-27	Wang et al. 2008			
Unionidae	Fatmucket (glochidia), *Lampsilis siliquoidea*	7.537	3.469	2.173	Am-Acute-32	Wang et al. 2007b			
Unionidae	Washboard, *Megalonaias nervosa*	5.420	1.566	3.461	Am-Acute-35	Wang et al. 2017	3.461	3.461	
Unionidae	Ellipse (glochidia), *Venustaconcha ellipsiformis*	5.360	1.899	2.822	Am-Acute-40	Wang et al. 2007b	2.822	2.822	
Unionidae	Rainbow mussel (2 mo old juvenile), *Villosa iris*	3.213	2.284	1.407	Am-Acute-41	Wang et al. 2007b	2.162	2.162	
Unionidae	Rainbow mussel (2 mo old juvenile), *Villosa iris*	11.135	3.992	2.789	Am-Acute-42	Wang et al. 2007b			

Family	Species	LC_{50} (mg/L)	LC_{05} (mg/L)	LC_{50}: LC_{05}	C-R Curve Label	Reference	Species-level TAF LC_{50}:LC_{05}	Genus-level TAF LC_{50}:LC_{05}	Family-level TAF LC_{50}:LC_{05}
Unionidae	Rainbow mussel (5 d old juvenile), *Villosa iris*	16.04	6.391	2.509	Am-Acute-43	Scheller 1997			
Unionidae	Rainbow mussel (<5 d old juvenile), *Villosa iris*	6.337	3.340	1.897	Am-Acute-44	Wang et al. 2007b			
Unionidae	Rainbow mussel (<3 d old juvenile), *Villosa iris*	8.380	2.340	3.581	Am-Acute-46	Scheller 1997			
Unionidae	Rainbow mussel (2 h old glochidia), *Villosa iris*	11.80	7.727	1.527	Am-Acute-48	Wang et al. 2007b			

2.6.1.3 Calculating Dwarf Wedgemussel Acute Ammonia Minimum Effect Threshold

Dividing the dwarf wedgemussel LC_{50} value (>109.0 mg/L) by the Unionidae family-level TAF (2.441) results in an acute minimum effect threshold concentration of >44.65 mg/L (normalized to pH 7 and 20°C).

2.6.1.4 Dwarf Wedgemussel: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 and 20°C (17 mg/L), is 2.6 times lower than the dwarf wedgemussel acute minimum effect threshold of >44.65 mg/L. The dwarf wedgemussel acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. EPA relied on the Unionidae family-level TAF as the primary method for identifying a low-level effect concentration from the dwarf wedgemussel SMAV (i.e., LC_{50}). As a secondary analysis, EPA also considered the single C-R curve available for the dwarf wedgemussel (Wang et al. 2007b; Am-Acute-93) to directly calculate a species-level LC_5 value of 7.114 mg TAN/L (test pH = 8.3; test temperature = 20°C), which is a relatively uncertain estimate given the lack of acute responses (i.e., no responses beyond a 42% effect level) at the highest concentration tested. The species-level LC_5 normalized to reference conditions (pH = 7.0; temperature = 20°C) is 54.45 mg TAN/L. The species level LC_5 (54.46 mg TAN/L; pH = 7.0; temperature = 20°C) identified from curve Am-Acute-93, is 3.2 times greater than the CMC, further suggesting the dwarf wedgemussel is not acutely sensitive to ammonia at exposures concentrations and durations specified by the acute ammonia criterion. As a result, refined assessment and consideration of the criterion duration is not necessary and approval of the freshwater acute ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the dwarf wedgemussel through direct acute effects.

2.6.2 Dwarf Wedgemussel Chronic Ammonia Effects Assessment: Freshwater

2.6.2.1 Identifying Dwarf Wedgemussel Chronic Ammonia Data

High-quality species-level or genus-level chronic toxicity data from Appendix B of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for the dwarf wedgemussel. Family-level chronic toxicity data were, therefore, used to determine a chronic toxicity value (i.e., EC_{20}) of 2.728 mg/L (pH 7 and 20°C) representative of the dwarf wedgemussel (Table 2-17). The Unionidae FMCV is based on chronic toxicity test results reported for the fatmucket and wavy-rayed lamp mussel (Genus *Lampsilis*), and the rainbow mussel (Genus *Villosa*). The test endpoint for each test was juvenile survival. The two GMCVs used to derive the Unionidae FMCV were obtained from Appendix B of the 2013 Freshwater Ammonia 304(a) Aquatic Life Criteria document and have been normalized to a pH of 7 and water temperature of 20°C, consistent with the 2013 chronic ammonia criterion.

Table 2-17. Data used to calculate the Unionidae FMCV representative of dwarf wedgemussel chronic sensitivity to ammonia.

Family	Species	SMCV (mg/L)[a]	GMCV (mg/L)[a]	FMCV (mg/L)[a]
Unionidae	Dwarf wedgemussel, *Alasmidonta heterodon*	N/A	N/A	2.728
Unionidae	Wavy-rayed lamp mussel, *Lampsilis fasciola*	1.408	2.126	
Unionidae	Fatmucket, *Lampsilis siliquoidea*	3.211		
Unionidae	Rainbow mussel, *Villosa iris*	3.501	3.501	

[a] Normalized to pH 7 and 20°C (USEPA 2013). N/A: not available

2.6.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

Chronic C-R data are not available for the dwarf wedgemussel or other members of the Genus *Alasmidonta* to support the derivation of an EC_{20}:EC_5 adjustment factor within the Genus *Alasmidonta*. EPA analyzed C-R data for the same three tests with family-level surrogate species used to calculate the FMCV for the dwarf wedgemussel, which were the only three chronic toxicity tests with members of the Family Unionidae used to derive the chronic ammonia criterion (bold values of Appendix B in USEPA 2013). All three TRAP models, however, were determined to be unacceptable or uncertain. Both C-R models for members of the Genus *Lampsilis* (Am-Chronic-1, Am-Chronic-2) were not used because of poor model fit, which missed the initial decline in response at low effect concentrations. The rainbow mussel TRAP model (Am-Chronic-3) was considered uncertain/unacceptable because it did not exhibit a unique solution (inadequate partial effects). No other acceptable C-R data were available within the Order Unionoida, requiring the application of the chronic MAF (see previous analysis from Section 2.4.2.2 for chronic MAF derivation). The chronic MAF, calculated as the geometric mean of all acceptable genus-level EC_{20}:EC_5 ratios, is 1.412 (see Appendix A.3 for raw empirical toxicity test data, TRAP models and outputs for the 20 chronic ammonia toxicity tests used to derive the chronic MAF).

The family-level TAF of the three less-robust C-R models for unionid mussels in the Family Unionidae is 1.285, which likely underestimates the EC_{20}:EC_5 ratio by over estimating the EC_5 values in the two *Lampsilis* (Am-Chronic-1, Am-Chronic-2) C-R models. Thus, the use of the chronic MAF of 1.412 to calculate the chronic minimum effect threshold for dwarf wedgemussel is a reasonable approach.

2.6.2.3 Calculating Dwarf Wedgemussel Chronic Ammonia Minimum Effect Threshold

Dividing the estimated dwarf wedgemussel EC_{20} value (2.728 mg/L; family-level surrogate) by the chronic MAF (1.412) results in a chronic minimum effect threshold concentration of 1.932 mg/L (normalized to pH 7 and 20°C).

2.6.2.4 Dwarf Wedgemussel: Chronic Ammonia Effects Determination

The chronic ammonia CCC at pH 7 and 20°C (1.9 mg/L) is the same as the dwarf wedgemussel chronic minimum effect threshold concentration of 1.932 mg/L, when rounded to two significant figures, suggesting the dwarf wedge mussel is tolerant to chronic ammonia exposure specified by the criterion. Therefore, approval of the freshwater chronic ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the dwarf wedgemussel through direct chronic effects.

2.6.3 Dwarf Wedgemussel Ammonia Indirect Effects Assessment: Freshwater

The dwarf wedgemussel filters phytoplankton and zooplankton from the water column as a primary food source, both of which are relatively insensitive to acute and chronic ammonia exposures. For example, USEPA (2013) states, plants (e.g., phytoplankton) were not used to derive the ammonia criteria because "*plants are substantially less sensitive than animals*." Moreover, the most sensitive daphnid genus (i.e., *Daphnia*) represents the 50th and 87th centile of the acute and chronic species sensitivity distributions (SSD), respectively (USEPA 2013). Because dwarf wedgemussel food sources are insensitive to ammonia, EPA approval of Virginia freshwater acute and chronic ammonia standards is Not Likely to Adversely Affect (NLAA) the dwarf wedgemussel through indirect effects.

2.7 Oyster Mussel (*Epioblasma capsaeformis*) and Other Mussels in Genus *Epioblasma (Epioblasma brevidens, Epioblasma walkeri, Epioblasma torulosa, Epioblasma triquetra)*

2.7.1 Oyster Mussel and Epioblasma Acute Ammonia Effects Assessment

2.7.1.1 Identifying Oyster Mussel and Epioblasma Acute Ammonia Data

High-quality species-level acute toxicity data are available for the oyster mussel. These data are also representative of other mussels in the Genus *Epioblasma* that are lacking species-level data (see Appendix A of USEPA 2013). The oyster mussel SMAV is 31.14 mg/L (normalized to pH 7 and 20°C). The oyster mussel SMAV and *Epioblasma* GMAV are based on the geometric mean of three definitive LC_{50} values reported by Wang et al. (2007b). The normalized LC_{50} values range from a low of 17.81 mg/L for the glochidia life stage (via a 6-hr test, which is an acceptable duration for glochidia life stages see USEPA [2013]) to 53.63 mg/L for <5 d old juveniles (via a 96-hr renewal test). The oyster mussel SMAV and *Epioblasma* GMAV are among the lowest for the Family Unionidae, and indicates the possibility of greater sensitivity of the species and genus to ammonia compared to other tested mussels in the family.

2.7.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical toxicity data were available from all three acute toxicity tests used to calculate the oyster mussel SMAV and *Epioblasma* GMAV. EPA obtained and analyzed C-R data for the tests. The raw empirical acute toxicity data were fit to a C-R model using EPA's TRAP software to calculate LC_{50} and corresponding LC_5 value for the tests. The acute species-level TAF for oyster mussel and genus-level TAF for *Epioblasma* is 2.110 (Table 2-16; see Am-Acute-6, Am-Acute-7 and Am-Acute-8 in Appendix A.1 for raw empirical toxicity test data, TRAP models and outputs for the three acute ammonia toxicity tests).

2.7.1.3 Calculating Oyster Mussel and Epioblasma Acute Ammonia Minimum Effect Threshold

Dividing the oyster mussel SMAV and *Epioblasma* GMAV (31.14 mg/L) by the oyster mussel species- and genus-level acute TAF (2.110) results in an acute minimum effect threshold concentration of 14.76 mg/L (normalized to pH 7 and 20°C).

2.7.1.4 Oyster Mussel and Epioblasma: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 and 20°C (17 mg/L) is greater than the oyster mussel and *Epioblasma* acute minimum effect threshold of 14.76 mg/L, suggesting the ammonia CMC may not be protective under continuous exposure conditions. All available oyster mussel data (and surrogate *Epioblasma*) were considered acceptable for criteria derivation and were used in this assessment, no other uncertain/unacceptable toxicity data are available to further support the acute effects assessment for the oyster mussel.

It is highly unlikely that the oyster mussel and *Epioblasma* will be exposed to ammonia *in situ* at the acute criterion magnitude and duration because aquatic life criteria are conservatively implemented in National Pollution Discharge Elimination System (NPDES) permit limits by assuming receiving streams are continually at low-flow conditions which significantly limits the probability of *in situ* pollutant concentrations reaching criteria magnitudes and durations. NPDES permit limits based on the acute ammonia criterion typically assume a receiving stream is continually at 1Q10 low-flow conditions, while the probability of these low-flow conditions occurring is exceedingly rare (i.e., 1-day average lowest flow over the course of a 10-year period). Similarly, NPDES permit limits based on the chronic ammonia criterion typically assume receiving streams are continually at 30Q10 or 30Q5 low-flow conditions (i.e., 30-day average lowest flow over the course of a 5 or 10-year period). As a result, excess dilution limits instream ammonia concentrations and drastically decreases the probability *in situ* ammonia concentrations will reach criteria magnitudes and durations. Independent of assuming low flow conditions, NPDES permits also provide an additional level of protection by ensuring facilities discharge ammonia at Long Term Average concentrations (LTAs), which are based on Waste Load Allocations[2] (WLAs) set as the 99th centile of a log-normal distribution that describes effluent variability. Setting WLAs as the 99th centile of an effluent distribution ensures permitted facilitates discharge relatively low concentrations of ammonia so that the probability of in stream ammonia concentrations reaching criteria concentrations is 1% under the additional protective assumption that streams are always at critical low flow conditions. Setting WLAs as the 99th centile of an effluent distribution while independently assuming streams are continually at critical low flow conditions, compounds protective conservative assumptions to considerably reduce the probability that in stream ammonia concentrations reach criteria magnitudes.

Because the probability of the oyster mussel and other Virginia listed mussels within the Genus *Epioblasma* (*E. brevidens*; *E. walkeri*; *E. torulosa*; *E. triquetra*) being exposed to ammonia at the acute criterion magnitude and duration is highly unlikely (e.g., 1% chance, assuming streams are at 1Q10 low flow conditions; USEPA 1991), approval of the acute ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the oyster mussel, Cumberlandian combshell, tan riffleshell, green-blossom pearly mussel, and snuffbox mussel through direct acute effects.

2.7.2 Oyster Mussel and Epioblasma Chronic Ammonia Effects Assessment

2.7.2.1 Identifying Oyster Mussel and Epioblasma Chronic Ammonia Data

High-quality species-level chronic toxicity data from Appendix B of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for the oyster mussel or for other species in Genus *Epioblasma.* Family-level chronic toxicity data were, therefore, used to determine a chronic toxicity value (i.e., EC_{20}) of 2.728 mg/L (pH 7 and 20°C) representative of Virginia listed mussel species within the Genus *Epioblasma* (see Table 2-17 and Section 2.6.2.1).

2.7.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

Chronic C-R data are not available for Virginia listed species within the Genus *Epioblasma* to support the derivation of an EC_{20}:EC_5 adjustment factor within the genus. EPA analyzed C-R data for the same three tests with family-level surrogate species used to calculate the FMCV for the oyster mussel, but because the C-R data were not acceptable and no other C-R data were available within the Order Unionoida, a chronic MAF was applied (see Section 2.6.2.2 and Section 2.4.2.2 for justification and basis for chronic MAF derivation, respectively). The chronic MAF, calculated as the geometric mean of all acceptable genus-level EC_{20}:EC_5 ratios, is 1.412 (see Appendix A.3 for raw empirical toxicity test data, TRAP models and outputs for the 20 chronic ammonia toxicity tests used to derive the chronic MAF).

2.7.2.3 Calculating Oyster Mussel and Epioblasma Chronic Ammonia Minimum Effect Threshold

Dividing the estimated *Epioblasma* GMCV (2.728 mg/L; family-level surrogate) by the chronic MAF (1.412) results in a chronic minimum effect threshold concentration of 1.932 mg/L (normalized to pH 7 and 20°C).

2.7.2.4 Oyster Mussel and Epioblasma: Chronic Ammonia Effects Determination

The chronic ammonia CCC at pH 7 and 20°C (1.9 mg/L) is the same as the *Epioblasma* chronic minimum effect threshold concentration of 1.932 mg/L (representative of the oyster mussel, Cumberlandian combshell, tan riffleshell, green-blossom pearly mussel, and snuffbox mussel), when rounded to two significant figures, suggesting Virginia listed mussel species in the Genus *Epioblasma* are tolerant to chronic ammonia exposure specified by the criterion. Approval of the freshwater chronic ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the oyster mussel, Cumberlandian combshell, tan riffleshell, green-blossom pearly mussel, and snuffbox mussel through direct chronic effects.

2.7.3 Oyster Mussel and Epioblasma Ammonia Indirect Effects Assessment

The oyster mussel, Cumberlandian combshell, tan riffleshell, green-blossom pearly mussel, and snuffbox mussel filter phytoplankton and zooplankton from the water column as a primary food source, both of which are relatively insensitive to acute and chronic ammonia exposures. For example, USEPA (2013) states, plants (e.g., phytoplankton) were not used to derive the ammonia criteria because "*plants are substantially less sensitive than animals*." Moreover, the most sensitive daphnid genus (i.e., *Daphnia*) represents the 50th and 87th centile of the acute and chronic species sensitivity distributions (SSD), respectively (USEPA 2013). Because criteria are based on the 5th centile of sensitive genera, and *Epioblasma* food sources are insensitive to

ammonia, EPA approval of Virginia acute and chronic ammonia standards is Not Likely to Adversely Affect (NLAA) the oyster mussel, Cumberlandian combshell, tan riffleshell, green-blossom pearly mussel, and snuffbox mussel through indirect effects.

2.8 Shiny (*Fusconaia cor*) and Finerayed (*Fusconaia cuneolus*) Pigtoe

2.8.1 Shiny and Finerayed Pigtoe Acute Ammonia Effects Assessment

2.8.1.1 Identifying Pigtoe Acute Ammonia Data

High-quality species-level acute toxicity data are not available for shiny and finerayed pigtoe. Genus-level acute toxicity data were, therefore, used to determine an acute toxicity value (i.e., LC_{50}) of 47.40 mg/L (pH 7 and 20°C; Table 2-18). The *Fusconaia* GMAV is based on a single SMAV for Atlantic pigtoe (*F. masoni*) which is based on a single definitive LC_{50} value reported for glochidia after 6 hours (acceptable acute exposure duration for glochidia life stage, see USEPA [2013]) of exposure to ammonia in a static test reported by Black (2001).

Table 2-18. Data used to calculate the *Fusconaia* GMAV representative of shiny and finerayed pigtoe acute sensitivity to ammonia.

Family	Species	SMAV (mg/L)[a]	GMAV (mg/L)[a]
Unionidae	Shiny pigtoe, *Fusconaia cor*	N/A	47.40
Unionidae	Finerayed pigtoe, *Fusconaia cuneolus*	N/A	
Unionidae	Atlantic pigtoe, *Fusconaia masoni*	47.40	

[a] Normalized to pH 7 and 20°C (USEPA 2013). N/A: not available

2.8.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

No raw empirical toxicity data are available to support the derivation of an LC_{50}:LC_5 adjustment factor for shiny and finerayed pigtoe mussels within the Genus *Fusconaia*. As a result, EPA obtained and analyzed C-R data for 45 tests with closely-related surrogate species (i.e., freshwater mussels within the Family Unionidae where raw empirical data were reported) to derive an acute family-level TAF of 2.441 (see Section 2.6.1.2 and Appendix A.1 for raw empirical toxicity data, TRAP models and outputs for the 22 acute ammonia toxicity tests used to derive the acute Unionidae family-level TAF; Appendix A.2 includes the raw empirical toxicity data, TRAP models and outputs for the unacceptable and uncertain ammonia toxicity tests excluded from the acute family-level TAF).

2.8.1.3 Calculating Shiny and Finerayed Pigtoe Acute Ammonia Minimum Effect Threshold

Dividing the estimated shiny and finerayed pigtoe GMAV (47.40 mg/L; genus-level surrogate) by the acute Unionidae family-level TAF (2.441) results in an acute minimum effect threshold concentration of 19.42 mg/L (normalized to pH 7 and 20°C).

2.8.1.4 Shiny and Finerayed Pigtoe: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 and 20°C (17 mg/L) is less than the shiny and finerayed pigtoe acute minimum effect threshold of 19.42 mg/L. The shiny and finerayed pigtoe acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the

corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary and approval of the acute ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the shiny and finerayed pigtoe through direct acute effects.

2.8.2 Shiny and Finerayed Pigtoe Chronic Ammonia Effects Assessment

2.8.2.1 Identifying Shiny and Finerayed Pigtoe Chronic Ammonia Data

High-quality species-level or genus-level chronic toxicity data from Appendix B of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for the shiny and finerayed pigtoe. Family-level chronic toxicity data were, therefore, used to determine a chronic toxicity value (i.e., EC_{20}) of 2.728 mg/L (pH 7 and 20°C) representative of the shiny and finerayed pigtoe (see Table 2-17 and Section 2.6.2.1).

2.8.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

Chronic C-R data are not available for the shiny and finerayed pigtoe or other members of the Genus *Fusconaia* to support the derivation of an EC_{20}:EC_5 adjustment factor within genus. EPA analyzed C-R data for the same three tests with family-level surrogate species used to calculate the Unionidae FMCV representative of the shiny mussel and finerayed pigtoe. However, the C-R data were not acceptable and no other C-R data were available within the Order Unionoida. Therefore, the chronic MAF was derived (see Section 2.6.2.2 and Section 2.4.2.2 for justification and basis for chronic MAF derivation, respectively) to transform the Unionidae FMCV to a low effect threshold concentration. The chronic MAF, calculated as the geometric mean of all acceptable genus-level EC_{20}:EC_5 ratios, is 1.412 (see Appendix A.3 for raw empirical toxicity test data, TRAP models and outputs for the 20 chronic ammonia toxicity tests used to derive the chronic MAF).

2.8.2.3 Calculating Shiny and Finerayed Pigtoe Chronic Ammonia Minimum Effect Threshold

Dividing the estimated shiny and finerayed pigtoe EC_{20} value (2.728 mg/L; family-level surrogate) by the chronic MAF (1.412) results in a chronic minimum effect threshold concentration of 1.932 mg/L (normalized to pH 7 and 20°C).

2.8.2.4 Shiny and Finerayed Pigtoe: Chronic Ammonia Effects Determination

The chronic ammonia CCC at pH 7 and 20°C (1.9 mg/L) is the same as the shiny and finerayed pigtoe chronic minimum effect threshold concentration of 1.932 mg/L, when rounded to two significant figures, suggesting the shiny and finerayed pigtoe mussels are tolerant to chronic ammonia exposure specified by the criterion. Therefore, approval of the freshwater chronic ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the shiny and finerayed pigtoe through direct chronic effects.

2.8.3 Shiny and Finerayed Pigtoe Ammonia Indirect Effects Assessment

The shiny and finerayed pigtoe in the Genus *Fusconaia* filter phytoplankton and zooplankton from the water column as a primary food source, both of which are relatively insensitive to acute and chronic ammonia exposures. For example, USEPA (2013) states, plants (e.g., phytoplankton) were not used to derive the ammonia criteria because "*plants are substantially*

less sensitive than animals." Moreover, the most sensitive daphnid genus (i.e., *Daphnia*) represents the 50th and 87th centile of the acute and chronic species sensitivity distributions (SSD), respectively (USEPA 2013). Because criteria are based on the 5th centile of sensitive genera, and shiny and finerayed pigtoe food sources are insensitive to ammonia, EPA approval of Virginia acute and chronic ammonia standards is Not Likely to Adversely Affect (NLAA) the shiny and finerayed pigtoe through indirect effects.

2.9 Purple (*Villosa perpurpurea*) and Cumberland (*Villosa trabalis*) Bean

2.9.1 Purple and Cumberland Bean Acute Ammonia Effects Assessment

2.9.1.1 Identifying Purple and Cumberland Bean Acute Ammonia Data

High-quality species-level acute toxicity data are not available for the purple and Cumberland bean, two species of freshwater mussel in the genus *Villosa*. Genus-level acute toxicity data were, therefore, used to determine an acute toxicity value (i.e., LC_{50}) of 34.23 mg/L (pH 7 and 20°C) representative of the purple and Cumberland bean (Table 2-19). The *Villosa* GMAV is based on a single SMAV for rainbow mussel (*V. iris*). The rainbow mussel SMAV (and GMAV since no other SMAVs within the Genus *Villosa* are available) is based on the geometric mean of 10 definitive LC_{50} values from five different studies (USEPA 2013, Appendix A). The normalized LC_{50} values range from a low of 12.62 to 99.28 mg/L based on tests with glochidia and juvenile life stages.

Table 2-19. Data used to calculate the *Villosa* GMAV representative of purple and Cumberland bean acute sensitivity to ammonia based on ten rainbow mussel LC_{50} values, with the individual test-level LC_{50} values listed to the left of the rainbow mussel SMAV of 34.23 mg/L.

Family	Species	SMAV (mg/L)[a]		GMAV (mg/L)[a]
Unionidae	Purple bean, *Villosa perpurpurea*	N/A		34.23
Unionidae	Cumberland bean, *Villosa trabalis*	N/A		
Unionidae	Rainbow mussel, *Villosa iris*	LC_{50} 23.29	34.23	
Unionidae	Rainbow mussel, *Villosa iris*	68.40		
Unionidae	Rainbow mussel, *Villosa iris*	71.66		
Unionidae	Rainbow mussel, *Villosa iris*	27.33		
Unionidae	Rainbow mussel, *Villosa iris*	15.17		
Unionidae	Rainbow mussel, *Villosa iris*	64.87		
Unionidae	Rainbow mussel, *Villosa iris*	12.62		
Unionidae	Rainbow mussel, *Villosa iris*	99.28		
Unionidae	Rainbow mussel, *Villosa iris*	21.89		

Unionidae	Rainbow mussel, *Villosa iris*	26.23		

[a] Normalized to pH 7 and 20°C (USEPA 2013). N/A: not available

2.9.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical toxicity data were available from eight of the 10 acute toxicity tests used to calculate the *Villosa* GMAV. The raw empirical acute toxicity data were fit to a C-R model using EPA's TRAP software to calculate LC_{50} and corresponding LC_5 value for each test. Two models were not used because either no effect within the area of concern (Am-Acute-45) or the model did not exhibit a unique solution (inadequate partial effects; Am-Acute-47). The acute *Villosa* genus-level TAF representative of the purple and Cumberland bean is 2.162 (Table 2-16) (see Am-Acute-41 through Am-Acute-44, Am-Acute-46, and Am-Acute-48 in Appendix A.1 for raw empirical toxicity test data, TRAP models and outputs for the six acute ammonia toxicity tests used to derive the acute genus-level TAF for purple and Cumberland Bean).

2.9.1.3 Calculating Purple and Cumberland Bean Acute Ammonia Minimum Effect Threshold

Dividing the estimated purple and Cumberland bean GMAV (34.23 mg/L; genus-level surrogate) by the acute *Villosa* genus-level TAF (2.162) results in an acute minimum effect threshold concentration of 15.83 mg/L (normalized to pH 7 and 20°C).

2.9.1.4 Purple and Cumberland Bean: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 and 20°C (17 mg/L) is greater than the purple and Cumberland bean acute minimum effect threshold of 15.83 mg/L, suggesting the ammonia CMC may not be protective of purple and Cumberland bean under continuous exposure conditions. All available toxicity data for species within the Genus *Villosa* were considered acceptable for criteria derivation and were used in this assessment, no other uncertain/unacceptable toxicity data are available to further support the acute effects assessment for the purple and Cumberland bean.

Even if the purple and Cumberland Bean are as sensitive to acute ammonia exposure as the surrogate species, rainbow mussel, it is highly unlikely they will be exposed to ammonia *in situ* at the acute criterion magnitude and duration because aquatic life criteria are conservatively implemented in National Pollution Discharge Elimination System (NPDES) permit limits by assuming receiving streams are continually at low-flow conditions which significantly limits the probability of *in situ* pollutant concentrations reaching criteria magnitudes and durations. NPDES permit limits based on the acute ammonia criterion typically assume a receiving stream is continually at 1Q10 low-flow conditions, while the probability of these low-flow conditions occurring is exceedingly rare (i.e., 1-day average lowest flow over the course of a 10-year period). Similarly, NPDES permit limits based on the chronic ammonia criterion typically assume receiving streams are continually at 30Q10 or 30Q5 low-flow conditions (i.e., 30-day average lowest flow over the course of a 5 or 10-year period). As a result, excess dilution limits instream ammonia concentrations and drastically decreases the probability *in situ* ammonia concentrations will reach criteria magnitudes and durations. Independent of assuming low flow conditions, NPDES permits also provide an additional level of protection by ensuring facilities discharge ammonia at Long Term Average concentrations (LTAs), which are based on Waste Load Allocations[2] (WLAs) set as the 99th centile of a log-normal distribution that describes effluent variability. Setting WLAs as the 99th centile of an effluent distribution ensures permitted

facilitates discharge relatively low concentrations of ammonia so that the probability of in stream ammonia concentrations reaching criteria concentrations is 1% under the additional protective assumption that streams are always at critical low flow conditions. Setting WLAs as the 99th centile of an effluent distribution while independently assuming streams are continually at critical low flow conditions, compounds protective conservative assumptions to considerably reduce the probability that in stream ammonia concentrations reach criteria magnitudes. Because the probability (e.g., 1% chance, assuming streams are at 30Q10 or 30Q5 low flow conditions; USEPA 1991) of the purple and Cumberland bean being exposed to ammonia at the acute criterion magnitude and duration is highly unlikely, approval of the acute ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the purple and Cumberland bean through direct acute effects.

2.9.2 Purple and Cumberland Bean Chronic Ammonia Effects Assessment

2.9.2.1 Identifying Purple and Cumberland Bean Chronic Ammonia Data

High-quality species-level chronic toxicity data from Appendix B of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for the purple or Cumberland bean. Genus-level chronic toxicity data were, therefore, used to determine a chronic toxicity value (i.e., EC_{20}) of 3.501 mg/L (pH 7 and 20°C) representative of the purple or Cumberland bean (Table 2-20). The *Villosa* GMCV is based on a chronic toxicity test result reported for the rainbow mussel. The test endpoint measured was 28-day juvenile survival. The value used to calculate the *Villosa* GMCV was used to derive the chronic ammonia criterion (bold values in Appendix B of USEPA [2013]) and has been normalized to a pH of 7 and water temperature of 20°C.

Table 2-20. Data used to calculate the *Villosa* GMCV representative of purple and Cumberland bean chronic sensitivity to ammonia.

Family	Species	SMCV (mg/L)[a]	GMCV (mg/L)[a]
Unionidae	Purple bean, *Villosa perpurpurea*	N/A	3.501
Unionidae	Cumberland bean, *Villosa trabalis*	N/A	
Unionidae	Rainbow mussel, *Villosa iris*	3.501	

[a] Normalized to pH 7 and 20°C (USEPA 2013). N/A: not available

2.9.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

EPA analyzed C-R data from the same surrogate species test used to calculate the *Villosa* GMCV representative of the purple and Cumberland bean (no species-level C-R data available). This was the only toxicity test with a species of the Genus *Villosa* used for ammonia chronic criteria derivation (bold values in Appendix B of USEPA 2013). The model (Am-Chronic-3) was not used because it did not exhibit a unique solution (inadequate partial effects) and cannot be used. No other acceptable C-R data were available within the Order Unionoida, requiring the derivation of the chronic MAF (see Section 2.6.2.2 and Section 2.4.2.2 for justification and basis for chronic MAF derivation, respectively). The chronic MAF, calculated as the geometric mean of all acceptable genus-level EC_{20}:EC_5 ratios, is 1.412 (see Appendix A.3 for raw empirical

toxicity test data, TRAP models and outputs for the 20 chronic ammonia toxicity tests used to derive the chronic MAF).

2.9.2.3 Calculating Purple and Cumberland Bean Chronic Ammonia Minimum Effect Threshold

Dividing the estimated purple and Cumberland bean EC_{20} value (3.501 mg/L; family-level surrogate) by the chronic MAF (1.412) results in a chronic minimum effect threshold concentration of 2.479 mg/L (normalized to pH 7 and 20°C).

2.9.2.4 Pigtoe: Chronic Ammonia Effects Determination

The chronic ammonia CCC at pH 7 and 20°C (1.9 mg/L) is lower than the purple and Cumberland bean chronic minimum effect threshold concentration of 2.479 mg/L. The purple and Cumberland bean chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, approval of the chronic ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the purple and Cumberland bean through direct chronic effects.

2.9.3 Purple and Cumberland Bean Ammonia Indirect Effects Assessment

Purple and Cumberland bean filter phytoplankton and zooplankton from the water column as a primary food source, both of which are relatively insensitive to acute and chronic ammonia exposures. For example, USEPA (2013) states, plants (e.g., phytoplankton) were not used to derive the ammonia criteria because "*plants are substantially less sensitive than animals*." Moreover, the most sensitive daphnid genus (i.e., *Daphnia*) represents the 50th and 87th centile of the acute and chronic species sensitivity distributions (SSD), respectively (USEPA 2013). Because criteria are based on the 5th centile of sensitive genera, and purple and Cumberland bean food sources are insensitive to ammonia, EPA approval of Virginia acute and chronic ammonia standards is Not Likely to Adversely Affect (NLAA) purple and Cumberland bean through indirect effects.

2.10 Other Mussels in the Family Unionidae:

- Fanshell Mussel (*Cyprogenia stegaria*)
- Yellow Lance (*Elliptio lanceolata*)
- Dromedary Pearly Mussel (*Dromus dromas*)
- Cracking Pearly Mussel (*Hemistena lata*)
- Birdwing Pearly Mussel (*Lemiox rimosus*)
- Littlewing Pearly Mussel (*Pegias fabula*)
- Sheepnose Mussel (*Plethobasus cyphyus*)
- James Spinymussel and Rough Pigtoe (*Pleurobema collina, Pleurobema plenum*)
- Slabside Pearly Mussel (*Pleuronaia dolabelloides*)
- Fluted Kidneyshell (*Ptychobranchus subtentum*)
- Rough Rabbitsfoot (*Quadrula cylindrical strigillata*)
- Cumberland and Appalachian Monkeyface (*Theliderma intermedia, Theliderma sparsa*)

2.10.1 Other Family Unionidae Mussel Acute Ammonia Effects Assessment

2.10.1.1 Identifying Other Family Unionidae Mussel Acute Ammonia Data

High-quality species- or genus-level acute ammonia toxicity data are not available for the other 14 listed freshwater mussel species in Virginia within the Unionidae family. Data from other tested freshwater mussels in the Family Unionidae were, therefore, used to determine a family-level surrogate acute toxicity value (i.e., LC_{50}) of 43.44 mg/L (pH 7 and 20°C) representative of the 14 listed mussels (Table 2-21). The Unionidae FMAV is based on 13 GMAVs, comprised of 19 different species and encompasses 66 individual acute toxicity tests. The thirteen GMAVs used to derive the FMAV were obtained from Appendix A of the 2013 freshwater ammonia 304(a) aquatic life criteria document and from one additional study (Wang et al. 2017; this test was not included in EPA's 304(a) Aquatic Life Criteria for ammonia [USEP 2013] due to its later publication date; however, it meets the data quality objectives for deriving criteria as specified in the 1985 Guidelines [Stephan et al. 1985]). Values have been normalized to a pH of 7 and water temperature of 20°C, consistent with the 2013 acute ammonia criterion.

Table 2-21. Data used to calculate the FMAV representative of the acute sensitivity to ammonia of 14 other Virginia listed mussels in the Family Unionidae.

Family	Species	SMAV (mg/L)[a]	GMAV (mg/L)[a]	FMAV (mg/L)[a]
Unionidae	Mucket, *Actinonaias ligamentina*	63.89	71.25	43.44
Unionidae	Pheasant shell, *Actinonaias pectorosa*	79.46		
Unionidae	Dwarf wedge mussel, *Alasmidonta heterodon*	>109.0	>109.0	
Unionidae	Threeridge, *Amblema plecata*	14.72	14.72	
Unionidae	Oyster mussel, *Epioblasma capsaeformis*	31.14	31.14	
Unionidae	Atlantic pigtoe, *Fusconaia masoni*	47.40	47.40	
Unionidae	Pink mucket, *Lampsilis abrupta*	26.03	46.63	
Unionidae	Plain pocketbook, *Lampsilis cardium*	50.51		
Unionidae	Wavy-rayed lamp mussel, *Lampsilis fasciola*	48.11		
Unionidae	Higgin's eye, *Lampsilis higginsii*	41.90		
Unionidae	Fatmucket, *Lampsilis siliquoidea*	55.42		
Unionidae	Neosho mucket *Lampsilis rafinesqueana*	69.97		
Unionidae	Green floater, *Lasmigona subviridis*	23.41	23.41	
Unionidae	Washboard, *Megalonaias nervosa*	41.21	41.21	
Unionidae	Pink papershell, *Potamilus ohiensis*	>109.0	>109.0	

Family	Species	SMAV (mg/L)[a]	GMAV (mg/L)[a]	FMAV (mg/L)[a]
Unionidae	Giant Floater, *Pyganodon grandis*	70.73	70.73	
Unionidae	Pondshell mussel, *Utterbackia imbecillis*	42.39	42.39	
Unionidae	Ellipse, *Venustaconcha ellipsiformis*	23.12	23.12	
Unionidae	Rainbow mussel, *Villosa iris*	34.23	34.23	

[a] Normalized to pH 7 and 20°C (USEPA 2013). N/A: not available.

2.10.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

EPA obtained and analyzed C-R data for 45 tests with freshwater mussels within the Family Unionidae where raw empirical data were reported to derive an acute family-level TAF (see Section 2.6.1.2 and Table 2-16). The acute Unionidae family-level TAF representative of the 14 Virginia listed unionid mussels is 2.441.

2.10.1.3 Calculating Other Family Unionidae Mussel Acute Ammonia Minimum Effect Threshold

Dividing the estimated Unionidae FMAV (43.44 mg/L) by the acute Unionidae family-level TAF (2.441) results in an acute minimum effect threshold concentration of 17.80 mg/L (normalized to pH 7 and 20°C) that is representative of the 14 other Virginia listed unionid mussels.

2.10.1.4 Other Family Unionidae Mussel: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 and 20°C (17 mg/L), is lower than the acute minimum effect threshold of 17.80 mg/L for the 14 other listed mussels in the Family Unionidae. Refined assessment and consideration of the criterion duration and realistic exposure potential is not necessary and approval of the acute ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the fanshell mussel, yellow lance mussel, dromedary pearly mussel, cracking pearly mussel, birdwing pearly mussel, littlewing pearly mussel, sheepnose mussel, James spinymussel, rough pigtoe mussel, slabside pearly mussel, fluted kidneyshell, rough rabbitsfoot mussel, and Cumberland and Appalachian monkeyface mussels through direct acute effects.

2.10.2 Other Family Unionidae Mussel Chronic Ammonia Effects Assessment

2.10.2.1 Identifying Other Family Unionidae Mussel Chronic Ammonia Data

High-quality species-level or genus-level chronic toxicity data from Appendix B of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for the 14 other listed freshwater mussel species in Virginia. Data from tested freshwater mussels in the same family were, therefore, used to determine a Unionidae chronic toxicity value (i.e., EC_{20}) of 2.728 mg/L (pH 7 and 20°C) representative of the 14 mussels (Table 2-17 in Section 2.6.2.1).

2.10.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

EPA analyzed C-R data for the same three tests with family-level surrogate species used to calculate the Unioidae FMCV for the 14 other Virginia listed unionid mussels, but because the

C-R data were not acceptable and no other C-R data were available within the Order Unionoida, a chronic MAF was derived (see Section 2.6.2.2 and Section 2.4.2.2 for justification and basis for chronic MAF derivation, respectively). The chronic MAF, calculated as the geometric mean of all acceptable genus-level EC_{20}:EC_5 ratios, is 1.412 (see Appendix A.3 for raw empirical toxicity test data, TRAP models and outputs for the 20 chronic ammonia toxicity tests used to derive the chronic MAF).

2.10.2.3 Calculating Other Family Unionidae Mussel Chronic Ammonia Minimum Effect Threshold

Dividing the estimated Unionidae EC_{20} value (2.728 mg/L; family-level surrogate) by the chronic MAF (1.412) results in a chronic minimum effect threshold concentration of 1.932 mg/L (normalized to pH 7 and 20°C) that is representative of the 14 other Virginia listed unionid mussels.

2.10.2.4 Other Family Unionidae Mussel: Chronic Ammonia Effects Determination

The chronic ammonia CCC at pH 7 and 20°C (1.9 mg/L) is the same as the Unionidae chronic minimum effect threshold concentration of 1.932 mg/L based on continuous laboratory exposure, when rounded to two significant figures. Therefore, approval of the chronic ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the fanshell mussel, yellow lance mussel, dromedary pearly mussel, cracking pearly mussel, birdwing pearly mussel, littlewing pearly mussel, sheepnose mussel, James spinymussel, rough pigtoe mussel, slabside pearly mussel, fluted kidneyshell, rough rabbitsfoot mussel, Cumberland and Appalachian monkeyface mussels through direct chronic effects.

2.10.3 Other Family Unionidae Mussel Ammonia Indirect Effects Assessment

Freshwater unionid mussels filter phytoplankton and zooplankton from the water column as a primary food source, both of which are relatively insensitive to acute and chronic ammonia exposures. For example, USEPA (2013) states, plants (e.g., phytoplankton) were not used to derive the ammonia criteria because "*plants are substantially less sensitive than animals*." Moreover, the most sensitive daphnid genus (i.e., *Daphnia*) represents the 50th and 87th centile of the acute and chronic species sensitivity distributions (SSD), respectively (USEPA 2013). Because criteria are based on the 5th centile of sensitive genera, and unionid mussel food sources are insensitive to ammonia, EPA approval of Virginia acute and chronic ammonia standards is Not Likely to Adversely Affect (NLAA) the fanshell mussel, yellow lance mussel, dromedary pearly mussel, cracking pearly mussel, birdwing pearly mussel, littlewing pearly mussel, sheepnose mussel, James spinymussel, rough pigtoe mussel, slabside pearly mussel, fluted kidneyshell, rough rabbitsfoot mussel, and Cumberland and Appalachian monkeyface mussels through indirect effects.

2.11 Spectaclecase Mussel (*Cumberlandia monodonta*)

2.11.1 Spectaclecase Mussel Acute Ammonia Effects Assessment

2.11.1.1 Identifying Spectaclecase Mussel Acute Ammonia Data

High-quality acute toxicity data are unavailable for the spectaclecase mussel or other members of the Genus *Cumberlandia*. Family-level acute toxicity data were, therefore, used to determine an acute toxicity value (i.e., LC_{50}) of 61.23 mg/L (pH 7 and 20°C) representative of the spectaclecase mussel. The Margaritiferidae FMAV is based on single GMAV for Genus *Margaritifera*, which is represented by the western pearlshell (*Margaritifera falcata*) SMAV (61.23 mg/L; normalized to pH 7 and 20°C). The western pearlshell SMAV is based on a definitive LC_{50} value reported by Wang et al. (2017). This test was not included in EPA's 304(a) Aquatic Life Criteria for ammonia (USEP 2013) due to its later publication date; however, it meets the data quality objectives for deriving criteria as specified in the 1985 Guidelines (Stephan et al. 1985).

2.11.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Acute C-R data were not available for the spectaclecase mussel or other members of the Genus *Cumberlandia*. EPA obtained and analyzed all available high-quality raw C-R data from members of the Family Margaritiferidae, which consisted of the single test with the western pearlshell (Wang et al. 2017), to derive an acute Margaritiferidae family-level TAF (see Am-Acute-34 in Appendix A.1 for raw empirical toxicity test data, TRAP model and output for the test). The raw empirical acute toxicity data from this test were fit to a C-R model using EPA's TRAP software to calculate an LC_{50} and corresponding LC_5 value for the test. The acute Margaritiferidae family-level TAF based on the test with western pearlshell is 1.576.

2.11.1.3 Calculating Spectaclecase Mussel Acute Ammonia Minimum Effect Threshold

Dividing the estimated spectaclecase mussel acute value (61.23 mg/L; family-level surrogate) by the acute Margaritiferidae family-level TAF (1.576) results in an acute minimum effect threshold concentration of 38.85 mg/L (normalized to pH 7 and 20°C) that is representative of the spectaclecase mussel.

2.11.1.4 Spectaclecase Mussel: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 and 20°C (17 mg/L) is 2.3 times lower than the spectaclecase acute minimum effect threshold concentration of 38.85 mg/L. The spectaclecase mussel acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration and realistic exposure potential is not necessary and approval of the acute ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the spectaclecase mussel through direct acute effects.

2.11.2 Spectaclecase Mussel Chronic Ammonia Effects Assessment

2.11.2.1 Identifying Spectaclecase Mussel Chronic Ammonia Data

High-quality chronic toxicity data from Appendix B of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for the spectaclecase mussel or other species within the

Family Margaritiferidae. Order-level chronic toxicity data were, therefore, used to determine a chronic toxicity value (i.e., EC_{20}) of 2.728 mg/L (pH 7 and 20°C) representative of the spectaclecase mussel (Table 2-22). The Unionoida Order Mean Chronic Value (OMCV) is based on a single FMCV calculated as the geometric mean of two GMCVs derived from chronic toxicity tests results for three species, the wavy-rayed lamp mussel, the fatmucket and the rainbow mussel. The test endpoint used for EC_{20} estimation for all three tests was 28-day juvenile survival. EC_{20} values were obtained from Appendix B of the 2013 freshwater ammonia 304(a) aquatic life criteria document and have been normalized to a pH of 7 and water temperature of 20°C, consistent with the 2013 chronic ammonia criterion.

Table 2-22. Data used to calculate the Unionoida OMCV representative of spectaclecase mussel chronic sensitivity to ammonia

<table>
<tr><th>Order</th><th>Family</th><th>Species</th><th>GMCV (mg/L)[a]</th><th>FMCV (mg/L)[a]</th><th>OMCV (mg/L)[a]</th></tr>
<tr><td>Unionoida</td><td>Margaritiferidae</td><td>Spectaclecase mussel, Cumberlandia monodonta</td><td>N/A</td><td>N/A</td><td rowspan="4">2.728</td></tr>
<tr><td>Unionoida</td><td>Unionidae</td><td>Wavy-rayed lamp mussel, Lampsilis fasciola</td><td rowspan="2">2.126</td><td rowspan="3">2.728</td></tr>
<tr><td>Unionoida</td><td>Unionidae</td><td>Fatmucket, Lampsilis siliquoidea</td></tr>
<tr><td>Unionoida</td><td>Unionidae</td><td>Rainbow mussel, Villosa iris</td><td>3.501</td></tr>
</table>

[a] Normalized to pH 7 and 20°C (USEPA 2013). N/A: not available.

2.11.2.2 Deriving the EC_{20} to EC_5 Chronic Adjustment Factor

Chronic C-R data are not available for the spectaclecase mussel or any other members within the Family Margaritiferidae to support the derivation of an EC_{20}:EC_5 adjustment factor within the Family Margaritiferidae. EPA analyzed C-R data for the same three tests with family-level surrogate species used to calculate the Unionoida OMCV for the spectaclecase mussel, but because the C-R data were not acceptable and no other C-R data were available within the Order Unionoida, a chronic MAF was derived (see Section 2.6.2.2 and Section 2.4.2.2 for justification and basis for chronic MAF derivation, respectively). The chronic MAF, calculated as the geometric mean of all acceptable genus-level EC_{20}:EC_5 ratios, is 1.412 (see Appendix A.3 for raw empirical toxicity test data, TRAP models and outputs for the 20 chronic ammonia toxicity tests used to derive the chronic MAF).

The Order-level TAF of the three unacceptable/uncertain models for unionid mussels in the Order Unionoida is 1.285, which likely underestimates the EC_{20}:EC_5 ratio by over estimating the EC_5 values in the two *Lampsilis* (Am-Chronic-1, Am-Chronic-2) C-R models. Thus, the use of the chronic MAF of 1.412 to calculate the chronic minimum effect threshold for the spectaclecase mussel is a reasonable approach.

2.11.2.3 Calculating the Spectaclecase Mussel Chronic Ammonia Minimum Effect Threshold
Dividing the estimated spectaclecase mussel EC_{20} value (2.728 mg/L; order-level surrogate) by the chronic MAF (1.412) results in a chronic minimum effect threshold concentration of 1.932 mg/L (normalized to pH 7 and 20°C) that is representative of the spectaclecase mussel.

2.11.2.4 Spectaclecase Mussel: Chronic Ammonia Effect Determination
The chronic ammonia CCC at pH 7 (1.9 mg/L), is the same as the spectaclecase mussel chronic minimum effect threshold concentration of 1.932 mg/L based on continuous laboratory exposures, when rounded to two significant figures, suggesting the spectaclecase mussel is tolerant to chronic ammonia exposure specified by the criterion. Therefore, approval of the freshwater chronic ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the spectaclecase mussel through direct chronic effects.

2.11.3 Spectaclecase Mussel Ammonia Indirect Effects Assessment

The spectaclecase mussel filters phytoplankton and zooplankton from the water column as a primary food source, both of which are relatively insensitive to acute and chronic ammonia exposures. For example, USEPA (2013) states, plants (e.g., phytoplankton) were not used to derive the ammonia criteria because "*plants are substantially less sensitive than animals*." Moreover, the most sensitive daphnid genus (i.e., *Daphnia*) represents the 50th and 87th centile of the acute and chronic species sensitivity distributions (SSD), respectively (USEPA 2013). Because criteria are based on the 5th centile of sensitive genera, and spectaclecase mussel food sources are insensitive to ammonia, EPA approval of Virginia acute and chronic ammonia standards is Not Likely to Adversely Affect (NLAA) the spectaclecase mussel through indirect effects.

2.12 Lee County Cave Isopod (*Lirceus usdagalun*)

2.12.1 Lee County Cave Isopod Ammonia Acute Effects Assessment: Freshwater

2.12.1.1 Identifying Lee County Cave Isopod Acute Ammonia Data
High-quality species- and genus-level acute ammonia toxicity data from Appendix A of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for Lee County cave isopod. Family-level acute toxicity data were, therefore, used to determine an acute toxicity value (i.e., LC_{50}) of 382.6 mg/L (normalized to pH 7 and 20°C) representative of the Lee County cave isopod (Table 2-23). The Asellidae FMAV is based on a two GMAVs each derived from a single SMAV. The SMAV for *Asellus aquaticus* is based on the geometric mean of nine definitive LC_{50} values from a single study (Dehedin et al. 2012). The normalized LC_{50} values range from 246.6 to 603.8 mg/L and were conducted as 96-hr flow-through tests. The *Caecidotea* SMAV is based on a single SMAV for *Caecidotea racovitzai* which is based on the geometric mean of three definitive LC_{50} values from three studies (Arthur et al. 1987, Thurston et al. 1983 and West 1985). The normalized LC_{50} values range from 272.2 to 522.3 mg/L also conducted as 96-hr flow-through tests.

Table 2-23. Data used to calculate the Asellidae FMAV representative of Lee County cave isopod acute sensitivity to ammonia.

Family	Species	SMAV (mg/L)[a]	GMAV (mg/L)[a]	FMAV (mg/L)[a]
Asellidae	Lee County cave isopod, *Lirceus usdagalun*	N/A		382.6
Asellidae	Isopod, *Asellus aquaticus*	378.2	378.2	
Asellidae	Aquatic sowbug, *Caecidotea racovitzai*	387.0	387.0	

[a] Normalized to pH 7 and 20°C (USEPA 2013). N/A: not available.

2.12.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

The published acute toxicity studies used to calculate the Asellidae FMAV did not contain or report raw empirical toxicity data. Because no raw empirical acute toxicity data are available for invertebrate species in the same order, no acute order-level TAF could be calculated. As a result, EPA obtained and analyzed C-R data for all tests used to derive the acute criterion where such data were reported or could be obtained to derive an invertebrate-level TAF and an acute MAF, if necessary (i.e., if the vertebrate and invertebrate-level acute TAFs differ from one another).

Raw empirical acute toxicity data were fit to concentration-response (C-R) models using EPA's Toxicity Relationship Analysis Program (TRAP, version 1.3a) to calculate LC_{50} and corresponding LC_5 values for 83 tests representing 34 species (18 invertebrates and 16 vertebrates). C-R models were excluded from TAF and MAF calculation if 1) models did not exhibit a unique solution and were flagged by TRAP as having inadequate partial effects; 2) models did not include observations in the region of interest which did not allow TRAP to accurately model a no-response plateau and; 3) models exhibited incongruities such as no or poor fit to key points or excessive variation in the observations of C-R relationship. After exclusion of unacceptable or uncertain LC_{50}:LC_5 ratios, 44 ratios remained resulting in nine genus-level LC_{50}:LC_5 ratios for invertebrate species (arithmetic mean = 2.157 mg/L, variance = 0.4447 mg/L) and eleven genus-level LC_{50}:LC_5 ratios for vertebrate species (arithmetic mean = 1.440 mg/L, variance = 0.0491 mg/L). Analysis of the two arithmetic means via a two-sample t-test assuming unequal variances ($\alpha = 0.05$) indicated that the means are significantly different (*t stat [3.088] > t critical for two tail [2.262]*). Therefore, an acute invertebrate TAF is more appropriate than an acute MAF to transform the Asellidae FMAV applicable to the Lee County cave isopod (382.6 mg/L) to an acute minimum effect threshold concentration.

Table 2-24 provides the nine genus-level LC_{50}:LC_5 ratios used to derive the acute invertebrate TAF. Individual test ratios ranged from 1.245 to 3.581. The acute invertebrate TAF calculated as the geometric mean of all genus-level LC_{50}:LC_5 ratios is 2.070 (See Appendix A.1 for raw empirical toxicity test data, TRAP models and output for the 27 acute ammonia toxicity tests used to derive the acute invertebrate TAF; Appendix A.2 includes the raw empirical toxicity data, TRAP models and output for all unacceptable and uncertain ammonia C-R models).

Table 2-24. Acute LC_{50}:LC_5 ratios from analysis of 27 high-quality acute ammonia toxicity tests with freshwater aquatic invertebrates used to derive an acute invertebrate taxonomic adjustment factor (acute invertebrate TAF) for the Lee County cave isopod.
(Note: the acute invertebrate TAF is the geometric mean of all available genus-level LC_{50}:LC_5 ratios for invertebrates).

Order	Family	Species	LC_{50} (mg/L)	LC_{05} (mg/L)	LC_{50}: LC_{05}	C-R Curve Label	Reference	Species-level TAF (LC_{50}:LC_{05})	Genus-level TAF (LC_{50}:LC_{05})
Unionoida	Margaritiferidae	Western pearlshell, *Margaritifera falcata*	8.225	5.218	1.576	Am-Acute-34	Wang et al. 2017	1.576	1.576
Unionoida	Unionidae	Mucket (glochidia), *Actinonaias ligamentina*	8.681	4.250	2.043	Am-Acute-2	Wang et al. 2007b	2.258	2.258
Unionoida	Unionidae	Mucket (glochidia), *Actinonaias ligamentina*	5.634	2.256	2.497	Am-Acute-3	Wang et al. 2007b		
Unionoida	Unionidae	Oyster mussel (<5 d old juvenile), *Epioblasma capsaeformis*	5.657	3.651	1.549	Am-Acute-6	Wang et al. 2007b	2.110	2.110
Unionoida	Unionidae	Oyster mussel (glochidia), *Epioblasma capsaeformis*	6.165	2.992	2.060	Am-Acute-7	Wang et al. 2007b		
Unionoida	Unionidae	Oyster mussel (glochidia), *Epioblasma capsaeformis*	3.215	1.092	2.944	Am-Acute-8	Wang et al. 2007b		
Unionoida	Unionidae	Pink mucket (2 mo old juvenile), *Lampsilis abrupta*	2.559	1.518	1.687	Am-Acute-10	Wang et al. 2007a	1.687	2.102
Unionoida	Unionidae	Wavy-rayed lampmussel (<5 d old juvenile), *Lampsilis fasciola*	7.896	2.476	3.189	Am-Acute-12	Wang et al. 2007b	2.725	
Unionoida	Unionidae	Wavy-rayed lampmussel (glochidia), *Lampsilis fasciola*	8.435	3.786	2.228	Am-Acute-13	Wang et al. 2007b		
Unionoida	Unionidae	Wavy-rayed lampmussel (glochidia), *Lampsilis fasciola*	6.133	2.153	2.849	Am-Acute-14	Wang et al. 2007b		
Unionoida	Unionidae	Neosho mucket (<5 d old juvenile), *Lampsilis rafinesqueana*	11.26	4.835	2.328	Am-Acute-16	Wang et al. 2007b	2.328	
Unionoida	Unionidae	Fatmucket (2 mo old juvenile), *Lampsilis siliquoidea*	3.959	2.010	1.970	Am-Acute-21	Wang et al. 2007a	1.825	
Unionoida	Unionidae	Fatmucket (7 d old juvenile), *Lampsilis siliquoidea*	10.75	5.677	1.894	Am-Acute-22	Wang et al. 2008		
Unionoida	Unionidae	Fatmucket (7 d old juvenile), *Lampsilis siliquoidea*	12.01	8.766	1.370	Am-Acute-27	Wang et al. 2008		
Unionoida	Unionidae	Fatmucket (glochidia), *Lampsilis siliquoidea*	7.537	3.469	2.173	Am-Acute-32	Wang et al. 2007b		

Order	Family	Species	LC_{50} (mg/L)	LC_{05} (mg/L)	LC_{50}: LC_{05}	C-R Curve Label	Reference	Species-level TAF (LC_{50}:LC_{05})	Genus-level TAF (LC_{50}:LC_{05})
Unionoida	Unionidae	Washboard, *Megalonaias nervosa*	5.420	1.566	3.461	Am-Acute-35	Wang et al. 2017	3.461	3.461
Unionoida	Unionidae	Ellipse (glochidia), *Venustaconcha ellipsiformis*	5.360	1.899	2.822	Am-Acute-40	Wang et al. 2007b	2.822	2.822
Unionoida	Unionidae	Rainbow mussel (2 mo old juvenile), *Villosa iris*	3.213	2.284	1.407	Am-Acute-41	Wang et al. 2007b	2.162	2.162
Unionoida	Unionidae	Rainbow mussel (2 mo old juvenile), *Villosa iris*	11.14	3.992	2.789	Am-Acute-42	Wang et al. 2007b		
Unionoida	Unionidae	Rainbow mussel (5 d old juvenile), *Villosa iris*	16.04	6.391	2.509	Am-Acute-43	Scheller 1997		
Unionoida	Unionidae	Rainbow mussel (<5 d old juvenile), *Villosa iris*	6.337	3.340	1.897	Am-Acute-44	Wang et al. 2007b		
Unionoida	Unionidae	Rainbow mussel (<3 d old juvenile), *Villosa iris*	8.380	2.340	3.581	Am-Acute-46	Scheller 1997		
Unionoida	Unionidae	Rainbow mussel (2 h old glochidia), *Villosa iris*	11.80	7.727	1.527	Am-Acute-48	Wang et al. 2007b		
Diplostraca	Daphniidae	Water flea (<24 hr), *Ceriodaphnia dubia*	19.91	9.731	2.046	Am-Acute-49	Andersen and Buckley 1998	1.678	1.678
Diplostraca	Daphniidae	Water flea, *Ceriodaphnia dubia*	30.37	21.41	1.419	Am-Acute-50	Sarda 1994		
Diplostraca	Daphniidae	Water flea, *Ceriodaphnia dubia*	29.23	17.96	1.628	Am-Acute-51	Sarda 1994		
Coleoptera	Elmidae	Beetle, *Stenelmis sexlineata*	29.92	24.04	1.245	Am-Acute-53	Hazel et al. 1979	1.245	1.245

2.12.1.3 Calculating Lee County Cave Isopod Acute Ammonia Minimum Effect Threshold

Dividing the estimated the Lee County cave isopod LC_{50} value (382.6 mg/L) by the acute invertebrate TAF (2.070) results in an acute minimum effect threshold concentration of 184.8 mg/L (normalized to pH 7 and 20°C).

2.12.1.1 Lee County Cave Isopod Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 and 20°C (17 mg/L) is nearly 11 times lower than the Lee County cave isopod acute minimum effect threshold concentration of 184.8 mg/L. The Lee County cave isopod acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration and realistic exposure potential is not necessary and approval of the acute ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the Lee County cave isopod through direct acute effects.

2.12.2 Lee County Cave Isopod Chronic Ammonia Effects Assessment: Freshwater

2.12.2.1 Identifying Lee County Cave Isopod Chronic Ammonia Data

High-quality species-, genus-, family-, or order-level chronic toxicity data from Appendix B of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for the Lee County cave isopod. As a result, the Asellidae family-level acute toxicity value was transformed to represent a chronic toxicity value (i.e., EC_{20}) of 24.20 mg/L (Table 2-25). This chronic value representative of Lee County cave isopod was calculated by dividing the Asellidae FMAV (representative of the Lee County cave isopod; 382.6 mg/L) by the reported ammonia acute:chronic ratio (ACR) for a species representing the same benthic crustacean minimum data requirement used for criteria derivation (MDR-ACR; USEPA 2013; see Stephan et al. 1985 for minimum data requirements). The benthic crustacean MDR-ACR (15.81) is based on the ACR for the amphipod, *Hyalella azteca* (see Appendix F of USEPA 2013). The Asellidae FMCV (calculated as *FMCV* = *FMAV*[382.6 mg/L]/*MDR-ACR*[15.81]) is 24.20 mg/L).

Table 2-25. Data used to calculate the Asellidae FMCV representative of Lee County cave isopod chronic sensitivity to ammonia.

Family	Species	SMAV (mg/L)[a]	GMAV (mg/L)[a]	FMAV (mg/L)[a]	MDR-ACR	FMCV (mg/L)[a]
Asellidae	Lee County cave isopod, *Lirceus usdagalun*	N/A	382.6	382.6	15.81	24.20
Asellidae	Isopod, *Asellus aquaticus*	378.2				
Asellidae	Aquatic sowbug, *Caecidotea racovitzai*	387.0				

[a] Normalized to pH 7 and 20°C (USEPA 2013). N/A: not available.

2.12.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

High-quality chronic toxicity data were not available for the Lee County cave isopod or surrogate species within the Order Isopoda, requiring the derivation of the chronic MAF (see Section 2.4.2.2 for chronic MAF derivation). The chronic MAF, calculated as the geometric mean of all acceptable genus-level EC_{20}:EC_5 ratios, is 1.412 (see Appendix A.3 for raw

empirical toxicity test data, TRAP models and outputs for the 20 chronic ammonia toxicity tests used to derive the chronic MAF).

2.12.2.3 Calculating Lee County Cave Isopod Chronic Ammonia Minimum Effect Threshold

Dividing the estimated Lee County cave isopod EC_{20} value (24.20 mg/L; family-level surrogate transformed by an MDR-ACR) by the chronic MAF (1.412) results in chronic minimum effect threshold concentration of 17.14 mg/L (normalized to pH 7 and 20°C).

2.12.2.4 Lee County Cave Isopod Chronic Ammonia Effects Determination

The chronic ammonia CCC at pH 7 (1.9 mg/L) is 9 times lower than the chronic minimum effect threshold concentration of 17.14 mg/L estimated for the Lee County cave isopod. The Lee County cave isopod chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the chronic ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the Lee County cave isopod through direct chronic effects.

2.12.3 Lee County Cave Isopod Ammonia Indirect Effects Assessment: Freshwater

Little is known of the life history of the Lee County cave isopod. Mouth parts are for chewing, so common foods likely include decaying plant material, such as dead leaves, and other refuse. Assuming plant material is a primary food source, prey items are likely insensitive to acute and chronic ammonia exposures. For example, USEPA (2013) states, plants (e.g., phytoplankton) were not used to derive the ammonia criteria because "*plants are substantially less sensitive than animals*." Moreover, the most sensitive daphnid genus (i.e., *Daphnia*) represents the 50th and 87th centile of the acute and chronic species sensitivity distributions (SSD), respectively (USEPA 2013). Because criteria are based on the 5th centile of sensitive genera, and Lee County cave isopod food sources are insensitive to ammonia, EPA approval of Virginia acute and chronic ammonia standards is Not Likely to Adversely Affect (NLAA) the Lee County cave isopod through indirect effects.

2.13 Madison Cave Isopod (*Antrolana lira*)

2.13.1 Madison Cave Isopod Ammonia Acute Effects Assessment: Freshwater

2.13.1.1 Identifying Madison Cave Isopod Acute Ammonia Data

High-quality ammonia toxicity data from Appendix A of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for Madison cave isopod or other species within the Family Cirolanidae. Order-level acute toxicity data were, therefore, used to determine an acute toxicity value (i.e., LC_{50}) of 382.6 mg/L (normalized to pH 7 and 20°C) representative of the Madison cave isopod (see Section 2.12.1.1 and Table 2-23).

2.13.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

The published acute toxicity studies used to calculate the Isopoda Order Mean Acute Value (OMAV) did not contain or report raw empirical toxicity data. Because no raw empirical acute toxicity data are available for invertebrate species in the same order, no acute order-level TAF

could be calculated. As a result, EPA obtained and analyzed C-R data for all tests used to derive the acute criterion where such data were reported or could be obtained to derive an invertebrate TAF. The acute invertebrate TAF calculated as the geometric mean of all genus-level LC_{50}:LC_5 ratios is 2.070 (see Section 2.12.1.2).

2.13.1.3 Calculating Madison Cave Isopod Acute Ammonia Minimum Effect Threshold

Dividing the estimated the Madison cave isopod LC_{50} value (382.6 mg/L; order-level surrogate toxicity value) by the acute invertebrate TAF (2.070) results in an acute minimum effect threshold concentration of 184.8 mg/L (normalized to pH 7 and 20°C).

2.13.1.4 Madison Cave Isopod Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 and 20°C (17 mg/L) is nearly 11 times lower than the Madison cave isopod acute minimum effect threshold concentration of 184.8 mg/L. The Madison cave isopod acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration and realistic exposure potential is not necessary and approval of the acute ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the Madison cave isopod through direct acute effects.

2.13.2 Madison Cave Isopod Chronic Ammonia Effects Assessment: Freshwater

2.13.2.1 Identifying Madison Cave Isopod Chronic Ammonia Data

High-quality species-, genus-, family- or order-level chronic toxicity data from Appendix B of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for the Madison cave isopod. As a result, the Isopoda OMCV (see Section 2.13.1.1) was transformed to represent a chronic toxicity value (i.e., EC_{20}) of 24.20 mg/L, by dividing the Madison cave isopod acute toxicity value (382.6 mg/L) by the benthic crustacean MDR-ACR (15.81; similar to the chronic toxicity value for Lee County cave isopod, see Section 2.12.2.1).

2.13.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

High-quality chronic toxicity data were not available for the Madison cave isopod or surrogate species within the Order Isopoda, requiring the derivation of the chronic MAF (see Section 2.4.2.2 for chronic MAF derivation). The chronic MAF, calculated as the geometric mean of all acceptable genus-level EC_{20}:EC_5 ratios, is 1.412 (see Appendix A.3 for raw empirical toxicity test data, TRAP models and outputs for the 20 chronic ammonia toxicity tests used to derive the chronic MAF).

2.13.2.3 Calculating Madison Cave Isopod Chronic Ammonia Minimum Effect Threshold

Dividing the estimated Madison cave isopod EC_{20} value (24.20 mg/L; order-level surrogate transformed by an MDR-ACR) by the chronic MAF (1.412) results in chronic minimum effect threshold concentration of 17.14 mg/L (normalized to pH 7 and 20°C).

2.13.2.4 Madison Cave Isopod Chronic Ammonia Effects Determination

The chronic ammonia CCC at pH 7 (1.9 mg/L) is 9 times lower than the chronic minimum effect threshold concentration of 17.14 mg/L estimated for the Madison cave isopod. The Madison cave isopod chronic minimum effect threshold concentration, based on continuous laboratory

exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the chronic ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the Madison cave isopod through direct effects.

2.13.3 Madison Cave Isopod Ammonia Indirect Effects Assessment: Freshwater

Little is known of the life history of the Madison cave isopod. Mouth parts are for chewing, so common foods likely include decaying plant material, such as dead leaves, and other refuse. Assuming plant material is a primary food source, prey items are likely insensitive to acute and chronic ammonia exposures. For example, USEPA (2013) states, plants (e.g., phytoplankton) were not used to derive the ammonia criteria because "*plants are substantially less sensitive than animals*." Moreover, the most sensitive daphnid genus (i.e., *Daphnia*) represents the 50th and 87th centile of the acute and chronic species sensitivity distributions (SSD), respectively (USEPA 2013). Because criteria are based on the 5th centile of sensitive genera, and Madison cave isopod food sources are insensitive to ammonia, EPA approval of Virginia acute and chronic ammonia standards is Not Likely to Adversely Affect (NLAA) the Madison cave isopod through indirect effects.

2.14 Big Sandy Crayfish (*Cambarus veteranus*)

2.14.1 Big Sandy Crayfish Ammonia Acute Effects Assessment: Freshwater

2.14.1.1 Identifying Big Sandy Crayfish Acute Ammonia Data

High-quality species- or genus-level acute ammonia toxicity data from Appendix A of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for big sandy crayfish. Family-level acute toxicity data were therefore, used to determine an acute toxicity value (i.e., LC_{50}) of 307.7 mg/L (normalized to pH 7 and 20°C) representative of the big sandy crayfish (Table 2-26). The Cambaridae FMAV of 307.7 mg/L is based on two GMAVs, with the GMAV for *Orconectes* based on two SMAVs, 303.8 and 1,550 mg/L, and the GMAV for *Procambarus* based on a single SMAV of 138.0 mg/L (Table 2-26).

Table 2-26. Data used to calculate the Cambaridae FMAV representative of big sandy crayfish acute sensitivity to ammonia.

Family	Species	SMAV (mg/L)[a]	GMAV (mg/L)[a]	FMAV (mg/L)[a]
Cambaridae	Big sandy crayfish, *Cambarus veteranus*	N/A	N/A	307.7
Cambaridae	Calico crayfish, *Orconectes immunis*	1,550	686.2	
Cambaridae	Virile crayfish, *Orconectes nais*	303.8		
Cambaridae	Red swamp crayfish, *Procambarus clarkii*	138.0	138.0	

[a] Normalized to pH 7 and 20°C (USEPA 2013). N/A: not available.

2.14.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

The published acute toxicity studies used to calculate the Cambaridae FMAV did not contain or report raw empirical toxicity data. Because no raw empirical acute toxicity data are available for

invertebrate species in the same order, an acute order-level TAF could not be calculated. As a result, EPA obtained and analyzed C-R data for all tests used to derive the acute criterion where such data were reported or could be obtained to derive an invertebrate TAF. The acute invertebrate TAF calculated as the geometric mean of all genus-level LC_{50}:LC_5 ratios is 2.070 (see Section 2.12.1.2).

2.14.1.3 Calculating Big Sandy Crayfish Acute Ammonia Minimum Effect Threshold

Dividing the estimated the big sandy crayfish LC_{50} value (307.7 mg/L; family-level surrogate) by the acute invertebrate TAF (2.070) results in an acute minimum effect threshold concentration of 148.7 mg/L (normalized to pH 7 and 20°C).

2.14.1.4 Big Sandy Crayfish Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 and 20°C (17 mg/L) is 8.7 times lower than the big sandy crayfish acute minimum effect threshold concentration of 148.7 mg/L. The big sandy crayfish acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration and realistic exposure potential is not necessary and approval of the acute ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the big sandy crayfish through direct acute effects.

2.14.2 Big Sandy Crayfish Chronic Ammonia Effects Assessment: Freshwater

2.14.2.1 Identifying Big Sandy Crayfish Chronic Ammonia Data

High-quality chronic toxicity data from Appendix B of the 2013 Ammonia 304(a) Aquatic Life Criteria document are not available for the big sandy crayfish or other species within the Order Decapoda. As a result, the Cambaridae family-level acute toxicity value (307.7 mg/L; Table 2-26) was transformed to represent a chronic toxicity value by dividing the Cambaridae FMAV (307.7 mg/L; Table 2-26) by the benthic crustacean MDR-ACR of 15.81 (similar to Section 2.12.2.1). The benthic crustacean MDR-ACR (15.81) is based on the ACR for the amphipod, *Hyalella azteca* (see Appendix F of USEPA 2013). The Cambaridae FMCV (calculated as *FMCV* = *FMAV*[307.7 mg/L]/*MDR-ACR*[15.81]) is 19.46 mg/L). Deriving EC_{20} to EC_5 Chronic Adjustment Factor

High-quality chronic toxicity data were not available for big sandy crayfish or surrogate species within the Order Decapoda, requiring the derivation of a chronic MAF (see Section 2.4.2.2 for chronic MAF derivation). The chronic MAF, calculated as the geometric mean of all acceptable genus-level EC_{20}:EC_5 ratios, is 1.412 (see Appendix A.3 for raw empirical toxicity test data, TRAP models and outputs for the 20 chronic ammonia toxicity tests used to derive the chronic MAF).

2.14.2.2 Calculating Big Sandy Crayfish Chronic Ammonia Minimum Effect Threshold

Dividing the estimated big sandy crayfish EC_{20} value (19.46 mg/L; order-level surrogate transformed by an MDR-ACR) by the chronic MAF (1.412) results in a chronic minimum effect threshold concentration of 13.78 mg/L (normalized to pH 7 and 20°C).

2.14.2.3 Big Sandy Crayfish Chronic Ammonia Effects Determination

The chronic ammonia CCC at pH 7 (1.9 mg/L) is 7.3 times lower than the chronic minimum effect threshold concentration of 13.78 mg/L estimated for the big sandy crayfish. The big sandy crayfish chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the chronic ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the big sandy crayfish through direct effects.

2.14.3 Big Sandy Crayfish Ammonia Indirect Effects Assessment: Freshwater

Big sandy crayfish are opportunistic omnivores frequently consuming both plants and animals, living and dead (USFWS 2016). Aquatic life criteria are based on the fifth centile of sensitive genera to ensure the broad aquatic community, including benthic crustaceans, is adequately protected. Freshwater mussels consistently rank the most sensitive taxa to acute and chronic ammonia exposures. The most sensitive animal to acute ammonia exposure is the Ellipse (*Venustaconcha ellipsiformis*) with a SMAV (and resultant GMAV) of 23.12 mg/L, while most sensitive animal to chronic ammonia exposure are *Lampsilis* sp. (fatmucket and wavy-rayed lamp mussel) with a GMCV of 2.126 mg/L (see Table 3 and Table 4 in USEPA 2013). A limited number of big sandy crayfish prey items, therefore, could be sensitive to ammonia at magnitudes and exposure durations specified by the acute and chronic ammonia criteria, but effects on a large portion of potential prey/food items (which is not an anticipated effect of the proposed actions) would translate minimally to the big sandy crayfish prey base because the crayfish also relies on other living and dead organisms which are more tolerant to ammonia exposures (USEPA 2016). Furthermore, USEPA (2013) states, plants (e.g., phytoplankton) were not used to derive the ammonia criteria because "*plants are substantially less sensitive than animals*." Because criteria are derived to protect the broad aquatic community (including animals and plants), and big sandy crayfish are not specialized feeders, instead relying on a range of organisms and plant matter, EPA approval of Virginia acute and chronic freshwater ammonia standards is Not Likely to Adversely Affect (NLAA) the big sandy crayfish through indirect effects.

2.15 Aquatic/Semi-Aquatic Plants: Freshwater

- Virginia sneezeweed (*Helenium virginicum*)
- Swamp pink (*Helonias bullata*)
- Eastern prairie fringed orchid (*Platanthera leucophaea*)
- Harperella (*Ptilimnium nodosum*)
- Northeastern bulrush (*Scirpus ancistrochaetus)*

Five listed aquatic/semi-aquatic plant species occur in Virginia freshwaters and may be exposed to ammonia at magnitudes and durations specified by the freshwater ammonia criteria. According to EPA's ammonia criteria document (USEPA 2013), however, "…*data available on the toxicity of ammonia to freshwater plants indicate that plants are approximately two orders of magnitude less sensitive than the aquatic animals tested. Therefore, plant endpoints were not*

used in criteria derivation." Therefore, approval of the acute and chronic freshwater ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the Virginia sneezeweed, swamp pink, Eastern prairie fringed orchid, harperella, and Northeastern bullrush through direct and indirect effects.

2.16 Bats: Northern Long-Eared Bat (*Myotis septentrionalis*), Gray Bat (*Myotis grisescens*), and Indiana Bat (*Myotis sodalist*)

2.16.1 Bat Ammonia Indirect Effects Assessment: Freshwater

The northern long-eared, gray, and Indiana bats will not be meaningfully exposed to ammonia through direct exposure. As a result, EPA's approval action will have no direct effect on the bats. All three bats and especially the gray and Indiana bats, however, rely on emergent aquatic insects as a dietary resource and may be indirectly affected if ammonia, at water column concentrations specified by the freshwater acute or chronic criteria magnitude and duration, were to adversely affect a large portion of emergent aquatic insects. EPA's aquatic life criteria are based on the fifth centile of sensitive genera to ensure the broad aquatic community, including emerging aquatic insects, is adequately protected. Aquatic insects ranked among the most tolerant taxa to acute ammonia exposures (Table 2-27). Chronic toxicity data with emerging aquatic insects were relatively limited; however, an insect represented the most tolerant genus to chronic ammonia exposures (*Pteronarcella* genus mean chronic value [GMCV] = 73.74 mg/L, normalized to pH 7 and 20°C).

In addition to emerging aquatic insects, all three bats, but the northern long-eared bat in particular, also rely on terrestrial insects as a food source (USFWS 1997, 2006, 2015b). Therefore, the effect of eliminating a large portion of emerging aquatic insects (which is not the anticipated effect of action) would likely translate minimally to the gray and Indiana bats, and insignificantly to the northern long-eared bat given the available land-based food resources. Because criteria are derived to protect the broad aquatic community (including emergent insects), and northern long-eared, gray, and Indiana bats do not rely exclusively on aquatic food resources, EPA approval of Virginia acute and chronic freshwater ammonia standards is Not Likely to Adversely Affect (NLAA) the northern long-eared, gray, and Indiana bats through indirect effects.

Table 2-27. Acute insect toxicity data used to derive the acute ammonia criterion. Note, 69 GMAVs were available to derive the acute criterion, with insects ranking among the least sensitive taxa.

Genus	Genus Mean Acute Value (mg/L)[a]	Genus Rank in SSD
Erythromma (insect)	2,515	69
Philarctus (caddisfly)	994.5	68
Stenelmis (beetle)	735.9	67
Chironomus (midge)	681.8	65
Drunella (mayfly)	442.4	64

Callibaetis (mayfly)	246.5	60
Pachydiplax (dragonfly)	233.0	59
Skwala (stonefly)	192.4	52
Enallagma (damselfly)	164.0	47

[a] Normalized to pH 7 and 20°C (USEPA 2013).

2.17 Piping Plover (*Charadrius melodus melodus*)

2.17.1 Piping Plover Ammonia Indirect Effects Assessment: Freshwater

The threatened Atlantic coast population of piping plover will not be meaningfully exposed to ammonia through direct or dietary exposure. As a result, EPA's approval action will have no direct effect on Atlantic coast piping plover. Piping plovers that breed on the Atlantic Coast of the United States and Canada belong to the subspecies, *Charadrius melodus melodus* (USFWS 2015c). Intertidal areas provide key foraging habitats for over-wintering, non-breeding piping plover. Feeding areas include intertidal portions of ocean beaches; washover areas; mudfiats; sandfiats; wrack lines'; and shorelines of coastal ponds, lagoons, or salt marshes where plovers prey on invertebrates such as marine worms, fly larvae, beetles, crustaceans, and mollusks (USFWS 1996). Because piping plover prey items are primarily marine/estuarine organisms, EPA approval of Virginia acute and chronic ammonia standards is Not Likely to Adversely Affect (NLAA) Atlantic coast piping plover through indirect effects.

2.18 Red Knot (*Calidris canutus rufa*)

2.18.1 Red Knot Ammonia Indirect Effects Assessment: Freshwater

The red knot will not be meaningfully exposed to ammonia through direct or dietary exposure and EPA's approval action will, therefore, have no direct effect on the red knot. However, when red knots migrate between summer and wintering grounds, they often cross and rest at critical stopover areas (USFWS 2013a). For much of the year red knots eat small clams, mussels, snails and other invertebrates. In spring, migrating knots appear to follow a northward "wave" in quality prey and time their stopovers with the spawning seasons of readily digestible food resources like juvenile clams and mussels and horseshoe crab eggs (USFWS 2013a). Because these red knot prey items are primarily marine/estuarine organisms, EPA approval of Virginia acute and chronic ammonia standards is Not Likely to Adversely Affect (NLAA) red knot through indirect effects.

3 Cadmium Effects Assessments

(*Note: For economy of space, the effects assessments of several species are grouped together when taxonomic relatedness and data availability result in redundant calculations of acute and chronic low effect threshold values for species within a particular taxonomic group)*

3.1 Spotfin Chub (*Erimonax monachus*), Slender Chub (*Erimystax cahni*), and Blackside Dace (*Chrosomus cumberlandensis*)

3.1.1 Chub and Dace Acute Cadmium Effects Assessment: Freshwater

3.1.1.1 Identifying Chub and Dace Acute Cadmium Data

High-quality species-level or genus-level acute toxicity data from Appendix A of the 2016 Cadmium 304(a) Aquatic Life Criteria document are not available for spotfin chub, slender chub or blackside dace. Family-level acute toxicity data were, therefore, used to represent the sensitivity of the chubs and dace to acute cadmium exposures. The Cyprinidae FMAV (1,821 µg/L, normalized to a total hardness of 100 mg/L as $CaCO_3$) is based on seven GMAVs, which all, except *Ptychocheilus* (n = 2), are composed of a single SMAV (Table 3-1).

Table 3-1. Data used to calculate the Cyprinidae FMAV representative of spotfin chub, slender chub and blackside dace acute sensitivity to cadmium.

Family	Species	SMAV (µg/L)[a]	GMAV (µg/L)[a]	FMAV (µg/L)[a]
Cyprinidae	Spotfin chub, *Erimonax monachus*	N/A	N/A	1,821
Cyprinidae	Slender chub, *Erimystax cahni*	N/A	N/A	
Cyprinidae	Blackside dace, *Chrosomus cumberlandensis*	N/A	N/A	
Cyprinidae	Goldfish, *Carassius auratus*	1,656	1,656	
Cyprinidae	Common Carp, *Cyprinus carpio*	30,781	30,781	
Cyprinidae	Redshiner, *Cyprinella lutrensis*	7,716	7,716	
Cyprinidae	Zebrafish, *Danio rerio*	2,967	2,967	
Cyprinidae	Fathead minnow, *Pimephales promelas*	1,582	1,582	
Cyprinidae	Colorado pikeminnow, *Ptychocheilus lucius*	46.79	446.7	
Cyprinidae	Northern pikeminnow, *Ptychocheilus oregonensis*	4,265		
Cyprinidae	Bonytail, *Gila elegans*	80.38	80.38	

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016). N/A: not available.

3.1.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical data were not available for the spotfin chub, slender chub or blackside dace or surrogate species within the same genera: *Erimonax*, *Erimystax*, and *Chrosomus*, respectively, to support the derivation of a taxonomic-specific LC_{50}:LC_5 adjustment factor at or below the genus level. As a result, EPA analyzed C-R data for three acute cadmium toxicity tests with surrogate species in the same family that reported raw data: a single acute toxicity test with adult red shiner (*Cyprinella lutrensis*; Carrier 1987, Carrier and Beitinger 1988a) and two tests with adult zebrafish (*Danio rerio*; Vergauwen 2012, Vergauwen et al. 2013).

Raw empirical acute toxicity data were fit to C-R models using EPA's TRAP software to calculate LC_{50} and corresponding LC_5 values for the three tests (Table 3-2). Ratios from the tests ranged from 1.373 to 1.951. The acute Cyprinidae family-level TAF calculated as the geometric mean of the two genus-level LC_{50}:LC_5 ratios in the Family Cyprinidae is 1.532 (see Appendix B.1 for raw empirical toxicity data, TRAP models and output).

3.1.1.3 Calculating Chub and Dace Acute Cadmium Minimum Effect Threshold

Dividing the estimated spotfin chub, slender chub or blackside dace FMAV (1,821 µg/L; family-level surrogate) by the acute Cyprinidae family-level TAF (1.532) results in an acute minimum effect threshold concentration of 1,189 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.1.1.4 Chub and Dace: Acute Cadmium Effects Determination

The acute cadmium CMC at a hardness of 100 mg/L as $CaCO_3$ (1.9 µg/L total Cd), is almost three orders of magnitude lower than the acute cadmium minimum effect threshold of 1,189 µg/L total cadmium calculated for the spotfin chub, slender chub or blackside dace. As a result, refined assessment and consideration of the criterion duration is not necessary and approval of the acute cadmium water quality standard is Not Likely to Adversely Affect (NLAA) the spotfin chub, slender chub or blackside dace through direct acute effects.

Table 3-2. Acute LC_{50}:LC_5 ratios from analysis of three high-quality acute cadmium toxicity tests with fishes in the Family Cyprinidae used to derive an acute family taxonomic adjustment factor (TAF) for the spotfin chub, slender chub and blackside dace.

Family	Species	LC_{50} (µg/L)	LC_{05} (µg/L)	LC_{50}:LC_{05}	C-R Curve Label	Reference	Species-Level TAF LC_{50}:LC_{05}	Genus-level TAF LC_{50}:LC_{05}	Family-level TAF LC_{50}:LC_{05}
Cyprinidae	Red shiner (adult, 0.80-2.0 g), *Cyprinella lutrensis*	6,731	4,903	1.373	Cd-Acute-85	Carrier 1987; Carrier and Beitinger 1988a	1.373	1.373	1.532
Cyprinidae	Zebrafish (adult), *Danio rerio*	15,631	8,012	1.951	Cd-acute-86	Vergauwen 2012; Vergauwen et al. 2013	1.710	1.710	
Cyprinidae	Zebrafish (adult), *Danio rerio*	12,384	8,263	1.499	Cd-acute-87	Vergauwen 2012; Vergauwen et al. 2013			

3.1.2 Chub and Dace Chronic Cadmium Effects Assessment: Freshwater

3.1.2.1 Identifying Chub and Dace Chronic Cadmium Data

High-quality species- or genus-level chronic toxicity data from Appendix C of the 2016 Cadmium 304(a) Aquatic Life Criteria document are not available for the spotfin chub, slender chub or blackside dace. Family-level chronic toxicity data were, therefore, used to determine a chronic toxicity value (i.e., EC_{20}) of 14.16 µg/L representative of the three species (Table 3-3). The Cyprinidae FMCV is based on a single, high-quality chronic life-cycle toxicity assay with the fathead minnow (Pickering and Gast 1972; endpoint = eggs/F1 female).

Table 3-3. Data used to calculate the Cyprinidae FMCV representative of spotfin chub, slender chub or blackside dace chronic sensitivity to cadmium.

Family	Species	SMCV (µg/L)[a]	GMCV (µg/L)[a]	FMCV (µg/L)[a]
Cyprinidae	Spotfin chub, *Erimonax monachus*	N/A	N/A	14.16
Cyprinidae	Slender chub, *Erimystax cahni*	N/A	N/A	
Cyprinidae	Blackside dace, *Chrosomus cumberlandensis*	N/A	N/A	
Cyprinidae	Fathead minnow, *Pimephales promelas*	14.16	14.16	

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016). N/A: not available.

3.1.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

Raw C-R data are available for the same fathead minnow test (Pickering and Gast 1972) used to calculate the Cyprinidae FMCV for the spotfin chub, slender chub or blackside dace, however, the underlying C-R model was unacceptable due to noise at low-level effects resulting in an uncertain EC_x estimate (see Cd-Chronic-47 in Appendix B.4; EC_{20}:EC_5 ratio = 1.383). Because no raw empirical acute toxicity data are available for fish species in the same order (Cypriniformes), no acute order-level TAF could be calculated. As a result, EPA obtained and analyzed C-R data for all tests used to derive the chronic criterion (USEPA 2016 Appendix C underlined values) where such data were reported or could be obtained to derive a chronic vertebrate TAF or chronic MAF, if necessary (i.e., if the vertebrate- and invertebrate-level chronic TAFs do not differ from one another).

Raw empirical chronic toxicity data were fit to C-R models using EPA's TRAP software to calculate EC_{20} and corresponding EC_5 values for 40 tests representing 17 species (8 invertebrate and 9 fish species). C-R models were excluded from TAF and MAF calculation if: 1) models did not exhibit a unique solution and were flagged by TRAP as having inadequate partial effects; 2) models did not include observations in the region of interest which did not allow TRAP to accurately model a no-response plateau and; 3) models exhibited incongruities such as no or poor fit to key points or excessive noise in the C-R relationship. After exclusion of unacceptable or uncertain EC_{20}:EC_5 ratios, 13 ratios remained resulting in three genus-level EC_{20}:EC_5 ratios for invertebrate species (arithmetic mean = 1.779 µg/L, variance = 0.07706 µg/L) and four genus-level EC_{20}:EC_5 ratios for vertebrate species (arithmetic mean = 1.332 µg/L, variance = 0.008872

µg/L). Analysis of the two means via a two-sample t-test assuming unequal variances ($\alpha = 0.05$) indicated that the means are the same (*t stat [2.677] < t critical for two tail [4.303]*). As a result, the chronic MAF was used to transform the FMCV applicable to the spotfin chub, slender chub or blackside dace (14.16 µg/L) to a chronic minimum effect threshold concentration.

Table 3-4 provides the seven genus-level EC_{20}:EC_5 ratios used to derive the chronic MAF. Individual test ratios ranged from 1.229 to 2.097. The chronic MAF calculated as the geometric mean of all genus-level EC_{20}:EC_5 ratios is 1.502 (see Appendix B.3 for raw empirical toxicity test data, TRAP models and outputs for the 13 chronic cadmium toxicity tests used to derive the chronic MAF; Appendix B.4 includes the raw empirical toxicity data, TRAP models and outputs for all unacceptable and uncertain cadmium toxicity tests). The less-robust EC_{20}:EC_5 ratio from Pickering and Gast (1972) is 1.383, suggesting the chronic MAF of 1.502 serves as a reasonable and slightly conservative EC_{20} to EC_5 adjustment factor.

Table 3-4. Chronic EC_{20}:EC_5 ratios from analysis of 13 high-quality chronic cadmium toxicity tests with freshwater aquatic organisms used to derive a chronic cadmium mean adjustment factor (MAF) representative of the spotfin chub, slender chub or blackside dace.

Order	Family	Species	EC_{20} (µg/L)	EC_{05} (µg/L)	EC_{20}: EC_{05}	C-R Curve Label	Reference	Species-level TAF (EC_{20}:EC_{05})	Genus-level TAF (EC_{20}:EC_{05})
N/A[a]	Aeolosomatidae	Oligochaete, *Aeolosoma headleyi*	57.35	27.35	2.097	Cd-Chronic-1	Niederlehner et al. 1984	2.097	2.097
Diplostraca	Daphniidae	Cladoceran, *Ceriodaphnia dubia*	4.940	3.352	1.474	Cd-Chronic-12	Southwest Texas State University 2000	1.584	1.584
Diplostraca	Daphniidae	Cladoceran, *Ceriodaphnia dubia*	5.505	3.235	1.702	Cd-Chronic-13	Southwest Texas State University 2000		
Diplostraca	Daphniidae	Cladoceran, *Daphnia magna*	0.2118	0.1059	2.000	Cd-Chronic-15	Chapman et al. Manuscript	1.657	1.657
Diplostraca	Daphniidae	Cladoceran, *Daphnia magna*	6.166	4.489	1.374	Cd-Chronic-17	Bodar et al. 1988b		
Salmoniformes	Salmonidae	Rio Grande cutthroat trout *Oncorhynchus clarkii virginalis*	2.354	1.659	1.419	Cd-Chronic-24	Brinkman 2012	1.419	1.365
Salmoniformes	Salmonidae	Rainbow trout, *Oncorhynchus mykiss*	2.283	1.774	1.287	Cd-Chronic-26	Davies et al. 1993	1.312	
Salmoniformes	Salmonidae	Rainbow trout, *Oncorhynchus mykiss*	4.956	3.719	1.333	Cd-Chronic-27	Davies et al. 1993		
Salmoniformes	Salmonidae	Rainbow trout, *Oncorhynchus mykiss*	4.315	3.272	1.319	Cd-Chronic-28	Davies et al. 1993		
Salmoniformes	Salmonidae	Brown trout, *Salmo trutta*	5.187	4.221	1.229	Cd-Chronic-42	Brinkman and Hansen 2004a; 2007	1.229	1.229
Cyprinodontiformes	Cyprinodontidae	Flagfish, *Jordanella floridae*	5.018	3.470	1.446	Cd-Chronic-48	Spehar 1976a,b	1.446	1.446
Scorpaeniformes	Cottidae	Mottled sculpin, *Cottus bairdii*	1.762	1.329	1.326	Cd-Chronic-52	Besser et al. 2007	1.289	1.289
Scorpaeniformes	Cottidae	Mottled sculpin, *Cottus bairdii*	1.285	1.026	1.252	Cd-Chronic-53	Besser et al. 2007		

[a] N/A; not available, no order listed in the Integrated Taxonomic Information System (www.itis.gov) for the species.

3.1.2.3 Calculating Chub and Dace Chronic Cadmium Minimum Effect Threshold
Dividing the spotfin chub, slender chub or blackside dace EC_{20} value (14.16 µg/L; family-level surrogate) by the chronic MAF (1.502), results in a chronic minimum effect threshold concentration of 9.427 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.1.2.4 Chubs and Dace: Chronic Cadmium Effects Determination
The chronic cadmium CCC of 0.79 µg/L total cadmium (at a hardness of 100 mg/L as $CaCO_3$) is nearly 12 times lower than the cadmium minimum effect threshold concentration of 9.427 µg/L total cadmium calculated for the spotfin chub, slender chub or blackside dace. The chub and dace chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the chronic cadmium water quality standard is Not Likely to Adversely Affect (NLAA) the spotfin chub, slender chub or blackside dace through direct acute effects.

3.1.3 Chub and Dace Cadmium Indirect Effects Assessment: Freshwater

The spotfin and slender chubs are primarily benthic insectivores, while the blackside dace frequently consumes algae and plant matter and occasionally aquatic insect larvae (USFWS 1983a, 1983b, 2014, 2015a). Aquatic life criteria are based on the fifth centile of sensitive genera to ensure the broad aquatic community, including emerging aquatic insects, are adequately protected. Aquatic insects consistently rank among the more tolerant taxa to acute cadmium exposures, with midges (*Chironomus*) representing the most tolerant (USEPA 2016). Chronic toxicity data with emerging aquatic insects are limited; however, the only insect genus represented is the 4th most sensitive genus to chronic cadmium exposures (*Chironomus* GMCV = 2.000 µg/L, normalized to a total hardness of 100 mg/L as $CaCO_3$ – a value 2.5 times greater than the CCC of 0.79 µg/L). Furthermore, USEPA (2016) states, "*Data for aquatic plants indicated that a reduction in growth occurred at concentrations above the lowest effect concentrations for fish and invertebrates, so aquatic life criteria were not developed for plants*." Because spotfin and slender chubs rely on a range of aquatic insects, it is not likely that either would be indirectly affected by approval of the acute and chronic cadmium criteria even if a specific food resource (e.g., *Chironomus* larvae) was severely limited (which is not the intent of the action). As a result, approval of the acute and chronic cadmium water quality standards is Not Likely to Adversely Affect (NLAA) the spotfin chub, slender chub or blackside dace through indirect effects.

3.2 Duskytail Darter (*Etheostoma percnurum*), Candy Darter (*Etheostoma osburni*), and Roanoke Logperch (*Percina Rex)*

3.2.1 Darters and Logperch Acute Cadmium Effects Assessment: Freshwater

3.2.1.1 Identifying Darters and Logperch Acute Cadmium Data
High-quality species- or genus-level acute toxicity data from Appendix A of the Cadmium 304(a) Aquatic Life Criteria document (USEPA 2016) are not available for the duskytail darter, candy darter or Roanoke logperch. Family-level acute toxicity data were, therefore, used to determine an acute toxicity value (i.e., LC_{50}) of 6,808 µg/L (normalized to a total hardness of

100 mg/L as $CaCO_3$) representative of the darters and logperch (Table 3-5). The Percidae FMAV is based on a single GMAV for the Genus *Perca* which is represented by a single SMAV of 6,808 µg/L for the yellow perch (*Perca flavescens*). The yellow perch SMAV is based on a single definitive LC_{50} value reported by Niyogi et al. (2004b).

Table 3-5. Data used to calculate the Percidae FMAV representative of duskytail and candy darters and Roanoke logperch acute sensitivity to cadmium.

Family	Species	SMAV (µg/L)[a]	GMAV (µg/L)[a]	FMAV (µg/L)[a]
Percidae	Duskytail Darter, *Etheostoma percnurum*	N/A	N/A	6,808
Percidae	Candy Darter, *Etheostoma osburni*	N/A		
Percidae	Roanoke logperch, *Percina rex*	N/A	N/A	
Percidae	Yellow Perch, *Perca flavescens*	6,808	6,808	

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016). N/A: not available.

3.2.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

The published acute toxicity study (Niyogi et al. 2004b) used to calculate the Percidae FMAV representative of duskytail darter, candy darter or Roanoke logperch did not contain or report raw empirical toxicity data. Because no raw empirical acute toxicity data are available for fish species in the same order, no acute order-level TAF could be calculated. As a result, EPA obtained and analyzed C-R data for all tests used to derive the acute criterion where such data were reported or could be obtained to derive an acute vertebrate TAF or acute MAF, if necessary (i.e., if the vertebrate and invertebrate acute TAFs do not differ from one another).

Raw empirical acute toxicity data were fit to C-R models using EPA's TRAP software to calculate LC_{50} and corresponding LC_5 values for 69 tests representing 28 species (18 invertebrate and 10 vertebrates). C-R models were excluded from TAF and MAF calculation if: 1) models did not exhibit a unique solution and were flagged by TRAP as having inadequate partial effects; 2) models did not include observations in the region of interest which did not allow TRAP to accurately model a no-response plateau; and 3) models exhibited incongruities such as no or poor fit to key points or excessive noise in the C-R relationship. After exclusion of unacceptable or uncertain LC_{50}:LC_5 ratios, 35 ratios remained resulting in seven genus-level LC_{50}:LC_5 ratios for invertebrate species (arithmetic mean = 2.857 µg/L, variance = 2.186 µg/L) and six genus-level LC_{50}:LC_5 ratios for vertebrate species (arithmetic mean = 2.106 µg/L, variance = 0.2589 µg/L). Analysis of the two arithmetic means via a two sample t-test assuming unequal variances (α = 0.05) indicated the means are the same (t stat [1.259] < t critical for two tail [2.306]). As a result, the acute MAF was used to transform the Percidae FMAV representative of the duskytail darter, candy darter or Roanoke logperch (6,808 µg/L) to an acute minimum effect threshold concentration.

Table 3-6 provides the 13 genus-level LC_{50}:LC_5 ratios used to derive the cadmium acute MAF. The acute MAF calculated as the geometric mean of all genus-level LC_{50}:LC_5 ratios is 2.310 (see

Appendix B.1 for raw empirical toxicity test data, TRAP models and outputs for the 35 acute cadmium toxicity tests used to derive the acute MAF; Appendix B.2 includes the raw empirical toxicity data, TRAP models and output for all unacceptable and uncertain cadmium toxicity tests).

Table 3-6. Acute LC_{50}:LC_5 ratios from analysis of 35 high-quality acute cadmium toxicity tests with freshwater aquatic organisms used to derive an acute MAF representative of the duskytail darter, candy darter or Roanoke logperch.

Order	Family	Species	LC_{50} (µg/L)	LC_{05} (µg/L)	LC_{50}: LC_{05}	C-R Curve Label	Reference	Species-level TAF (LC_{50}:LC_{05})	Genus-level TAF (LC_{50}:LC_{05})
Tubificida	Naididae	Tubificid worm, *Tubifex tubifex*	56,141	27,732	2.024	Cd-Acute-2	Rathore and Khangarot 2002	2.278	2.278
Tubificida	Naididae	Tubificid worm, *Tubifex tubifex*	26,650	10,289	2.590	Cd-Acute-5	Rathore and Khangarot 2002		
Tubificida	Naididae	Tubificid worm, *Tubifex tubifex*	423.3	299.5	1.414	Cd-Acute-6	Rathore and Khangarot 2003		
Tubificida	Naididae	Tubificid worm, *Tubifex tubifex*	6,463	1,778	3.634	Cd-Acute-8	Rathore and Khangarot 2003		
Basommatophora	Lymnaeidae	Pond snail (juvenile, stage II, 9 wk), *Lymnaea stagnalis*	1,735	718.0	2.416	Cd-Acute-9	Coeurdassier et al. 2004	2.016	2.016
Basommatophora	Lymnaeidae	Pond snail (adult, 20 wk), *Lymnaea stagnalis*	1,670	1,051	1.590	Cd-Acute-10	Coeurdassier et al. 2004		
Basommatophora	Lymnaeidae	Pond snail (juvenile, 25 mm), *Lymnaea stagnalis*	350.8	164.3	2.135	Cd-Acute-12	Pais 2012		
Basommatophora	Physidae	Snail (adult, 3.3-15 mm), *Physa acuta*	1,619	1,375	1.177	Cd-Acute-14	Woodard 2005	1.177	1.177
Diplostraca	Daphniidae	Cladoceran (<24 hr), *Ceriodaphnia dubia*	30.54	13.76	2.220	Cd-Acute-17	Shaw et al. 2006	2.220	2.220
Diplostraca	Daphniidae	Cladoceran (<24 hr), *Daphnia magna*	170.8	13.67	12.49	Cd-Acute-19	Shaw et al. 2006	4.580	4.580
Diplostraca	Daphniidae	Cladoceran (<24 hr), *Daphnia magna*	517.6	308.3	1.679	Cd-Acute-22	Perez and Beiras 2010		
Decapoda	Cambaridae	Crayfish (adult), *Orconectes virilis*	6,007	2,427	2.475	Cd-Acute-30	Mirenda 1986	2.475	2.475
Ephemeroptera	Heptageniidae	Mayfly (nymph), *Rhithrogena hageni*	10,924	2,080	5.251	Cd-Acute-35	Brinkman and Vieira 2007; Brinkman and Johnston 2008	5.251	5.251
Salmoniformes	Salmonidae	Rainbow trout (8.8 g), *Oncorhynchus mykiss*	3.055	1.759	1.737	Cd-Acute-47	Phipps and Holcombe 1985	2.067	2.067
Salmoniformes	Salmonidae	Rainbow trout (juvenile, 18.3 g), *Oncorhynchus mykiss*	1.682	0.5849	2.876	Cd-Acute-48	Stubblefield 1990		

Order	Family	Species	LC_{50} (µg/L)	LC_{05} (µg/L)	LC_{50}: LC_{05}	C-R Curve Label	Reference	Species-level TAF (LC_{50}:LC_{05})	Genus-level TAF (LC_{50}:LC_{05})
Salmoniformes	Salmonidae	Rainbow trout (36 g), *Oncorhynchus mykiss*	2.679	1.683	1.591	Cd-Acute-49	Davies et al. 1993		
Salmoniformes	Salmonidae	Rainbow trout (36 g), *Oncorhynchus mykiss*	7.052	3.007	2.345	Cd-Acute-53	Davies et al. 1993		
Salmoniformes	Salmonidae	Rainbow trout (fry, 1.0 g), *Oncorhynchus mykiss*	2.773	1.726	1.606	Cd-Acute-55	Davies and Brinkman 1994b		
Salmoniformes	Salmonidae	Rainbow trout (fry, 1.0 g), *Oncorhynchus mykiss*	2.152	1.116	1.928	Cd-Acute-58	Davies and Brinkman 1994b		
Salmoniformes	Salmonidae	Rainbow trout (fry, 2.5 g), *Oncorhynchus mykiss*	10.14	5.298	1.914	Cd-Acute-60	Davies and Brinkman 1994b		
Salmoniformes	Salmonidae	Rainbow trout (263 mg), *Oncorhynchus mykiss*	0.6500	0.3493	1.861	Cd-Acute-61	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Rainbow trout (659 mg), *Oncorhynchus mykiss*	0.4134	0.2108	1.961	Cd-Acute-62	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Rainbow trout (1,150 mg), *Oncorhynchus mykiss*	0.4634	0.2174	2.132	Cd-Acute-63	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Rainbow trout (1,130 mg), *Oncorhynchus mykiss*	0.3528	0.2237	1.577	Cd-Acute-64	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Rainbow trout (299 mg), *Oncorhynchus mykiss*	1.210	0.3198	3.784	Cd-Acute-65	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Rainbow trout (289 mg), *Oncorhynchus mykiss*	2.548	1.042	2.445	Cd-Acute-66	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Brown trout (fingerling, 22.4 g), *Salmo trutta*	2.732	0.9770	2.797	Cd-Acute-76	Stubblefield 1990	2.797	2.797
Salmoniformes	Salmonidae	Bull trout (0.200 g), *Salvelinus confluentus*	0.9828	0.4530	2.169	Cd-Acute-79	Stratus Consulting 1999	2.402	2.402
Salmoniformes	Salmonidae	Bull trout (0.221 g), *Salvelinus confluentus*	0.9994	0.3656	2.734	Cd-Acute-80	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Bull trout (0.0842 g), *Salvelinus confluentus*	3.200	1.254	2.552	Cd-Acute-82	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Bull trout (0.0727 g), *Salvelinus confluentus*	5.942	2.700	2.201	Cd-Acute-83	Stratus Consulting 1999		
Cypriniformes	Cyprinidae	Red shiner (adult, 0.80-2.0 g), *Cyprinella lutrensis*	6,731	4,903	1.373	Cd-Acute-85	Carrier 1987; Carrier and Beitinger 1988a	1.373	1.373

Order	Family	Species	LC_{50} (µg/L)	LC_{05} (µg/L)	LC_{50}: LC_{05}	C-R Curve Label	Reference	Species-level TAF (LC_{50}:LC_{05})	Genus-level TAF (LC_{50}:LC_{05})
Cypriniformes	Cyprinidae	Zebrafish (adult), *Danio rerio*	15,631	8,012	1.951	Cd-Acute-86	Vergauwen 2012; Vergauwen et al. 2013	1.710	1.710
Cypriniformes	Cyprinidae	Zebrafish (adult), *Danio rerio*	12,384	8,263	1.499	Cd-Acute-87	Vergauwen 2012; Vergauwen et al. 2013		
Anura	Pipidae	African clawed frog, *Xenopus laevis*	3,314	1,447	2.290	Cd-Acute-101	Sunderman et al. 1991	2.290	2.290

3.2.1.3 Calculating Darters and Logperch Acute Cadmium Minimum Threshold

Dividing the Percidae FMAV (6,808 µg/L), representative of the duskytail darter, candy darter and Roanoke logperch, by the acute MAF (2.310) results in an acute minimum effect threshold concentration of 2,947 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.2.1.4 Darters and Logperch: Acute Ammonia Effects Determination

The acute cadmium CMC at a hardness of 100 mg/L as $CaCO_3$ (1.9 µg/L total Cd), is over three orders of magnitude lower than the acute cadmium minimum effect threshold of 2,947 µg/L total cadmium estimated for duskytail darter, candy darter or Roanoke logperch. The duskytail darter, candy darter and Roanoke logperch acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary and approval of the acute cadmium water quality standard is Not Likely to Adversely Affect (NLAA) the duskytail darter, candy darter or Roanoke logperch through direct acute effects.

3.2.2 Darters and Logperch Chronic Cadmium Effects Assessment: Freshwater

3.2.2.1 Identifying Darter and Logperch Chronic Cadmium Data

High-quality species, genus, or family-level acute toxicity data from Appendix C of the 2016 Cadmium 304(a) Aquatic Life Criteria document are not available for the duskytail darter, candy darter or Roanoke logperch. Order-level chronic toxicity data were, therefore, used to determine a chronic toxicity value (i.e., EC_{20}) of >24.31 µg/L (normalized to a total hardness of 100 mg/L as $CaCO_3$) representative of the duskytail darter, candy darter, and Roanoke logperch (Table 3-7). The Perciformes Order Mean Chronic Value (OMCV) is based on a geometric mean of two FMCVs (Centrarchidae and Cichlidae) from three GMCVs, each based on a single SMCV. The SMCVs are based on an EC_{20} value for survival of 16.43 µg/L from a life-cycle test with bluegill (*Lepomis macrochirus*) reported in Eaton (1974), a maximum acceptable toxicant concentration (MATC) of >38.66 µg/L from a life-cycle test with blue tilapia (*Oreochromis aureus*) reported in Papoutsoglou and Abel (1988), and an MATC of 14.22 µg/L from an early-life cycle test with smallmouth bass (*Micropterus dolomieu*) reported in Eaton et al. (1978). Effect concentrations (EC_x) are typically preferred over MATCs because MATCs can largely be influenced by the concentrations tested by investigators; however, MATCs are expected to be representative of a 20% effect in this assessment because of the relative similarity between the EC_{20} and MATCs available for fishes in the Order Perciformes.

Table 3-7. Data used to calculate the Perciformes OMCV representative of duskytail darter, candy darter or Roanoke logperch chronic sensitivity to cadmium.

Order	Family	Species	SMCV (µg/L)[a]	GMCV (µg/L)[a]	FMCV (µg/L)[a]	OMCV (µg/L)[a]
Perciformes	Percidae	Duskytail darter, *Etheostoma percnurum*	N/A	N/A	N/A	>24.31
Perciformes	Percidae	Candy darter, *Etheostoma osburni*	N/A			
Perciformes	Percidae	Roanoke logperch, *Percina rex*	N/A	N/A		
Perciformes	Centrarchidae	Bluegill, *Lepomis macrochirus*	16.43	16.43	15.29	
Perciformes	Centrarchidae	Smallmouth bass, *Micropterus dolomieu*	14.22	14.22		
Perciformes	Cichlidae	Blue tilapia, *Oreochromis aureus*	>38.66	>38.66	>38.66	

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016). N/A: not available.

3.2.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

Raw empirical chronic toxicity data are only available from the chronic life-cycle test with bluegill reported by Eaton (1974); however, the underlying C-R curve (Cd-Chronic-51) lacks partial effects, resulting in an uncertain EC_{20}:EC_5 ratio (1.236). No other acceptable C-R data were available within the Order Perciformes, requiring the derivation of the chronic MAF (see previous analysis from Section 3.1.2.2 for chronic MAF derivation). The chronic MAF, calculated as the geometric mean of all acceptable genus-level EC_{20}:EC_5 ratios, is 1.502 (see Appendix B.3 for raw empirical toxicity test data, TRAP models and outputs for the 13 chronic cadmium toxicity tests used to derive the chronic MAF). The less-robust EC_{20}:EC_5 ratio from Eaton (1974) is 1.236, suggesting the chronic MAF of 1.502 serves as a reasonable and slightly conservative EC_{20} to EC_5 adjustment factor.

3.2.2.3 Calculating Darter and Logperch Chronic Cadmium Minimum Effect Threshold

Dividing the Perciformes OMCV (>24.31 µg/L), which is representative of the duskytail darter, candy darter, and Roanoke logperch, by the chronic MAF (1.502) results in a chronic minimum effect threshold concentration of >16.19 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.2.2.4 Darter and Logperch: Chronic Cadmium Effects Determination

The chronic cadmium CCC of 0.79 µg/L total cadmium (at a hardness of 100 mg/L as $CaCO_3$) is over 20 times lower than the chronic cadmium minimum effect threshold concentration of >16.19 µg/L total cadmium estimated for the duskytail darter, candy darter, or Roanoke logperch. The duskytail darter, candy darter, and Roanoke logperch chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the chronic cadmium water quality standard is Not Likely to Adversely Affect (NLAA) the duskytail darter, candy darter, or Roanoke logperch through direct chronic effects.

3.2.3 Darter and Logperch Cadmium Indirect Effects Assessment: Freshwater

The duskytail darter, candy darter and Roanoke logperch are primarily benthic insectivores (Layman 1991, USFWS 2017). Aquatic life criteria are based on the fifth centile of sensitive genera to ensure the broad aquatic community, including emerging aquatic insects, is adequately protected. Aquatic insects consistently rank among the more tolerant taxa to acute cadmium exposures, with midges (*Chironomus*) the most tolerant (USEPA 2016). Chronic toxicity data with emerging aquatic insects are limited; however, the only insect genus represented is the 4th most sensitive genus to chronic cadmium exposures (*Chironomus* GMCV = 2.000 µg/L, normalized to a total hardness of 100 mg/L as $CaCO_3$ – a value 2.5 times greater than the CCC of 0.79 µg/L). Because the darters and logperch rely on a range of aquatic insects, it is not likely that either would be indirectly affected by approval of the acute and chronic cadmium criteria even if a specific food resource (e.g., *Chironomus* larvae) was severely limited (which is not the intent of the action). As a result, approval of the acute and chronic cadmium water quality standards is Not Likely to Adversely Affect (NLAA) the duskytail darter, candy darter or Roanoke logperch through indirect effects.

3.3 Yellowfin Madtom (*Noturus flavipinnis*)

3.3.1 Yellowfin Madtom Acute Cadmium Effects Assessment: Freshwater

3.3.1.1 Identifying Yellowfin Madtom Acute Cadmium Data

High-quality species- or genus-level acute toxicity data from Appendix A of the 2016 Cadmium 304(a) Aquatic Life Criteria document are not available for the yellowfin madtom. Family-level data were, therefore, used to determine an acute toxicity value (i.e., LC_{50}) of 9,917 µg/L (normalized to a total hardness of 100 mg/L as $CaCO_3$) representative of the yellowfin madtom (Table 3-8). The Ictluridae FMAV is based on a single GMAV. The *Ictalurus* GMAV is represented by a single SMAV of 9,917 µg/L (normalized to a total hardness of 100 mg/L as $CaCO_3$) for the channel catfish (*Ictalurus punctatus*). The channel catfish SMAV for is based on a single definitive LC_{50} value reported by Phipps and Holcombe (1985).

Table 3-8 Data used to calculate the Ictaluridae FMAV representative of yellowfin madtom acute sensitivity to cadmium.

Family	Species	SMAV (µg/L)[a]	GMAV (µg/L)[a]	FMAV (µg/L)[a]
Ictaluridae	Yellowfin madtom, *Noturus flavipinnis*	N/A	N/A	9,917
Ictaluridae	Channel catfish, *Ictalurus punctatus*	9,917	9,917	

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016). N/A: not available.

3.3.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

The published acute toxicity study (Phipps and Holcombe 1985) used to calculate the Ictaluridae FMAV representative of yellowfin madtom did not contain or report raw empirical toxicity data. No other acceptable C-R data were available within the Order Siluriformes, requiring the derivation of the acute MAF (see Section 3.2.1.2 for acute MAF derivation). The acute MAF, calculated as the geometric mean of all acceptable genus-level LC_{50}:LC_5 ratios, is 2.310 (see Appendix B.1 for raw empirical toxicity test data, TRAP models and outputs for the 35 acute cadmium toxicity tests used to derive the acute MAF).

3.3.1.3 Calculating Yellowfin Madtom Acute Cadmium Minimum Threshold

Dividing the estimated yellowfin madtom FMAV (9,917 µg/L) by the acute MAF (2.310) results in an acute minimum effect threshold concentration of 4,293 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.3.1.4 Yellowfin Madtom: Acute Ammonia Effects Determination

The acute cadmium CMC at a hardness of 100 mg/L as $CaCO_3$ (1.9 µg/L total Cd), is over three orders of magnitude lower than the yellowfin madtom acute cadmium minimum effect threshold of 4,293 µg/L total cadmium. The yellowfin madtom acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary and approval of the acute cadmium water quality standard is Not Likely to Adversely Affect (NLAA) the yellowfin madtom through direct acute effects.

3.3.2 Yellowfin Madtom Chronic Cadmium Effects Assessment: Freshwater

3.3.2.1 Identifying Yellowfin Madtom Chronic Cadmium Data

High-quality empirical chronic toxicity data for species within the Order Siluriformes are not available to serve as chronic toxicity data representative of the yellowfin madtom. As a result, the Ictaluridae FMAV was transformed to represent a chronic toxicity value (i.e., EC_{20}) of 1,196 µg/L (Table 3-9). This representative chronic value for the yellowfin madtom was calculated by dividing the acute toxicity value for channel catfish (9,917 µg/L; representative of yellowfin madtom) by the Final Acute-to-Chronic Ratio (FACR) reported in the cadmium criteria document (USEPA 2016). The FACR was used because the individual ACRs reported in USEPA (2016; see Table 16) vary by more than a factor of ten, even when only considering ACRs from vertebrate species or fish in a second family in the Class Osteichthyes (minimum data requirement #2; Stephan et al. 1985). Additionally, USEPA (2016), states *"... none of the four methods suggested in the 1985 Guidelines (Stephan et al. 1985) for calculating the FACR are appropriate for cadmium... Thus, an alternate approach was used to determine the FACR. The recommended FACR of 8.291 was obtained from the geometric mean of seven genus-level ACRs... Americamysis (7.070), Ceriodaphnia (19.84), Daphnia (23.90), Cottus (11.22), Oncorhynchus (2.0), Salmo (2.0) and Pimephales (17.90).*" The FACR is intended to broadly relate a species acute effect concentration to an estimated chronic effect concentration.

Table 3-9. Data used to calculate the FMCV representative of yellowfin madtom sensitivity to cadmium.

Order	Family	Species	SMAV (µg/L)[a]	GMAV (µg/L)[a]	FMAV (µg/L)[a]	FACR	FMCV (µg/L)[a]
Siluriformes	Ictaluridae	Channel catfish, *Ictalurus punctatus*	9,917	9,917	9,917	8.291	1,196
Siluriformes	Ictaluridae	Yellowfin madtom, *Noturus flavipinnis*	N/A	N/A			

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016). N/A: not available

3.3.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

Raw empirical chronic toxicity data were not available for the yellowfin madtom and no other acceptable C-R data were available within the Order Siluriformes, requiring the derivation of the chronic MAF (see Section 3.1.2.2 for chronic MAF derivation). The chronic MAF, calculated as the geometric mean of all acceptable genus-level EC_{20}:EC_5 ratios, is 1.502 (see Appendix B.3 for raw empirical toxicity test data, TRAP models and outputs for the 13 chronic cadmium toxicity tests used to derive the chronic MAF).

3.3.2.3 Calculating Yellowfin Madtom Chronic Cadmium Minimum Effect Threshold

Dividing the estimated yellowfin madtom EC_{20} value (1,196 µg/L) by the chronic MAF (1.502) results in chronic minimum effect threshold concentration of 796.3 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.3.2.4 Yellowfin Madtom: Chronic Cadmium Effects Determination

The chronic cadmium CCC of 0.79 µg/L total cadmium (at a hardness of 100 mg/L as $CaCO_3$) is three orders of magnitude lower than the yellowfin madtom chronic cadmium minimum effect threshold concentration of 796.3 µg/L total cadmium. The yellowfin madtom chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the chronic cadmium water quality standard is Not Likely to Adversely Affect (NLAA) the yellowfin madtom through direct effects.

3.3.3 Yellowfin Madtom Cadmium Indirect Effects Assessment: Freshwater

The yellowfin madtom feeds from dusk into night on aquatic insect larvae (USFWS 1983c). Aquatic life criteria are based on the fifth centile of sensitive genera to ensure the broad aquatic community, including emerging aquatic insects, is adequately protected. Aquatic insects consistently rank among the more tolerant taxa to acute cadmium exposures, with midges (*Chironomus*) the most tolerant (USEPA 2016). Chronic toxicity data with emerging aquatic insects are limited; however, the only insect genus represented is the 4th most sensitive genus to chronic cadmium exposures (*Chironomus* GMCV = 2.000 µg/L, normalized to a total hardness of 100 mg/L as $CaCO_3$ – a value 2.5 times greater than the CCC of 0.79 µg/L). Because yellowfin madtom rely on a range of aquatic insects, it is not likely that yellowfin madtom would be indirectly affected by approval of the acute and chronic cadmium criteria even if a specific food resource (e.g., *Chironomus* larvae) was severely limited (which is not the intent of the action). As a result, approval of the acute and chronic cadmium water quality standards is Not Likely to Adversely Affect (NLAA) the yellowfin madtom through indirect effects.

3.4 Pink Mucket (*Lampsilis abrupta*)

3.4.1 Pink Mucket Cadmium Acute Effects Assessment: Freshwater

3.4.1.1 Identifying Pink Mucket Acute Cadmium Data

High-quality pink mucket acute cadmium toxicity data were not available to derive the acute criterion (Appendix A of USEPA 2016). Genus-level acute toxicity data were, therefore, used to determine an acute toxicity value (i.e., LC_{50}) of 51.34 µg/L (normalized to a total hardness of 100 mg/L as $CaCO_3$) representative of the pink mucket (see Table 3-10). The *Lampsilis* GMAV is based on four SMAVs that range from 35.73 µg/L for fatmucket (*L. siliquoidea*) to 93.17 µg/L for southern fatmucket (*L. straminea claibornensis*).

Table 3-10. Data used to calculate the *Lampsilis* GMAV representative of pink mucket acute sensitivity to cadmium.

Family	Species	SMAV (µg/L)[a]	GMAV (µg/L)[a]
Unionidae	Pink mucket, *Lampsilis abrupta*	N/A	51.34
Unionidae	Neosho mucket, *Lampsilis rafinesqueana*	44.67	
Unionidae	Fatmucket, *Lampsilis siliquoidea*	35.73	
Unionidae	Southern fatmucket, *Lampsilis straminea claibornensis*	93.17	
Unionidae	Yellow sandshell, *Lampsilis teres*	46.71	

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016). N/A: not available.

3.4.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical acute toxicity data are only available from two tests out of the several that were used to calculate the *Lampsilis* GMAV representative of the pink mucket (tests with 5-d old juvenile Neosho mucket [*Lampsilis rafinesqueana*] and fatmucket [*L. siliquoidea*] reported by Wang et al. [2010d]). The C-R models for the two tests, however, are unacceptable (see Cd-Acute-15 and Cd-Acute-16 in Appendix B.2). The Neosho mucket C-R model (Cd-Acute-15; EC_{20}:EC_5 ratio = 1.332) does not provide a unique solution and was flagged in TRAP for inadequate partial effects, while the fatmucket C-R model (Cd-Acute-16; EC_{20}:EC_5 ratio = 1.426) is a poor fit. No other acute toxicity tests with C-R data are available for the Order Unionoida. As a result, EPA obtained and analyzed C-R data for all tests used to derive the acute cadmium criterion (underlined values in Appendix A of USEPA 2016) where such data were reported or could be obtained to derive an acute MAF of 2.310 (see Section 3.2.1.2 and Table 3-6). Considering the unacceptable/uncertain ratios from data reported by Wang et al (2010d) ranged from 1.332 to 1.426, the chronic MAF of 2.310 serves as a conservative EC_{20} to EC_5 adjustment factor.

3.4.1.3 Calculating Pink Mucket Acute Cadmium Minimum Effect Threshold

Dividing the *Lampsilis* GMAV (51.34 µg/L), which is representative of the pink mucket, by the acute MAF (2.310) results in an acute minimum effect threshold concentration of 22.23 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.4.1.4 Pink Mucket Acute Cadmium Effects Determination

The acute cadmium CMC at a hardness of 100 mg/L as $CaCO_3$ (1.9 µg/L total Cd), is nearly 12 times lower than the pink mucket acute cadmium minimum effect threshold of 22.23 µg/L total cadmium. The pink mucket acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary and approval of the acute freshwater cadmium water quality standard is Not Likely to Adversely Affect (NLAA) pink mucket through direct acute effects.

3.4.2 Pink Mucket Cadmium Chronic Effects Assessment: Freshwater

3.4.2.1 Identifying Pink Mucket Chronic Cadmium Data

High quality species-level chronic toxicity data are not available for the pink mucket (underlined values in Appendix C of USEPA 2016). Genus-level chronic toxicity data were, therefore, used to determine a chronic toxicity value (i.e., EC_{20}) of 11.29 µg/L (normalized to a total hardness of 100 mg/L as $CaCO_3$) representative of the pink mucket (see Table 3-11). The *Lampsilis* GMCV is based on a single SMCV of 11.29 µg/L reported for the fatmucket (*L. siliquoidea*; Wang et al. 2010d; endpoint = 28-d survival).

Table 3-11. Data used to calculate the *Lampsilis* GMCV representative of pink fatmucket sensitivity to cadmium.

Family	Species	SMCV (µg/L)[a]	GMCV (µg/L)[a]	FMCV (µg/L)[a]
Unionidae	Pink mucket, *Lampsilis abrupta*	N/A	N/A	11.29
Unionidae	Fatmucket, *Lampsilis siliquoidea*	11.29	11.29	

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016).N/A: not available

3.4.2.1 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

Raw empirical chronic toxicity data are available from the same test (Wang et al. 2010d) used to calculate the GMCV representative of the pink mucket; however, the underlying C-R model (Cd-Chronic-9; EC_{20}:EC_5 ratio = 1.334) lacks partial effects and does not provide a unique solution resulting in an uncertain EC_x estimate, particularly when estimating a low-level effects concentration (see Appendix B.4). No other chronic toxicity tests with C-R data are available for the Order Unionoida. As a result, EPA obtained and analyzed C-R data for all tests used to derive the chronic cadmium criterion (underlined values in Appendix C of USEPA 2016) where such data were reported or could be obtained to derive a chronic MAF of 1.502 (see Section 3.1.2.2 and Table 3-4). The uncertain EC_{20}:EC_5 ratio from Wang et al. (2010d; Cd-Chronic-9) is 1.334, suggesting the chronic MAF of 1.502 serves as a reasonable and slightly conservative EC_{20} to EC_5 adjustment factor.

3.4.2.1 Calculating Pink Mucket Chronic Cadmium Minimum Effect Threshold
Dividing the estimated pink mucket EC_{20} value (11.29 µg/L; genus-level surrogate) by the chronic MAF (1.502) results in a chronic minimum effect threshold concentration of 7.517 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.4.2.2 Pink Mucket Chronic Cadmium Effects Determination
The cadmium CCC of 0.79 µg/L total cadmium (at a hardness of 100 mg/L as $CaCO_3$) is 9.5 times lower than the pink mucket chronic cadmium minimum effect threshold concentration of 7.517 µg/L total cadmium. The pink mucket chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the chronic cadmium freshwater quality standard is Not Likely to Adversely Affect (NLAA) the pink mucket through direct chronic effects.

3.4.3 Pink Mucket Cadmium Indirect Effects Assessment: Freshwater

The pink mucket filters phytoplankton and zooplankton from the water column as a primary food source, with plants (e.g., phytoplankton) being relatively insensitive to acute and chronic cadmium exposures. For example, USEPA (2016) states, "*Available data for aquatic plants and algae were reviewed to determine if they were more sensitive to cadmium than aquatic animals... Effect concentrations for freshwater plants and algae were well above the freshwater criteria...and it was therefore unnecessary to develop criteria based on the toxicity of cadmium to aquatic plants…*" Acute toxicity data used to derive the acute freshwater cadmium criterion (Table 7 of USEPA 2016) indicate fish are the most sensitive to acute cadmium exposures, with pelagic crustaceans (e.g., zooplankton) being less sensitive and, therefore, adequately protected from acute cadmium exposures. Pelagic crustaceans (*Ceriodaphnia* and *Daphnia*) did comprise the two of the five most-sensitive genera to chronic cadmium exposures (Table 9 of USEPA 2016); however, a large portion of individuals (i.e., < 20%) within the most sensitive genera are not anticipated to be affected because chronic toxicity values (i.e., EC_{20} values) are based on exposure durations significantly longer (e.g., 7 to 28 days for invertebrate tests) than the chronic criterion duration (i.e., 4 days). Further, chronic effects on a large portion of zooplankton (which is not an anticipated effect of the proposed actions) would translate minimally to the pink mucket prey base because mussels also rely on phytoplankton, which are tolerant to cadmium exposures (USEPA 2016). Because criteria are derived to protect the broad aquatic community (including zooplankton and phytoplankton), and pink mucket are not specialized feeders, instead relying on a range of pelagic organisms, EPA approval of Virginia acute and chronic freshwater cadmium standards is Not Likely to Adversely Affect (NLAA) the pink mucket through indirect effects.

3.5 Cumberland (*Villosa trabalis*) and Purple Bean (*Villosa perpurpurea*)

3.5.1 Cumberland and Purple Bean Cadmium Acute Effects Assessment: Freshwater

3.5.1.1 Identifying Cumberland and Purple Bean Acute Cadmium Data
High-quality acute cadmium toxicity data are not available for Cumberland and purple bean (Appendix A of USEPA 2016). Genus-level acute toxicity data were, therefore, used to determine an acute toxicity value (i.e., LC_{50}) of 70.76 µg/L (normalized to a total hardness of

100 mg/L as $CaCO_3$) representative of the Cumberland and purple bean (see Table 3-12). The *Villosa* GMAV is based on a single SMAV (70.76 µg/L) determined from two juvenile Southern rainbow mussel (*V. vibex*) LC_{50} values from static, measured acute toxicity tests (Keller, unpublished).

Table 3-12. Data used to calculate the *Villosa* GMAV representative of Cumberland and purple bean acute sensitivity to cadmium.

Family	Species	SMAV (µg/L)[a]	GMAV (µg/L)[a]
Unionidae	Cumberland bean, *Villosa trabalis*	N/A	70.76
Unionidae	Purple bean, *Villosa perpurpurea*	N/A	
Unionidae	Southern rainbow mussel, *Villosa vibex*	70.76	

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016). N/A: not available.

3.5.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

The acute toxicity study (Keller, unpublished) used to calculate the *Villosa* GMAV representative of Cumberland and purple bean did not contain or report raw empirical toxicity data. Raw empirical acute toxicity data, however, are available from two tests with surrogate species in the same family (Unionidae) as the Cumberland and purple bean, but the C-R models for the two tests are unacceptable (see Section 3.4.1.2). No other acute toxicity tests with C-R data are available for the Order Unionoida. As a result, EPA obtained and analyzed C-R data for all tests used to derive the acute cadmium criterion (underlined values in Appendix A of USEPA 2016) where such data were reported or could be obtained to derive an acute MAF of 2.310 (see Section 3.2.1.2 and Table 3-6).

3.5.1.3 Calculating Cumberland and Purple Bean Acute Cadmium Minimum Effect Threshold

Dividing the estimated the Cumberland and purple bean LC_{50} value (70.76 µg/L) by the acute MAF (2.310) results in an acute minimum effect threshold concentration of 30.63 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.5.1.4 Cumberland and Purple Bean Acute Cadmium Effects Determination

The acute cadmium CMC at a hardness of 100 mg/L as $CaCO_3$ (1.9 µg/L total Cd), is 16 times lower than the Cumberland and purple bean acute cadmium minimum effect threshold of 30.63 µg/L total cadmium. The Cumberland and purple bean acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary and approval of the acute freshwater cadmium water quality standard is Not Likely to Adversely Affect (NLAA) Cumberland and purple bean through direct acute effects.

3.5.2 Cumberland and Purple Bean Cadmium Chronic Effects Assessment: Freshwater

3.5.2.1 Identifying Cumberland and Purple Bean Chronic Cadmium Data

High-quality chronic toxicity data are unavailable for Cumberland bean, purple bean, or other species within the genus *Villosa* (Appendix C of USEPA 2016). Family-level chronic toxicity

data were, therefore, used to determine a chronic toxicity value (i.e., EC_{20}) of 11.29 µg/L (normalized to a total hardness of 100 mg/L as $CaCO_3$) representative of the Cumberland and purple bean (see Section 3.4.2.1 and Table 3-11).

3.5.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

Raw empirical chronic toxicity data are available from the same test (Wang et al. 2010d) used to calculate the Unionidae FMCV representative of the Cumberland and purple bean; however, the underlying C-R model does not provide a unique solution resulting in an uncertain EC_x estimate (see Section 3.4.2.1). No other chronic toxicity tests with C-R data are available for the Order Unionoida. As a result, EPA obtained and analyzed C-R data for all tests used to derive the chronic cadmium criterion (underlined values in Appendix C of USEPA 2016) where such data were reported or could be obtained to derive a chronic MAF of 1.502 (see Section 3.1.2.2 and Table 3-4).

3.5.2.3 Calculating Cumberland and Purple Bean Chronic Cadmium Minimum Effect Threshold

Dividing the estimated Cumberland and purple bean EC_{20} value (11.29 µg/L; family-level surrogate) by the chronic MAF (1.502) results in a chronic minimum effect threshold concentration of 7.517 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.5.2.4 Cumberland and Purple Bean Chronic Cadmium Effects Determination

The cadmium CCC of 0.79 µg/L total cadmium (at a hardness of 100 mg/L as $CaCO_3$) is 9.5 times lower than the Cumberland and purple bean chronic cadmium minimum effect threshold concentration of 7.517 µg/L total cadmium. The Cumberland and purple bean chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the chronic cadmium freshwater quality standard is Not Likely to Adversely Affect (NLAA) the Cumberland and purple bean through direct effects.

3.5.3 Cumberland and Purple Bean Cadmium Indirect Effects Assessment: Freshwater

The Cumberland and purple bean mussels filter phytoplankton and zooplankton from the water column as a primary food source, with plants (e.g., phytoplankton) being relatively insensitive to acute and chronic cadmium exposures. For example, USEPA (2016) states, "*Available data for aquatic plants and algae were reviewed to determine if they were more sensitive to cadmium than aquatic animals... Effect concentrations for freshwater plants and algae were well above the freshwater criteria...and it was therefore unnecessary to develop criteria based on the toxicity of cadmium to aquatic plants…*" Acute toxicity data used to derive the acute freshwater cadmium criterion (Table 7 of USEPA 2016) indicate fish are the most sensitive to acute cadmium exposures, with pelagic crustaceans (e.g., zooplankton) being less sensitive and, therefore, adequately protected from acute cadmium exposures. Pelagic crustaceans (*Ceriodaphnia* and *Daphnia*) did comprise the two of the five most-sensitive genera to chronic cadmium exposures (Table 9 of USEPA 2016); however, a large portion of individuals (i.e., < 20%) within the most sensitive genera are not anticipated to be affected because chronic toxicity values (i.e., EC_{20} values) are based on exposure durations significantly longer (e.g., 7 to 28 days

for invertebrate tests) than the chronic criterion duration (i.e., 4 days). Further, chronic effects on a large portion of zooplankton (which is not an anticipated effect of the proposed actions) would translate minimally to the Cumberland and purple bean prey base because these mussels also rely on phytoplankton, which are tolerant to cadmium exposures (USEPA 2016). Because criteria are derived to protect the broad aquatic community (including zooplankton and phytoplankton), and Cumberland and purple bean are not specialized feeders, instead relying on a range of pelagic organisms, EPA approval of Virginia acute and chronic freshwater cadmium standards is Not Likely to Adversely Affect (NLAA) the Cumberland and purple bean through indirect effects.

3.6 Other Mussels in the Family Unionidae:

- Dwarf Wedgemussel (*Alasmidonta heterodon*)
- Fanshell Mussel (*Cyprogenia stegaria*)
- Yellow lance (*Elliptio lanceolata*)
- Cumberlandian Combshell (*Epioblasma brevidens)*, Tan Riffleshell (*Epioblasma walker*), Green Pearly Mussel Blossom (*Epioblasma torulosa gubernaculum*), Snuffbox Mussel (*Epioblasma triquetra*), and Oyster Mussel (*Epioblasma capsaeformis*)
- Dromedary Pearly Mussel (*Dromus dromas*)
- Shiny Pigtoe and Fine Rayed Pigtoe (*Fusconaia cor, Fusconaia cuneolus*)
- Cracking Pearly Mussel (*Hemistena lata*)
- Birdwing Pearly Mussel (*Lemiox rimosus*)
- Littlewing Pearly Mussel (*Pegias fabula*)
- Sheepnose Mussel (*Plethobasus cyphyus*)
- James Spinymussel and Rough Pigtoe (*Pleurobema collina, Pleurobema plenum*)
- Slabside Pearly Mussel (*Pleuronaia dolabelloides*)
- Fluted Kidneyshell (*Ptychobranchus subtentum*)
- Rough Rabbitsfoot (*Quadrula cylindrical strigillata*)
- Cumberland and Appalachian Monkeyface (*Theliderma intermedia, Theliderma sparsa*)

3.6.1 Other Family Unionidae Mussel Acute Cadmium Effects Assessment: Freshwater

3.6.1.1 Identifying Family Unionidae Mussel Acute Cadmium Data

High-quality species- or genus-level acute cadmium toxicity data from Appendix A of the 2016 Cadmium 304(a) Aquatic Life Criteria document are not available for 22 listed mussels in the Family Unionidae with range in Virginia. Family-level acute toxicity data from eight different related mussel species were, therefore, used to determine an acute toxicity value (i.e., LC_{50}) representative of the 22 mussels (Table 3-13). The Unionidae FMAV of 65.58 µg/L is based on five GMAVs, ranging from51.34 µg/L for *Lampsilis* to 71.76 µg/L for *Utterbackia*.

Table 3-13. Data used to calculate the Unionidae FMAV representative of the acute sensitivity of the other 22 Listed mussels in Virginia to cadmium.

Family	Species	SMAV (µg/L)[a]	GMAV (µg/L)[a]	FMAV (µg/L)[a]
Unionidae	Mussel, *Actinonaias pectorosa*	67.90	67.90	65.58

Unionidae	Neosho mucket, *Lampsilis rafinesqueana*	44.67	51.34	
Unionidae	Fatmucket, *Lampsilis siliquoidea*	35.73		
Unionidae	Southern fatmucket, *Lampsilis straminea claibornensis*	93.17		
Unionidae	Yellow sandshell, *Lampsilis teres*	46.71		
Unionidae	Mussel, *Lasmigona subviridis*	68.51	68.51	
Unionidae	Mussel, *Utterbackia imbecillis*	71.76	71.76	
Unionidae	Southern rainbow mussel, *Villosa vibex*	70.76	70.76	

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016).

N/A: not available.

3.6.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical acute toxicity data are available from two tests used with surrogate species in the same family (Unionidae) as the 22 untested unionid mussels, but the C-R models for the two tests are unacceptable (see Section 3.4.1.2). No other acute toxicity tests with C-R data are available for the Order Unionoida. As a result, EPA obtained and analyzed C-R data for all tests used to derive the acute cadmium criterion (underlined values in Appendix A of USEPA 2016) where such data were reported or could be obtained to derive an acute MAF of 2.310 (see Section 3.2.1.2 and Table 3-6).

3.6.1.3 Calculating Family Unionidae Mussel Acute Cadmium Minimum Effect Threshold

Dividing the estimated Family Unionidae LC_{50} value (65.58 µg/L) by the acute MAF (2.310) results in an acute minimum effect threshold concentration of 28.39 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.6.1.4 Family Unionidae Mussel: Acute Cadmium Effects Determination

The acute cadmium CMC at a hardness of 100 mg/L as $CaCO_3$ (1.9 µg/L total Cd), is 15 times lower than the acute cadmium minimum effect threshold of 28.39 µg/L total cadmium estimated for the other 22 listed mussels in the Family Unionidae. The acute minimum effect threshold concentration for the 22 mussels, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary and approval of the acute freshwater cadmium water quality standard is Not Likely to Adversely Affect (NLAA) the dwarf wedgemussel, fanshell mussel, yellow lance, Cumberlandian combshell, tan riffleshell, green blossom pearly mussel, snuffbox mussel, oyster mussel, dromedary pearly mussel, shiny pigtoe, fine rayed pigtoe, cracking pearly mussel, birdwing pearly mussel, littlewing pearly mussel, sheepnose mussel, James spinymussel, rough pigtoe, slabside pearly mussel, fluted kidneyshell, rough rabbitsfoot, and Cumberland and Appalachian monkeyface mussels through direct acute effects.

3.6.2 Family Unionidae Mussel Cadmium Chronic Effects Assessment: Freshwater

3.6.2.1 Identifying Family Unionidae Chronic Cadmium Data

High quality species or genus-level chronic toxicity data from Appendix C of the 2016 Cadmium 304(a) Aquatic Life Criteria document are not available for the other 22 Listed mussels in Virginia. Family-level chronic toxicity data were, therefore, used to determine a chronic toxicity value (i.e., EC_{20}) of 11.29 µg/L (normalized to a total hardness of 100 mg/L as $CaCO_3$) representative of all unionid mussels (see Section 3.4.2.1 and Table 3-11).

3.6.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

Raw empirical chronic toxicity data are available from the same test (Wang et al. 2010d) used to calculate the Unionidae FMCV representative of the 22 listed mussels; however, the underlying C-R model does not provide a unique solution (inadequate partial effects) resulting in an uncertain EC_x estimate (see Section 3.4.2.1). No other chronic toxicity tests with C-R data are available for the Order Unionoida. As a result, EPA obtained and analyzed C-R data for all tests used to derive the chronic cadmium criterion (underlined values in Appendix C of USEPA 2016) where such data were reported or could be obtained to derive a chronic MAF of 1.502 (see Section 3.1.2.2 and Table 3-4).

3.6.2.3 Calculating Family Unionidae Mussel Chronic Cadmium Minimum Effect Threshold

Dividing the estimated Family Unionidae EC_{20} value (11.29 µg/L; family-level surrogate) by the chronic MAF (1.502) results in a chronic minimum effect threshold concentration of 7.517 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.6.2.4 Family Unionidae Mussel: Chronic Cadmium Effects Determination

The cadmium CCC of 0.79 µg/L total cadmium (at a hardness of 100 mg/L as $CaCO_3$) is 9.5 times lower than the chronic cadmium minimum effect threshold concentration of 7.517 µg/L total cadmium estimated for the other 22 Listed mussels in Virginia. The chronic minimum effect threshold concentration for these mussels, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the chronic cadmium freshwater quality standard is Not Likely to Adversely Affect (NLAA) the dwarf wedgemussel, fanshell mussel, yellow lance, Cumberlandian combshell, tan riffleshell, green blossom pearly mussel, snuffbox mussel, oyster mussel, dromedary pearly mussel, shiny pigtoe, fine rayed pigtoe, cracking pearly mussel, birdwing pearly mussel, littlewing pearly mussel, sheepnose mussel, James spinymussel, rough pigtoe, slabside pearly mussel, fluted kidneyshell, rough rabbitsfoot, and Cumberland and Appalachian monkeyface mussels through direct chronic effects.

3.6.3 Family Unionidae Mussel Cadmium Indirect Effects Assessment: Freshwater

Freshwater mussels in the Family Unionidae filter phytoplankton and zooplankton from the water column as a primary food source, with plants (e.g., phytoplankton) being relatively insensitive to acute and chronic cadmium exposures. For example, USEPA (2016) states, "*Available data for aquatic plants and algae were reviewed to determine if they were more*

sensitive to cadmium than aquatic animals... Effect concentrations for freshwater plants and algae were well above the freshwater criteria...and it was therefore unnecessary to develop criteria based on the toxicity of cadmium to aquatic plants…" Acute toxicity data used to derive the acute freshwater cadmium criterion (Table 7 of USEPA 2016) indicate fish are the most sensitive to acute cadmium exposures, with pelagic crustaceans (e.g., zooplankton) being less sensitive and, therefore, adequately protected from acute cadmium exposures. Pelagic crustaceans (*Ceriodaphnia* and *Daphnia*) did comprise the two of the five most-sensitive genera to chronic cadmium exposures (Table 9 of USEPA 2016); however, a large portion of individuals (i.e., < 20%) within the most sensitive genera are not anticipated to be affected because chronic toxicity values (i.e., EC_{20} values) are based on exposure durations significantly longer (e.g., 7 to 28 days for invertebrate tests) than the chronic criterion duration (i.e., 4 days). Further, chronic effects on a large portion of zooplankton (which is not an anticipated effect of the proposed actions) would translate minimally to the unionid mussel prey base because mussels also rely on phytoplankton, which are tolerant to cadmium exposures (USEPA 2016). Because criteria are derived to protect the broad aquatic community (including zooplankton and phytoplankton), and unionid mussels in general are not specialized feeders, instead relying on a range of pelagic organisms, EPA approval of Virginia acute and chronic freshwater cadmium standards is Not Likely to Adversely Affect (NLAA) the dwarf wedgemussel, fanshell mussel, yellow lance, Cumberlandian combshell, tan riffleshell, green blossom pearly mussel, snuffbox mussel, oyster mussel, dromedary pearly mussel, shiny pigtoe, fine rayed pigtoe, cracking pearly mussel, birdwing pearly mussel, littlewing pearly mussel, sheepnose mussel, James spinymussel, rough pigtoe, slabside pearly mussel, fluted kidneyshell, rough rabbitsfoot, and Cumberland and Appalachian monkeyface mussels through indirect effects.

3.7 Spectaclecase Mussel (*Cumberlandia monodonta*)

3.7.1 Spectaclecase Mussel Acute Cadmium Effects Assessment: Freshwater

3.7.1.1 Identifying Spectaclecase Mussel Acute Cadmium Data

High-quality acute cadmium toxicity data are unavailable for the spectaclecase mussel or other members within the family Margaritiferidae (Appendix A of USEPA 2016). Order-level acute toxicity data were, therefore, used to determine an acute toxicity value (i.e., LC_{50}) of 65.58 µg/L (normalized to a total hardness of 100 mg/L as $CaCO_3$) representative of the spectaclecase mussel (see Section 3.6.1.1 and Table 3-13).

3.7.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical acute toxicity data are only available from two tests out of the several that were used to calculate the Unionoida OMAV representative of the spectaclecase mussel, but the C-R models for the two tests are unacceptable (see Section 3.4.1.2). No other acute toxicity tests with C-R data are available for the Order Unionoida. As a result, EPA obtained and analyzed C-R data for all tests used to derive the acute cadmium criterion (underlined values in Appendix A of USEPA 2016) where such data were reported or could be obtained to derive an acute MAF of 2.310 (see Section 3.2.1.2 and Table 3-6).

3.7.1.3 Calculating Spectaclecase Mussel Acute Cadmium Minimum Effect Threshold
Dividing the estimated spectaclecase mussel LC_{50} value (65.58 µg/L) by the acute MAF (2.310) results in an acute minimum effect threshold concentration of 28.39 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.7.1.4 Spectaclecase Mussel: Acute Cadmium Effects Determination
The acute cadmium CMC at a hardness of 100 mg/L as $CaCO_3$ (1.9 µg/L total Cd), is 15 times lower than the spectaclecase mussel acute cadmium minimum effect threshold of 28.39 µg/L total cadmium. The spectaclecase mussel acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary and approval of the acute freshwater cadmium water quality standard is Not Likely to Adversely Affect (NLAA) the spectaclecase mussel through direct acute effects.

3.7.2 Spectaclecase Mussel Cadmium Chronic Effects Assessment: Freshwater

3.7.2.1 Identifying Spectaclecase Mussel Chronic Cadmium Data
High-quality chronic cadmium toxicity data are unavailable for the spectaclecase mussel or other members within the family Margaritiferidae (Appendix C of USEPA 2016). Order-level chronic toxicity data were, therefore, used to determine a chronic toxicity value (i.e., EC_{20}) of 11.29 µg/L (normalized to a total hardness of 100 mg/L as $CaCO_3$) representative of the spectaclecase mussel (see Section 3.4.2.1 and Table 3-11).

3.7.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor
Raw empirical chronic toxicity data are available from the same test (Wang et al. 2010d) used to calculate the Unionoida OMCV representative of the spectaclecase mussel; however, the underlying C-R model does not provide a unique solution resulting in an uncertain EC_x estimate (see Section 3.4.2.1). No other chronic toxicity tests with C-R data are available for the Order Unionoida. As a result, EPA obtained and analyzed C-R data for all tests used to derive the chronic cadmium criterion (underlined values in Appendix C of USEPA 2016) where such data were reported or could be obtained to derive a chronic MAF of 1.502 (see Section 3.1.2.2 and Table 3-4).

3.7.2.3 Calculating Spectaclecase Mussel Chronic Cadmium Minimum Effect Threshold
Dividing the estimated spectaclecase mussel EC_{20} value (11.29 µg/L; family-level surrogate) by the chronic MAF (1.502) results in a chronic minimum effect threshold concentration of 7.517 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.7.2.4 Spectaclecase Mussel: Chronic Cadmium Effects Determination
The cadmium CCC of 0.79 µg/L total cadmium (at a hardness of 100 mg/L as $CaCO_3$) is 9.5 times lower than the spectaclecase mussel chronic cadmium minimum effect threshold concentration of 7.517 µg/L total cadmium. The spectaclecase mussel chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the chronic cadmium freshwater quality

standard is Not Likely to Adversely Affect (NLAA) the spectaclecase mussel through direct effects.

3.7.3 Spectaclecase Mussel Cadmium Indirect Effects Assessment: Freshwater

The spectaclecase, like other freshwater mussels in the Order Unionida, filters phytoplankton and zooplankton from the water column as a primary food source, with plants (e.g., phytoplankton) being relatively insensitive to acute and chronic cadmium exposures. For example, USEPA (2016) states, "*Available data for aquatic plants and algae were reviewed to determine if they were more sensitive to cadmium than aquatic animals... Effect concentrations for freshwater plants and algae were well above the freshwater criteria...and it was therefore unnecessary to develop criteria based on the toxicity of cadmium to aquatic plants…*" Acute toxicity data used to derive the acute freshwater cadmium criterion (Table 7 of USEPA 2016) indicate fish are the most sensitive to acute cadmium exposures, with pelagic crustaceans (e.g., zooplankton) being less sensitive and, therefore, adequately protected from acute cadmium exposures. Pelagic crustaceans (*Ceriodaphnia* and *Daphnia*) did comprise the two of the five most-sensitive genera to chronic cadmium exposures (Table 9 of USEPA 2016); however, a large portion of individuals (i.e., < 20%) within the most sensitive genera are not anticipated to be affected because chronic toxicity values (i.e., EC_{20} values) are based on exposure durations significantly longer (e.g., 7 to 28 days for invertebrate tests) than the chronic criterion duration (i.e., 4 days). Further, chronic effects on a large portion of zooplankton (which is not an anticipated effect of the proposed actions) would translate minimally to the spectaclecase prey base because these mussels also rely on phytoplankton, which is tolerant to cadmium exposures (USEPA 2016). Because criteria are derived to protect the broad aquatic community (including zooplankton and phytoplankton), and spectaclecase are not specialized feeders, instead relying on a range of pelagic organisms, EPA approval of Virginia acute and chronic freshwater cadmium standards is Not Likely to Adversely Affect (NLAA) the spectaclecase through indirect effects.

3.8 Lee County Cave Isopod (*Lirceus usdagalun*)

3.8.1 Lee County Cave Isopod Cadmium Acute Effects Assessment: Freshwater

3.8.1.1 Identifying Lee County Cave Isopod Acute Cadmium Data

High-quality Lee County cave isopod acute cadmium toxicity data from Appendix A of the 2016 Cadmium 304(a) Aquatic Life Criteria document are not available. Genus-level acute toxicity data were, therefore, used to determine an acute toxicity value (i.e., LC_{50}) of 99.54 µg/L (normalized to a total hardness of 100 mg/L as $CaCO_3$) representative of the Lee County cave isopod (Table 3-14). The *Lirceus* GMAV is based on the *Lirceus alabamae* SMAV of 99.54 µg/L, from a flow-through, measured acute toxicity test (Bosnak and Morgan 1981).

Table 3-14. Data used to calculate the *Lirceus* GMAV representative of Lee County cave isopod acute sensitivity to cadmium.

Family	Species	SMAV (µg/L)[a]	GMAV (µg/L)[a]
Asellidae	Lee County cave isopod, *Lirceus usdagalun*	N/A	99.54
Asellidae	Isopod,	99.54	

	Lirceus alabamae		

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016). N/A: not available.

3.8.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical acute toxicity data was unavailable from the same test (Bosnak and Morgan 1981) that was used to calculate the *Lirceus* GMAV representative of the Lee County cave isopod. No other acute toxicity tests with C-R data are available for the Order Isopoda. As a result, EPA obtained and analyzed C-R data for all tests used to derive the acute cadmium criterion (underlined values in Appendix A of USEPA 2016) where such data were reported or could be obtained to derive an acute MAF of 2.310 (see Section 3.2.1.2 and Table 3-6).

3.8.1.3 Calculating Lee County Cave Isopod Acute Cadmium Minimum Effect Threshold

Dividing the estimated the Lee County cave isopod LC_{50} value (99.54 µg/L) by the acute MAF (2.310) results in an acute minimum effect threshold concentration of 43.09 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.8.1.4 Lee County Cave Isopod Acute Cadmium Effects Determination

The acute cadmium CMC at a hardness of 100 mg/L as $CaCO_3$ (1.9 µg/L total Cd), is nearly 23 times lower than Lee County cave isopod acute cadmium minimum effect threshold of 43.09 µg/L total cadmium. The Lee County cave isopod acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary and approval of the acute freshwater cadmium water quality standard is Not Likely to Adversely Affect (NLAA) Lee County cave isopod through direct acute effects.

3.8.2 Lee County Cave Isopod Chronic Cadmium Effects Assessment: Freshwater

3.8.2.1 Identifying Lee County Cave Isopod Chronic Cadmium Data

High-quality chronic toxicity data from Appendix C of the 2016 Cadmium 304(a) Aquatic Life Criteria document are not available within the Order Isopoda. As a result, the *Licerus* GMAV was transformed to represent a chronic toxicity value (i.e., EC_{20}) of 5.721 µg/L (Table 3-15). This representative chronic value for the Lee County cave isopod was calculated by dividing the acute toxicity value for *Licerus* (99.54 µg/L; representative of Lee County cave isopod) by the invertebrate acute-to-chronic ratio (17.40) calculated from the individual ACRs reported in Table 16 in the cadmium criteria document (USEPA 2016).

An invertebrate acute-to-chronic ratio (Inv-ACR) is the geometric mean of all available ACRs for invertebrates, calculated with an LC_{50} value as the numerator and a corresponding EC_{20} value as the denominator (see Table 3-16). Other forms of chronic toxicity test endpoints (e.g., NOEC, LOEC, and MATC) were not used to derive ACRs, consistent with the 2016 cadmium criteria document. The Inv-ACR was used because no ACRs were available within the minimum data requirement (MDR) classification for isopods (benthic crustaceans), and is more conservative than the FACR of 8.291 (see USEPA 2016). The use of a more conservative ACR for estimating chronic toxicity to invertebrates is appropriate because several invertebrates are sensitive to chronic cadmium exposure (USEPA 2016). The lowest ACR (>1.446) for an invertebrate is based on acute and chronic values from paired toxicity tests reported by Chadwick Ecological

Consultants (2003). The ratio includes a non-definitive LC_{50} value as the numerator, as does a second ACR calculated with paired acute and chronic values from the same study (>2.745) – see Table 3-16. These non-definitive (greater than) ACRs are one to two orders of magnitude lower than four other ACRs for *Daphnia magna*, one of which represents the highest ACR for an invertebrate (i.e., an ACR of 155.8 from paired acute and chronic values from tests reported in the Chapman et al. manuscript). Otherwise, individual ACRs for invertebrates are generally within a factor of ten and, therefore, appropriate for estimating the *Licerus* GMCV of 5.721 µg/L, which is representative of the Lee County cave isopod.

Table 3-15. Data used to calculate the GMCV representative of Lee County cave isopod chronic sensitivity to cadmium.

Order	Family	Species	SMAV (µg/L)[a]	GMAV (µg/L)[a]	Invert ACR	GMCV (µg/L)[a]
Isopoda	Asellidae	Lee County cave isopod, *Lirceus usdagalun*	N/A	99.54	17.40	5.721
Isopoda	Asellidae	Isopod, *Lirceus alabamae*	99.54			

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016). N/A: not available.

Table 3-16. ACRs used to calculate the invertebrate ACR (Inv-ACR) used to estimate the *Lirceus* GMCV representative of Lee County cave isopod chronic sensitivity to cadmium.

Species	Acute Method[a]	Acute-Hardness (mg/L as $CaCO_3$)	Chronic-Hardness (mg/L as $CaCO_3$)	Acute Value (µg/L)	Chronic Value (µg/L)	Chronic Test Endpoint	ACR	Reference
Snail, *Aplexa hypnorum*	F,M	44.8	45.3	93	4.002	EC20	23.24	Holcombe et al. 1984; Phipps and Holcombe 1985
Snail, *Aplexa hypnorum*	F,M	44.8	45.3	93	0.8737	EC20	106.4	Holcombe et al. 1984; Phipps and Holcombe 1985
Pond snail (25 mm), *Lymnaea stagnalis*	R,M	135 (130-140)	135 (130-140)	367.5	28.68	EC20	12.81	Pais 2012
Fatmucket (5-d old juvenile), *Lampsilis siliquoidea*	R,M	44 (40-48)	44 (40-48)	16	5.868	EC20	2.727	Wang et al. 2010d
Cladoceran, *Ceriodaphnia dubia*	R,M	170	170	38.3	1.93	MATC[d]	19.84	Brooks et al. 2004
Cladoceran, *Daphnia magna*	S,M	51	53	9.9	0.1523	MATC[d]	65.00	Chapman et al. manuscript
Cladoceran, *Daphnia magna*	S,M	104	103	33	0.2118	EC20	155.8	Chapman et al. manuscript
Cladoceran, *Daphnia magna*	S,M	209	209	49	0.3545	EC20	138.2	Chapman et al. manuscript
Cladoceran, *Daphnia magna*	R,M	209.2	200	30	0.37	EC20	81.08	Canton and Slooff 1982
Cladoceran, *Daphnia magna*	S,M	170	170	12.66[b]	1.10	MATC[d]	11.51	Baird et al. 1990, 1991
Cladoceran, *Daphnia magna*	R,M	100	99	>6.85[c]	2.496	EC20	>2.745	Chadwick Ecological Consultants 2003
Cladoceran, *Daphnia magna*	R,M	50	51	>3.43[c]	2.373	EC20	>1.446	Chadwick Ecological Consultants 2003
Cladoceran, *Daphnia magna*	S,M	-	-	41.1	1.528	EC20	26.89	Jemec et al. 2007, 2008
Cladoceran, *Daphnia pulex*	S,M	65	65	62	6.214	EC20	9.977	Niederlehner 1984a
Cladoceran, *Daphnia pulex*	R,M	50	52	>14.6[c]	3.051	EC20	>4.785	Chadwick Environmental Consultants 2003

a S=static, R=renewal, F=flow-through, U=unmeasured, M=measured. b Geometric mean of 6 LC_{50}s from Baird et al. (1991).
c Test species fed. d Not used for calculating the Inv-ACR (see text).

3.8.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

Raw empirical chronic toxicity data were not available for the Lee County cave isopod or surrogate species within the Order Isopoda, requiring the application of the chronic MAF (see Section 3.1.2.2 for chronic MAF derivation). The chronic MAF, calculated as the geometric mean of all acceptable genus-level EC_{20}:EC_5 ratios, is 1.502 (see Appendix B.3 for raw empirical toxicity test data, TRAP models and outputs for the 13 chronic cadmium toxicity tests used to derive the chronic MAF).

3.8.2.3 Calculating Lee County Cave Isopod Chronic Cadmium Minimum Effect Threshold

Dividing the estimated Lee County cave isopod EC_{20} value (5.721 µg/L) by the chronic MAF (1.502) results in chronic minimum effect threshold concentration of 3.809 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.8.2.4 Lee County Cave Isopod Chronic Cadmium Effects Determination

The chronic cadmium CCC of 0.79 µg/L total cadmium (at a hardness of 100 mg/L as $CaCO_3$) is 4.8 times lower than the Lee County cave isopod chronic cadmium minimum effect threshold concentration of 3.809 µg/L total cadmium. The Lee County cave isopod chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the chronic cadmium water quality standard is Not Likely to Adversely Affect (NLAA) the Lee County cave isopod through direct chronic effects.

3.8.3 Lee County Cave Isopod Cadmium Indirect Effects Assessment: Freshwater

Little is known of the life history of the Lee County cave isopod. Mouth parts are for chewing, so common foods likely include decaying plant material, such as dead leaves, and other refuse. Assuming plant material is a primary food source, prey items are likely insensitive to acute and chronic cadmium exposures. For example, USEPA (2016) states, "*Available data for aquatic plants and algae were reviewed to determine if they were more sensitive to cadmium than aquatic animals... Effect concentrations for freshwater plants and algae were well above the freshwater criteria...and it was therefore unnecessary to develop criteria based on the toxicity of cadmium to aquatic plants…*" Because criteria are derived to protect the broad aquatic community (including zooplankton and phytoplankton), and Lee County cave isopods are not specialized feeders, instead relying on algae and other tiny organisms that coat submerged rocks and logs, EPA approval of Virginia acute and chronic freshwater cadmium standards is Not Likely to Adversely Affect (NLAA) the Lee County cave isopods through indirect effects.

3.9 Madison Cave Isopod (*Antrolana lira*)

3.9.1 Madison Cave Isopod Cadmium Acute Effects Assessment: Freshwater

3.9.1.1 Identifying Madison Cave Isopod Acute Cadmium Data

High-quality acute cadmium toxicity data are not available for the Madison cave isopod or other species within the Family Cirolanidae (Appendix A of USEPA 2016). Order-level data were, therefore, used to determine an acute toxicity value (i.e., LC_{50}) of 312.9 µg/L (normalized to a total hardness of 100 mg/L as $CaCO_3$) representative of the Madison cave isopod (Table 3-17). The Isopoda OMAV is based on the Asellidae FMAV determined from two GMAVs, each based on single SMAVs. The SMAVs are based on single LC_{50} values of 99.54 µg/L from an acute toxicity test with isopod (*Lirceus alabamae*) and 983.8 µg/L from a test with isopod, *Caecidotea bicrenata* (formerly *Asellus bicrenata*) both reported in Bosnak and Morgan (1981).

Table 3-17. Data used to calculate the OMAV representative of Madison cave isopod acute sensitivity to cadmium.

Order	Family	Species	SMAV (µg/L)[a]	GMAV (µg/L)[a]	FMAV (µg/L)[a]	OMAV (µg/L)[a]
Isopoda	Cirolanidae	Madison cave isopod, *Antrolana lira*	N/A	N/A	N/A	312.9
Isopoda	Asellidae	Isopod, *Lirceus alabamae*	99.54	99.54	312.9	
Isopoda	Asellidae	Isopod, *Caecidotea bicrenata*	983.8	983.8		

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016).
N/A: not available

3.9.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical acute toxicity data were unavailable from the same two tests (Bosnak and Morgan 1981) that was used to calculate the Isopoda OMAV representative of the Madison cave isopod. No other acute toxicity tests with C-R data are available for the Order Isopoda. As a result, EPA obtained and analyzed C-R data for all tests used to derive the acute cadmium criterion (underlined values in Appendix A of USEPA 2016) where such data were reported or could be obtained to derive an acute MAF of 2.310 (see Section 3.2.1.2 and Table 3-6).

3.9.1.3 Calculating Madison Cave Isopod Acute Cadmium Minimum Effect Threshold

Dividing the estimated the Madison cave isopod LC_{50} value (312.9 µg/L) by the acute MAF (2.310) results in an acute minimum effect threshold concentration of 135.5 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.9.1.4 Madison Cave Isopod Acute Cadmium Effects Determination

The acute cadmium CMC at a hardness of 100 mg/L as $CaCO_3$ (1.9 µg/L total Cd), is 71 times lower than Madison cave isopod acute cadmium minimum effect threshold of 135.5 µg/L total cadmium. The Madison cave isopod acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a

result, refined assessment and consideration of the criterion duration is not necessary and approval of the acute freshwater cadmium water quality standard is Not Likely to Adversely Affect (NLAA) Madison Cave isopod through direct acute effects.

3.9.2 Madison Cave Isopod Chronic Cadmium Effects Assessment: Freshwater

3.9.2.1 Identifying Lee County Cave Isopod Chronic Cadmium Data

High-quality empirical chronic toxicity data are not available within the Order Isopoda (Appendix A of USEPA 2016). As a result, the Isopoda OMAV (Table 3-17) was transformed to represent a chronic toxicity value (i.e., EC_{20}) of 5.721 µg/L (Table 3-18). This representative chronic value for the Madison cave isopod was calculated by dividing the Isopoda OMAV for Isopoda (312.9 µg/L; representative of the Madison cave isopod) by the Inv-ACR of 17.40 (see Section 3.8.2.1 and Table 3-16).

Table 3-18. Data used to calculate the Isopoda OMCV representative of Madison cave isopod chronic sensitivity to cadmium.

Order	Family	Species	SMAV (µg/L)[a]	GMAV (µg/L)[a]	FMAV (µg/L)[a]	OMAV (µg/L)[a]	Inv-ACR	OMCV (µg/L)[a]
Isopoda	Cirolanidae	Madison cave isopod, *Antrolana lira*	N/A	N/A	N/A	312.9	17.40	17.98
Isopoda	Asellidae	Isopod, *Lirceus alabamae*	99.54	99.54	312.9			
Isopoda	Asellidae	Isopod, *Caecidotea bicrenata*	983.8	983.8				

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016).
N/A: not available.

3.9.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

High-quality chronic toxicity data were not available for the Madison cave isopod or surrogate species within the Order Isopoda to determine an Order-level TAF, requiring the derivation of the chronic MAF (see previous analysis from Section 3.1.2.2 for chronic MAF derivation). The chronic MAF, calculated as the geometric mean of all acceptable genus-level EC_{20}:EC_5 ratios, is 1.502 (see Appendix B.3 for raw empirical toxicity test data, TRAP models and outputs for the 13 chronic cadmium toxicity tests used to derive the chronic MAF).

3.9.2.3 Calculating Madison Cave Isopod Chronic Cadmium Minimum Effect Threshold

Dividing the estimated Madison cave isopod EC_{20} value (17.98 µg/L) by the chronic MAF (1.502) results in chronic minimum effect threshold concentration of 11.97 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.9.2.4 Madison Cave Isopod Chronic Cadmium Effects Determination

The chronic cadmium CCC of 0.79 µg/L total cadmium (at a hardness of 100 mg/L as $CaCO_3$) is nearly 15 times lower than the Madison cave isopod chronic cadmium minimum effect threshold concentration of 11.97 µg/L total cadmium. The Madison cave isopod chronic minimum effect

threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the chronic cadmium water quality standard is Not Likely to Adversely Affect (NLAA) the Madison cave isopod through direct chronic effects.

3.9.3 Madison Cave Isopod Cadmium Indirect Effects Assessment: Freshwater

Little is known of the life history of the Madison cave isopod. Mouth parts are for chewing, so common foods likely include decaying plant material, such as dead leaves, and other refuse. Assuming plant material is a primary food source, prey items are likely insensitive to acute and chronic cadmium exposures. For example, USEPA (2016) states, "*Available data for aquatic plants and algae were reviewed to determine if they were more sensitive to cadmium than aquatic animals... Effect concentrations for freshwater plants and algae were well above the freshwater criteria...and it was therefore unnecessary to develop criteria based on the toxicity of cadmium to aquatic plants…*" Because criteria are derived to protect the broad aquatic community (including zooplankton and phytoplankton), and Madison cave isopods are not specialized feeders, instead relying on algae and other tiny organisms that coat submerged rocks and logs, EPA approval of Virginia acute and chronic freshwater cadmium standards is Not Likely to Adversely Affect (NLAA) the Madison cave isopods through indirect effects.

3.10 Big Sandy Crayfish (*Cambarus veteranus*)

3.10.1 Big Sandy Crayfish Cadmium Acute Effects Assessment: Freshwater

3.10.1.1 Identifying Big Sandy Crayfish Acute Cadmium Data

High-quality acute cadmium toxicity data are not available for big sandy crayfish or other species within the Genus *Cambarus*. Family-level acute toxicity data were, therefore, used to determine an acute toxicity value (i.e., LC_{50}) of 1,705 µg/L (normalized to a total hardness of 100 mg/L as $CaCO_3$) representative of the big sandy crayfish (Table 3-19). The Cambaridae FMAV of 1,705 µg/L is based on the *Orconectes* GMAV (calculated from four SMAVs ranging from 66.89 to 22,800 µg/L) and the *Procambarus* GMAV (calculated from three SMAVs ranging from 812.8 to 6,592 µg/L [Table 3-19]).

Table 3-19. Data used to calculate the Cambaridae FMAV representative of big sandy crayfish acute sensitivity to cadmium.

Family	Species	SMAV (µg/L)[a]	GMAV (µg/L)[a]	FMAV (µg/L)[a]
Cambaridae	Big sandy crayfish, *Cambarus veteranus*	N/A	N/A	1,705
Cambaridae	Calico crayfish, *Orconectes immunis*	>22,579	1,466	
Cambaridae	Kentucky River crayfish, *Orconectes juvenilis*	134.0		
Cambaridae	Placid crayfish, *Orconectes placidus*	66.89		

Cambaridae	Virile crayfish, *Orconectes virilis*	22,800		
Cambaridae	White River crayfish, *Procambarus acutus*	812.8	1,983	
Cambaridae	Blue crayfish, *Procambarus alleni*	6,592		
Cambaridae	Red swamp crayfish, *Procambarus clarkii*	1,455		

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016).
N/A: not available.

3.10.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

Raw empirical acute toxicity test data are unavailable for the big sandy crayfish or the genus *Cambarus*, and therefore, no raw empirical toxicity data are available to support the derivation of an LC_{50}:LC_5 adjustment factor within the genus *Cambarus.* As a result, EPA obtained and analyzed C-R data for one test with a crayfish species (*Orconectes virilis*) in the same family as the big sandy crayfish (Cambaridae) to derive an acute family-level TAF (see Cd-Acute-30 in Appendix B.1 for raw empirical toxicity test data, TRAP model and output for the test). The raw empirical acute toxicity data from this test was fit to a C-R model using EPA's TRAP software to calculate an LC_{50} and corresponding LC_5 value for the test. The acute family-level TAF based on the tests is 2.475.

3.10.1.3 Calculating Big Sandy Crayfish Acute Cadmium Minimum Effects Threshold

Dividing the estimated the big sandy crayfish LC_{50} value (1,705 µg/L) by the acute family-level TAF (2.475) results in an acute minimum effect threshold concentration of 688.8 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.10.1.4 Big Sandy Crayfish Acute Cadmium Effects Determination

The acute cadmium CMC at a hardness of 100 mg/L as $CaCO_3$ (1.9 µg/L total Cd), is over two orders of magnitude lower than big sandy crayfish acute cadmium minimum effect threshold of 688.8 µg/L total cadmium. The big sandy crayfish acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary and approval of the acute freshwater cadmium water quality standard is Not Likely to Adversely Affect (NLAA) big sandy crayfish through direct acute effects.

3.10.2 Big Sandy Crayfish Chronic Cadmium Effects Assessment: Freshwater

3.10.2.1 Identifying Big Sandy Crayfish Chronic Cadmium Data

High-quality empirical chronic toxicity are not available within the Order Decapoda. As a result, the Cambaridae FMAV (Table 3-19) was transformed to represent a chronic toxicity value (i.e., EC_{20}) of 97.99 µg/L. This chronic value, representative of big sandy crayfish, was calculated by dividing the Cambaridae FMAV (1,705 µg/L) by the Inv-ACR of 17.40 (see Section 3.8.2.1 and Table 3-16).

3.10.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

Raw empirical chronic toxicity data were not available for the big sandy crayfish or surrogate species within the Order Decapoda, requiring the derivation of the chronic MAF (see Section 3.1.2.2 for chronic MAF derivation). The chronic MAF, calculated as the geometric mean of all acceptable genus-level EC_{20}:EC_5 ratios, is 1.502 (see Appendix B.3 for raw empirical toxicity test data, TRAP models and outputs for the 13 chronic cadmium toxicity tests used to derive the chronic MAF).

3.10.2.3 Calculating Big Sandy Crayfish Chronic Cadmium Minimum Effect Threshold

Dividing the estimated big sandy crayfish EC_{20} value (97.99 µg/L) by the chronic MAF (1.502) results in chronic minimum effect threshold concentration of 65.24 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$).

3.10.2.4 Big Sandy Crayfish: Chronic Cadmium Effects Determination

The chronic cadmium CCC of 0.79 µg/L total cadmium (at a hardness of 100 mg/L as $CaCO_3$) is over 82 times lower than the big sandy crayfish chronic cadmium minimum effect threshold concentration of 65.24 µg/L total cadmium. The big sandy crayfish chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the chronic cadmium water quality standard is Not Likely to Adversely Affect (NLAA) the big sandy crayfish through direct chronic effects.

3.10.3 Big Sandy Crayfish Cadmium Indirect Effects Assessment: Freshwater

Big sandy crayfish are opportunistic omnivores frequently consuming both plants and animals and decomposing organic matter (USFWS 2016). Aquatic life criteria are based on the fifth centile of sensitive genera to ensure the broad aquatic community, including benthic crustaceans, is adequately protected. Fish ranked among the most sensitive taxa to acute cadmium exposures while invertebrates (benthic and pelagic) and fish were most sensitive taxa to chronic cadmium exposures. The most sensitive benthic crustacean to acute and chronic cadmium exposure is the amphipod, *Hyalella azteca*, which ranked 7th and 1st most sensitive, respectively (Tables 7 and 9 in USEPA 2016). A limited number of big sandy crayfish prey items, therefore, could be sensitive to cadmium at magnitudes and exposure durations specified by the acute and chronic cadmium criteria, but effects on a large portion of potential prey/food items (which is not an anticipated effect of the proposed actions) would translate minimally to the big sandy crayfish prey base because the crayfish also relies on other living and dead organisms which are more tolerant to cadmium exposures (USEPA 2016). Furthermore, USEPA (2016) states: "*Available data for aquatic plants and algae were reviewed to determine if they were more sensitive to cadmium than aquatic animals... Effect concentrations for freshwater plants and algae were well above the freshwater criteria...and it was therefore unnecessary to develop criteria based on the toxicity of cadmium to aquatic plants…*" Because criteria are derived to protect the broad aquatic community (including animals and plants), and big sandy crayfish are not specialized feeders, instead relying on a range of organisms and plant matter, EPA approval of Virginia acute and

chronic freshwater cadmium standards is Not Likely to Adversely Affect (NLAA) the big sandy crayfish through indirect effects.

3.11 Aquatic/Semi-Aquatic Plants: Freshwater

- Virginia sneezeweed (*Helenium virginicum*)
- Swamp pink (*Helonias bullata*)
- Eastern prairie fringed orchid (*Platanthera leucophaea*)
- Harperella (*Ptilimnium nodosum*)
- Northeastern bulrush (*Scirpus ancistrochaetus)*

Five listed aquatic/semi-aquatic plant species occur in Virginia freshwaters and may be exposed to cadmium at magnitudes and durations specified by the freshwater cadmium criteria. According to EPA's cadmium criteria document (USEPA 2016), however, "*A relatively large number of tests from acceptable studies of aquatic algae and vascular plants*...indicates*…the relative sensitivity of fresh and estuarine/marine algae and plants to cadmium (Appendix E and Appendix F) is less than aquatic vertebrates and invertebrates so plant criteria are not developed*." Therefore, approval of the acute and chronic freshwater cadmium water quality standard is Not Likely to Adversely Affect (NLAA) the Virginia sneezeweed, swamp pink, Eastern prairie fringed orchid, harperella, and Northeastern bullrush through direct and indirect effects.

3.12 Aquatic/Semi-Aquatic Plants: Estuarine/Marine

- Sensitive joint-vetch (*Aeschynomene virginica*)

The sensitive joint-vetch is the only listed semi-aquatic plant to occur in Virginia estuarine/marine waters and may be exposed to cadmium at acute and chronic magnitudes and durations specified by the estuarine/marine cadmium criteria. According to EPA's cadmium criteria document (USEPA 2016), however, "*A relatively large number of tests from acceptable studies of aquatic algae and vascular plants*...indicates*…the relative sensitivity of fresh and estuarine/marine algae and plants to cadmium (Appendix E and Appendix F) is less than aquatic vertebrates and invertebrates so plant criteria are not developed*." Therefore, approval of the acute and chronic estuarine/marine cadmium estuarine/marine water quality standard is Not Likely to Adversely Affect (NLAA) the sensitive joint vetch through direct and indirect effects.

3.13 Bats: Northern Long-Eared Bat (*Myotis septentrionalis*), Gray Bat (*Myotis grisescens*), and Indiana Bat (*Myotis sodalist*)

3.13.1 Bat Cadmium Indirect Effects Assessment: Freshwater

The northern long-eared, gray, and Indiana bats will not be meaningfully exposed to cadmium through direct exposure. As a result, EPA's approval action will have no direct effect on the bats. All three listed bats, however, rely on emergent aquatic insects as a dietary resource and may be indirectly affected if cadmium, at water column concentrations specified by the freshwater acute

or chronic criteria magnitude and duration, were to adversely affect a large portion of emergent aquatic insects. However, aquatic life criteria are based on the fifth centile of sensitive genera to ensure the broad aquatic community, including emerging aquatic insects, are adequately protected. Northern long-eared bats feed on butterflies, moths, flies, leafhoppers, beetles, and emerging aquatic stoneflies (USFWS 2015b), while gray and Indiana bats eat a variety of flying aquatic and terrestrial insects present along rivers or lakes (USFWS 1997, 2006). Aquatic insects ranked among the most tolerant taxa to acute cadmium exposures (Table 3-20). Chronic toxicity data with emerging aquatic insects were relatively limited; however, a midge ranked fourth most sensitive to chronic exposures (*Chironomus* GMCV = 2.0 µg/L total cadmium, normalized to hardness of 100 mg/L). The midge GMCV is greater than the corresponding chronic criterion magnitude and a large portion of individuals (i.e., < 20%) are not anticipated to be affected if cadmium concentrations were hypothetically at the chronic criteria magnitude indefinitely in Virginia freshwaters (which is not the intent of the action). Further, the midge chronic toxicity value was based on exposure durations that were significantly longer than the 4-day chronic criterion duration.

In addition to emerging aquatic insects, all three bats, but the northern long-eared bat in particular, also rely on terrestrial insects as a food source. Therefore, the effect of eliminating a large portion of emerging aquatic insects (which is not the anticipated effect of action) would likely translate minimally to the gray and Indiana bats, and insignificantly to the northern long-eared bat given the available land-based food resources. Because criteria are derived to protect the broad aquatic community (including emergent insects), and northern long-eared, gray, and Indiana bats do not rely exclusively on aquatic food resources, EPA approval of Virginia acute and chronic freshwater cadmium standards is Not Likely to Adversely Affect (NLAA) the northern long-eared, gray, and Indiana bats through indirect effects.

Table 3-20. Acute insect toxicity data used to derive the acute freshwater cadmium criterion. Note, 75 GMAVs were available to derive the acute criterion, with insects ranking among the least sensitive taxa.

Genus	Genus Mean Acute Value (µg/L)[a]	Genus Rank in SSD
Chironomus (midge)	49,052	75
Rhithrogena (mayfly)	22,138	71
Sweltsa (stonefly)	>20,132	70
Hexagenia (mayfly)	7,798	63
Ephemerella (mayfly)	4,467	53
Arctopsyche (caddisfly)	>1,637	45
Baetis (mayfly)	350.4	32

[a] Normalized to a hardness of 100 mg/L, expressed as total cadmium.

3.14 Piping Plover (*Charadrius melodus melodus*)

3.14.1 Piping Plover Cadmium Indirect Effects Assessment: Freshwater and Estuarine/Marine

The piping plover (Atlantic Coast population) will not be meaningfully exposed to cadmium through direct exposure. As a result, EPA's approval action will have no direct effect on the piping plover. However, the piping plover relies on freshwater and estuarine/marine invertebrates as its prey base and may be indirectly affected if cadmium, at water column concentrations specified by the acute and chronic criteria magnitudes and durations, were to adversely affect a large portion of the prey items.

Piping plovers feed in many habitat types within their breeding and wintering areas, including wet sand in the wash zone, inter-tidal ocean beach, wrack lines, washover passes, mud, sand and algal flats, and shorelines of streams, ephemeral ponds, lagoons, and salt marshes (USFWS 1996). Piping plovers feed primarily on invertebrates that are 1/2 inch or less below the surface on exposed beach surfaces. They feed mostly during the day and eat insects, marine worms, crustaceans, and mollusks as well as eggs and larvae of flies and beetles (USFWS 1996). Where piping plovers forage depends on what habitats are available to them, the amount of prey, proximity of foraging areas to nest sites, and the amount of human disturbance.

Only fish are among the most sensitive taxa to acute cadmium exposures in freshwaters with invertebrates, including piping plover prey items, being more tolerant. The freshwater chronic cadmium criterion and saltwater acute and chronic cadmium criteria include benthic (*Hyalella*, freshwater chronic criterion) and pelagic crustaceans (*Neomysis*, *Tigriopus*, *Americamysis*; saltwater acute and chronic criteria) and at least one aquatic insect (*Chironomus*, freshwater chronic criterion) among the most sensitive taxa to cadmium exposure. Effects to these sensitive crustacean and aquatic insect populations, however, are expected to be minimal because criteria are derived to protect the fifth centile of the most sensitive genera. Further, any effects to these piping plover prey items would translate minimally to the piping plover because piping plovers do not rely exclusively on these species as a food source, with additional food sources [e.g., other insects (including terrestrial), benthic worms, and mollusk populations] remaining tolerant to cadmium exposures (USEPA 2016). As a result, EPA approval of Virginia acute and chronic freshwater and saltwater cadmium standards is Not Likely to Adversely Affect (NLAA) piping plover through indirect effects.

3.15 Roseate Tern (*Sterna dougallii dougallii*)

3.15.1 Roseate Tern Cadmium Indirect Effects Assessment: Estuarine/Marine

The roseate tern will not be meaningfully exposed to cadmium through direct exposure. As a result, EPA's approval action will have no effect on the least tern directly. However, the roseate tern relies on marine fishes as a primary dietary resource and may be indirectly affected if

cadmium, at water column concentrations specified by the cadmium criteria magnitudes and durations, were to adversely affect a large portion of the saltwater fishes the roseate tern commonly relies on as a dietary resource.

Roseate terns feed on a variety of small schooling marine fish species such as young mackerel, Atlantic silversides (*Menidia menidia*), sardines (*Sardinella* sp.), usually when predatory species chase prey fish near the sea surface (USFWS 2010). Studies of chick provisioning by roseate terns in the Northeast population indicate that the predominant prey species in the diet were American sand lance (*Ammodytes americanus*), hake spp., and Atlantic herring (*Clupea harengus*). The majority of estuarine/marine fish are insensitive acute cadmium exposure, with the *Morone* GMAV (GMAV = 75 µg/L; genus rank in SSD = 5) the most sensitive marine fish to acute cadmium exposures (Table 3-21).

Table 3-21. Acute toxicity data for Atlantic coast estuarine/marine fishes used to derive the estuarine/marine acute cadmium criterion. Note, 79 GMAVs were available to derive the acute criterion.

Genus	Genus Mean Acute Value (µg/L)	Genus Rank in SSD
Cyprinodon	28,196	75
Tautogolabrus	25,900	74
Fundulus	19,550	70
Pseudopleuronectes	14,297	68
Mugil	9,217	61
Menidia	1,054	33
Lagodon	1,000	31
Morone	75.0	5

Given the tolerance of most marine fish to cadmium exposure, it is not likely that roseate tern will experience any appreciable indirect effects of cadmium *in situ.* EPA approval of the Virginia acute and chronic estuarine/marine cadmium standards is Not Likely to Adversely Affect (NLAA) the roseate tern through indirect effects.

3.16 Red Knot (*Calidris canutus rufa*)

3.16.1 Red Knot Cadmium Indirect Effects Assessment: Freshwater and Estuarine/Marine

The red knot will not be meaningfully exposed to cadmium through direct exposure. As a result, EPA's approval action will have no direct effect on the red knot. However, the red knot relies on estuarine/marine invertebrates as its prey base and may be indirectly affected if cadmium, at

water column concentrations specified by the acute and chronic criteria magnitudes and durations, were to adversely affect a large portion of the prey items.

Red knot occurrence in Virginia is limited as the birds migrate long distances from south to north every spring and repeat the trip in reverse every autumn (USFWS 2013a). During migration, red knot converge on critical stopover areas to rest. For much of the year red knots eat small clams, mussels, snails and other invertebrates. In spring, migrating knots appear to follow a northward "wave" in quality prey and time their stopovers with the spawning seasons of readily digestible food resources like juvenile clams and mussels and horseshoe crab eggs.

Estuarine and marine mussels, clams and crabs are not among the most sensitive taxa to cadmium exposure (Table 3-22; USEPA 2016), and because criteria are derived to protect the broad aquatic community (including marine mollusks and crustaceans), EPA approval of Virginia acute and chronic freshwater and saltwater cadmium standards is Not Likely to Adversely Affect (NLAA) red knot through indirect effects.

Table 3-22. Acute toxicity data for estuarine/marine mussels and clams used to derive the estuarine/marine acute cadmium criterion. Note, 79 GMAVs were available to derive the acute criterion.

Genus	Genus Mean Acute Value (µg/L)	Genus Rank in SSD
Perna (mussel sp.)	1,506	38
Mytilus (mussel sp.)	736.2	25
Isognomon (oyster sp.)	422.6	19
Tresus (clam sp.)	188.1	10
Crassostrea (oyster sp.)	173.2	9

4 Final Effects Determinations

Many of the aquatic listed animal and plants occurring in Virginia freshwaters are insensitive to acute and chronic freshwater ammonia and cadmium exposures at the respective criteria magnitudes under conservative exposure conditions. For those aquatic species that are relatively sensitive to acute and/or chronic freshwater ammonia and cadmium exposures, aquatic life criteria are implemented conservatively and are based on the fifth centile of sensitive genera and will, therefore, protect listed species and the broader aquatic community, including prey items. As a result, approval of the acute and chronic ammonia (freshwater) and cadmium (freshwater and estuarine/marine) criteria as Virginia state water quality standards is Not Likely to Adversely Affect (NLAA) aquatic and aquatic-dependent listed species through direct and indirect effects (Table 4-1).

Table 4-1. Final effect determinations for aquatic and aquatic-dependent listed species occurring in Virginia that may be affected by the approval action. Final effects determinations for listed species were based on direct and/or indirect effects, depending on exposure potential.

Species	Final Effects Determination
Dwarf wedgemussel, (*Alasmidonta heterodon*)	***NLAA*** (direct and indirect effects)
Fanshell, (*Cyprogenia stegaria*)	***NLAA*** (direct and indirect effects)
Dromedary pearlymussel, (*Dromus dromas*)	***NLAA*** (direct and indirect effects)
Yellow Lance, (*Elliptio lanceolata*)	***NLAA*** (direct and indirect effects)
Cumberlandian combshell, (*Epioblasma brevidens*)	***NLAA*** (direct and indirect effects)
Oyster mussel, (*Epioblasma capsaeformis*)	***NLAA*** (direct and indirect effects)
Tan Riffleshell, (*Epioblasma walker*i)	***NLAA*** (direct and indirect effects)
Green-Blossom pearly mussel, (*Epioblasma torulosa gubernaculum*)	***NLAA*** (direct and indirect effects)
Snuffbox mussel, (*Epioblasma triquetra*)	***NLAA*** (direct and indirect effects)
Shiny pigtoe, (*Fusconaia cor*)	***NLAA*** (direct and indirect effects)
Finerayed pigtoe, (*Fusconaia cuneolus*)	***NLAA*** (direct and indirect effects)
Cracking pearlymussel, (*Hemistena lata*)	***NLAA*** (direct and indirect effects)
Pink mucket, (*Lampsilis abrupta*)	***NLAA*** (direct and indirect effects)
Birdwing pearlymussel, (*Lemiox rimosus*)	***NLAA*** (direct and indirect effects)
Littlewing pearlymussel, (*Pegias fabula*)	***NLAA*** (direct and indirect effects)

Species	Final Effects Determination
Sheepnose mussel, (*Plethobasus cyphyus*)	***NLAA*** (direct and indirect effects)
James spinymussel, (Pleurobema collina)	***NLAA*** (direct and indirect effects)
Rough pigtoe, (*Pleurobema plenum*)	***NLAA*** (direct and indirect effects)
Slabside pearlymussel, (*Pleuronaia dolabelloides*)	***NLAA*** (direct and indirect effects)
Fluted kidneyshell, (*Ptychobranchus subtentum*)	***NLAA*** (direct and indirect effects)
Rough rabbitsfoot, (*Quadrula cylindrica strigillata*)	***NLAA*** (direct and indirect effects)
Cumberland monkeyface, (*Theliderma intermedia*)	***NLAA*** (direct and indirect effects)
Appalachian monkeyface, (*Theliderma spars*)	***NLAA*** (direct and indirect effects)
Purple bean, (*Villosa perpurpurea*)	***NLAA*** (direct and indirect effects)
Cumberland bean, (*Villosa trabalis*)	***NLAA*** (direct and indirect effects)
Spectaclecase mussel, (*Cumberlandia monodonta*)	***NLAA*** (direct and indirect effects)
Madison cave Isopod, (*Antrolana lira*)	***NLAA*** (direct and indirect effects)
Lee County cave Isopod, (*Lirceus usdagalun*)	***NLAA*** (direct and indirect effects)
Big Sandy crayfish, (*Cambarus veteranus*)	***NLAA*** (direct and indirect effects)
Spotfin chub, (*Erimonax monachus*)	***NLAA*** (direct and indirect effects)
Slender chub, (*Erimystax cahni*)	***NLAA*** (direct and indirect effects)
Blackside dace, (*Chrosomus cumberlandensis*)	***NLAA*** (direct and indirect effects)

Species	Final Effects Determination
Yellowfin madtom, (*Noturus flavipinnis*)	***NLAA*** (direct and indirect effects)
Roanoke logperch, (*Percina rex*)	***NLAA*** (direct and indirect effects)
Candy darter, (*Etheostoma osburni*)	***NLAA*** (direct and indirect effects)
Duskytail carter, (*Etheostoma percnurum*)	***NLAA*** (direct and indirect effects)
Sensitive joint-vetch, (*Aeschynomene virginica*)	***NLAA*** (direct and indirect effects)
Virginia sneezeweed, (*Helenium virginicum*)	***NLAA*** (direct and indirect effects)
Swamp pink, (*Helonias bullata*)	***NLAA*** (direct and indirect effects)
Eastern prairie fringed orchid, (*Platanthera leucophaea*)	***NLAA*** (direct and indirect effects)
Harperella, (*Ptilimnium nodosum*)	***NLAA*** (direct and indirect effects)
Northeastern bulrush, (*Scirpus ancistrochaetus*)	***NLAA*** (direct and indirect effects)
Northern long-eared bat, (*Myotis septentrionalis*)	***NLAA*** (indirect effects only; direct effects = No Effect)
Gray Bat, (*Myotis grisescens*)	***NLAA*** (indirect effects only; direct effects = No Effect)
Indiana Bat, (*Myotis sodalist*)	***NLAA*** (indirect effects only; direct effects = No Effect)
Roseate Tern, (*Sterna dougallii dougallii*)	***NLAA*** (indirect effects only; direct effects = No Effect)
Piping Plover, (*Charadrius melodus*)	***NLAA*** (indirect effects only; direct effects = No Effect)
Red knot, (*Calidris canutus rufa*)	***NLAA*** (indirect effects only; direct effects = No Effect)

5 Critical Habitat: Effects Assessment and Final Critical Habitat Effects Determinations (Freshwater Ammonia and Cadmium: Acute and Chronic Criteria)

5.1 Spotfin Chub (*Erimonax monachus*) Critical Habitat

The spotfin chub was listed as a threatened species under Federal ESA in 1977 (42 FR 45526). Concurrent with that listing, the following critical habitat was designated in Virginia (Scott and Washington Counties): "*North Fork Holston River, main channel from the Virginia-Tennessee state line upstream through Scott and Washington Counties*" (USFWS 1983a). The critical habitat designation for spotfin chub does not include a description of primary constituent elements (PCEs) which USFWS considers to be the elements of physical and biological features (PBFs) that provide for a species' life-history processes and are essential to the conservation of the species. Instead, the recovery plan for spotfin chub (USFWS 1983a) provides descriptions of its ecology and life history, as well as a summary of reasons for the decline and continued threats to its existence taken from Jenkins and Burkhead (1984).

Broadly, spotfin chub habitat requirements have been observed to include slow to swift current over sand, gravel, rubble, boulder or bedrock substrates with little siltation in streams that range from 15-60 m in width and 0.3 – 1.90 m in depth (USFWS 1983a). Water temperature in summer habitat usually reaches greater than 20°C and submerged macrophytes are usually absent but occasionally common (USFWS 1983a). Reasons for decline and identified threats to continued existence in the North Fork Holston River system include direct impacts from siltation and/or sedimentation, pollution (inorganic and/or organic), and localized collecting (Jenkins and Burkheard 1984). Former spotfin chub populations in the lower North Fork Holston River "*…have either been extirpated by pollution moving downstream from Saltville [VA] or isolated in extant areas (possibly near tributary refugia), and are restricted from dispersion farther downstream by further pollution in the Kingsport [TN] area or by impoundment below Kingsport*" (USFWS 1983a). Furthermore, localized seining in the North Fork Holston River sharply depleted populations at that time, and natural factors such as temperature and stream size probably limited some populations (USFWS 1983a).

The spotfin chub is not likely to be adversely affected by direct ammonia or cadmium effects (see assessment of direct effects), ensuring the acute and chronic ammonia and cadmium criteria will provide adequate water quality, protecting both the species and its critical habitat. Furthermore, the acute and chronic ammonia and cadmium criteria are expected to protect spotfin chub food resources, ensuring spotfin chub are not likely to be adversely affected through indirect ammonia and cadmium effects (see assessment of indirect effects). As a result, approval of the acute and chronic ammonia and cadmium water quality criteria as Virginia state standards is Not Likely to Adversely Modify spotfin chub critical habitats and is expected to aid in the conservation role of critical habitat.

5.2 Slender Chub (*Slender chub*) Critical Habitat

The slender chub was listed as a threatened species in 1977 (42 FR 45526). Concurrent with that listing, the following critical habitat was designated in Virginia (Lee and Scott Counties): Powell River, main channel from the Tennessee-Virginia State line upstream through Lee County, and Clinch River, main channel from the Tennessee-Virginia State line upstream through Scott County (USFWS 1983b). The critical habitat designation for slender chub does not include a description of PCEs or PBFs. The most recent 5-year review of the slender chub recovery (USFWS 2014), however, describes the ecology and life history. In the 5-year review, USFWS cite Jenkins and Burkhead (1994) who describe the slender chub's specialized habitat as "*…clean swept, relatively loose, pea-sized gravel in moderate runs where water depth is 0.2 to 0.4 meters*." Unlike many minnows, larval and juvenile slender chubs are also thought to be strongly benthic and vulnerable to benthic habitat degradation (USFWS 2014). The slender chub's requirement for clean-swept gravel areas for feeding and breeding would be "*affected by sedimentation of fines (silts, clays, and coal washings), especially during low water from episodic droughts, when sediment might concentrate in these areas or not be flushed out, or when these areas could become eutrophic"* (USFWS 2014).

The slender chub is not likely to be adversely affected by direct ammonia or cadmium effects (see assessment of direct effects), ensuring the acute and chronic ammonia and cadmium criteria will provide adequate water quality, protecting both the species and its critical habitat. Furthermore, the acute and chronic ammonia and cadmium criteria are expected to adequately protect slender chub food resources, ensuring the fish are also not likely to be adversely affected through indirect ammonia and cadmium effects (see assessment of indirect effects). As a result, approval of the acute and chronic ammonia and cadmium water quality criteria as Virginia state standards is Not Likely to Adversely Modify slender chub critical habitats and is expected to aid in the conservation role of critical habitat.

5.3 Yellowfin Madtom (*Noturus flavipinnis*) Critical Habitat

The yellowfin madtom was listed as a threatened species in 1977 (42 FR 45526). Concurrent with that listing, the following critical habitat was designated in Virginia (Lee, Scott and Russel Counties): Powell River, main channel from the Virginia-Tennessee State line upstream through Lee County; Copper Creek, main channel from its junction with Clinch River upstream (USFWS 1983c). The critical habitat designation for yellowfin madtom does not include a description of PCEs or PBFs. The recovery plan for yellowfin madtom (USFWS 1983c) provides a description of ecology and life history. The recovery plan cites Jenkins (1975) as reporting the yellowfin "*occupies small -to-medium size (8 to 40 meters wide) warm streams with moderate current and prefer clean water with little siltation"* (USFWS 1983c). Jenkins further stated that nearly all specimens were taken from quiet sections of pools or backwaters.

Observations of yellowfin and smoky madtom reported in the most recently available 5-year review (USFWS 2012) are consistent with critical habitat designated in the original recovery plan. Specifically, the USFWS 5-year review cites Dinkins and Shute (1996) who found

yellowfin madtoms in shallow pools with gravel, pebble, boulders, and bedrock. The authors noted adults and young may prefer different water temperatures, with young being more active at cooler temperatures than adults. In addition, juveniles and some adults can be found in shallow water over clean fine substrates with gentle stream flow following the first leaf fall (Rakes and Shute 2003, as reported in USWFW 2012).

In 1983, the yellowfin madtom was only observed in relatively small reaches of Citico Creek, Powell River, and Copper Creek. As part of the 5-yr review, the range spans over 40 river kilometers (rkm; 25 river miles [RM]) in the Powell River, 6 km (3.7 RM) in Citico Creek, and 62 rkm (39 RM) of Copper Creek (USFWS 2012). Furthermore, the yellowfin madtom has been successfully reintroduced into at least 8 rkm (5 RM) of Abrams Creek, and is now being introduced into the Tellico River. In addition, the species has been rediscovered in the upper Clinch River and now occupies 45 rkm (28 RM). As indicated in the recovery plans (USFWS 1983c), coal mining, logging, road and bridge construction and maintenance, toxic chemical spills, and siltation were identified, and continue to remain, as threats to the yellowfin madtom. In particular, activities that contribute sediment discharges into a stream system change the erosion or sedimentation pattern, which can lead to the destruction of riparian vegetation, bank collapse, excessive instream sediment deposition, and increased water turbidity and temperatures.

The yellowfin madtom is not likely to be adversely affected by direct ammonia or cadmium effects (see assessment of direct effects), ensuring the acute and chronic ammonia and cadmium criteria will provide adequate water quality, protecting both the species and its critical habitat. Furthermore, the acute and chronic ammonia and cadmium criteria are expected to protect yellowfin madtom food resources, ensuring the yellowfin madtom are also not likely to be adversely affected through indirect ammonia and cadmium effects (see assessment of indirect effects). As a result, approval of the acute and chronic ammonia and cadmium water quality criteria as Virginia state standards is Not Likely to Adversely Modify yellowfin madtom critical habitats and is expected to aid in the conservation role of critical habitat.

5.4 Oyster Mussel (*Epioblasma capsaeformis*), Cumberlandian Combshell (*Epioblasma brevidens*), Purple Bean (*Villosa perpurpurea*), and Rough Rabbitsfoot (*Quadrula cylindrica strigillata*) Critical Habitat

The oyster mussel (*Epioblasma capsaeformis*), Cumberlandian combshell (*Epioblasma brevidens*), purple bean (*Villosa perpurpurea*), and rough rabbitsfoot (*Quadrula cylindrica strigillata*) are all species listed as endangered under the ESA (USFWS 2004). Critical habitat within Virginia is designated for all four mussel species in the Tennessee and Cumberland River basins. Critical habitat within individual counties is listed as follows: Lee County - Powell River, main channel from the Tennessee-Virginia State line upstream to the vicinity of Rock Island, near Pugh (river mile 159); Tazewell County - Clinch River, main channel from the Tennessee-Virginia State line upstream to its confluence with Indian Creek in Cedar Bluff, and Indian Creek, main channel from its confluence with the Clinch River upstream to the fourth Norfolk-

Southern Railroad crossing at Van Dyke; Scott County - Copper Creek, main channel from its confluence with the Clinch River upstream to Virginia State Route 72. PCEs for the four species are included in the final rule of the critical habitat designation report (USFWS 2004).

The oyster mussel, Cumberlandian combshell, purple bean, and rough rabbitsfoot are all bivalve mussels in the family Unionidae. Unionid mussels, in general, live embedded in the bottom (mud, sand, gravel, cobble/boulder substrates) of rivers, streams, and other bodies of water. These mussels siphon water into their shells and across gills that are specialized for respiration. Mussel diets include detritus (organic decomposed debris), diatoms, phytoplankton, zooplankton, and other microorganisms (i.e. bacteria and algae). On the basis of the best available information, USFWS (2004) includes the following as PCEs essential for the conservation of the four mussels: "*Permanent, flowing stream reaches with a flow regime…necessary for normal behavior, growth, and survival of all life stages of the…mussels and their host fish; geomorphically stable stream and river channels and banks (structurally stable stream cross section); stable substrates, consisting of mud, sand, gravel, and/or cobble/ boulder, with low amounts of fine sediments or attached filamentous algae; water quality (including temperature, turbidity, oxygen content, and other characteristics) necessary for the normal behavior, growth, and survival of all life stages of the…mussels and their host fish;* and, *fish hosts with adequate living, foraging, and spawning areas for them.*" The oyster mussel, Cumberlandian combshell, purple bean, and rough rabbitsfoot are not likely to be adversely affected by direct ammonia and cadmium effects (see assessment of direct effects), ensuring the acute and chronic ammonia and cadmium criteria will provide adequate water quality, protecting both the species and critical habitat. Furthermore, the acute and chronic ammonia and cadmium criteria are expected to adequately protect mussel food resources and fish hosts, ensuring the oyster mussel, Cumberlandian combshell, purple bean, and rough rabbitsfoot are also not likely to be adversely affected through indirect ammonia or cadmium effects (see assessment of indirect effects). As a result, approval of the acute and chronic water quality criteria as Virginia state standards is Not Likely to Adversely Modify oyster mussel, Cumberlandian combshell, purple bean, and rough rabbitsfoot habitats and is expected to aid in the conservation role of critical habitat.

5.5 Slabside Pearlymussel (*Pleuronaia dolabelloides*) and Fluted Kidneyshell (*Ptychobranchus subtentum*) Critical Habitat

The slabside pearlymussel (*Pleuronaia dolabelloides*) and fluted kidneyshell (*Ptychobranchus subtentum*) are also listed as endangered under the ESA. Critical habitat is designated for the two mussel species in the Tennessee and Cumberland River basins in Virginia (Bland, Lee, Russell, Scott, Smyth, Tazewell, Washington, and Wythe Counties: various portions of Indian Creek, Little River, North and Middle Fork Holston River, Big Moccasin Creek, Copper Creek, and Clinch and Powell Rivers; USFWS 2013b). PCEs for the two species were published under the same designation which outlines the same habitat requirements for both species (USFWS 2013b). The slabside pearlymussel and fluted kidneyshell are bivalve mussels in the family Unionidae. USFWS considers the PCEs for the fluted kidneyshell and slabside pearlymussel to be: "r*iffle habitats within large, geomorphically stable stream channels; stable substrates of*

sand, gravel, and cobble with low to moderate amounts of fine sediment and containing flow refugia with low shear stress; a natural hydrologic flow regime necessary to maintain benthic habitats where the species are found, and connectivity of rivers with the floodplain, allowing the exchange of nutrients and sediment for habitat maintenance, food availability for all life stages, and spawning habitat for native fishes; water quality with low levels of pollutants and including a natural temperature regime, pH (between 6.0 to 8.5), oxygen content (not less than 5.0 milligrams per liter (mg/L)), hardness, and turbidity necessary for normal behavior, growth, and viability of all life stages; and, for *presence of abundant fish hosts necessary for recruitment…which may include* [for fluted kidneyshell]*: barcheek darter, fantail darter, rainbow darter, redline darter, bluebreast darter, dusky darter and banded sculpin*; [for slabside pearlymussel]: *popeye shiner, rosyface shiner, saffron shiner, silver shiner, telescope shiner, Tennessee shiner, whitetail shiner, white shiner, and eastern blacknose dace*."

The slabside pearlymussel and fluted kidneyshell are not likely to be adversely affected through direct ammonia and cadmium effects (see assessment of direct effects), ensuring the acute and chronic ammonia and cadmium criteria will provide adequate water quality, protecting both the species and critical habitat. Furthermore, the acute and chronic ammonia and cadmium criteria are expected to adequately protect mussel food resources and fish hosts, ensuring the slabside pearlymussel and fluted kidneyshell are also not likely to be adversely affected through indirect ammonia or cadmium effects (see assessment of indirect effects). As a result, approval of the acute and chronic water quality criteria as Virginia state standards is Not Likely to Adversely Modify slabside pearlymussel and fluted kidneyshell habitats and is expected to aid in the conservation role of critical habitat.

5.6 Indiana Bat (*Myotis sodalist*) Critical Habitat

The Indiana bat was listed as endangered under the Federal ESA in 1967 (USFWS 2009), but critical habitat was not designated for the Indiana bat until 1976 (USFWS 1976). Critical habitat for the Indiana bat includes precise localities of caves and mines on file with the USFWS. At the time, 94 percent of the known Indiana bat population was expected to hibernate at these sites. No caves or mines were identified in Virginia (USFWS 1975). The bats are entirely dependent on the shelter provided by these caves and mines during the winter. Their loss or subjection to excessive disturbance or modification would lead to the near or total extinction of the species. Riparian habitat is also believed to be essential to the bat for feeding and reproduction, but no PCEs have been provided to date.

Approval of the acute and chronic ammonia and cadmium criteria are expected to protect Indiana bat food resources, ensuring the bats are not likely to be adversely affected through indirect ammonia and cadmium effects (see assessment of indirect effects). As a result, approval of the acute and chronic ammonia and cadmium water quality criteria as Virginia state standards is Not Likely to Adversely Modify Indiana bat critical habitats and is expected to aid in the conservation role of critical habitat.

6 Conclusion

EPA views the ammonia and cadmium criteria revisions as beneficial to the conservation and protection of aquatic life, including listed species and their food sources in Virginia. EPA recognizes the need to revise its decision if this consultation identifies situations where the criteria may not be adequately protective of listed species populations. If this should be the case, EPA will coordinate with the FWS to determine a reasonable approach.

7 References[3]

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Attachment 1

United States Department of the Interior

FISH AND WILDLIFE SERVICE

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In Reply Refer To: February 13, 2018

Consultation Code: 05E2VA00-2018-SLI-0325

Event Code: 05E2VA00-2018-E-04130

Project Name: EPA Approval of Virginia CWA Aquatic Life Ammonia and Cadmium Criteria

Subject: Updated list of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed and candidate species, as well as proposed and final designated critical habitat, that may occur within the boundary of your proposed project and/or may be affected by your proposed project. The species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under section 7(c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 et seq.). Any activity proposed on National Wildlife Refuge lands must undergo a 'Compatibility Determination' conducted by the Refuge. Please contact the individual Refuges to discuss any questions or concerns.

New information based on updated surveys, changes in the abundance and distribution of species, changed habitat conditions, or other factors could change this list. Please feel free to contact us if you need more current information or assistance regarding the potential impacts to federally proposed, listed, and candidate species and federally designated and proposed critical habitat. Please note that under 50 CFR 402.12(e) of the regulations implementing section 7 of the Act, the accuracy of this species list should be verified after 90 days. This verification can be completed formally or informally as desired. The Service recommends that verification be completed by visiting the ECOS-IPaC website at regular intervals during project planning and implementation for updates to species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.

The purpose of the Act is to provide a means whereby threatened and endangered species and the ecosystems upon which they depend may be conserved. Under sections 7(a)(1) and 7(a)(2) of the Act and its implementing regulations (50 CFR 402 et seq.), Federal agencies are required to utilize their authorities to carry out programs for the conservation of threatened and endangered species and to determine whether projects may affect threatened and endangered species and/or designated critical habitat.

A Biological Assessment is required for construction projects (or other undertakings having similar physical impacts) that are major Federal actions significantly affecting the quality of the human environment as defined in the National Environmental Policy Act (42 U.S.C. 4332(2)(c)). For projects other than major construction activities, the Service suggests that a BE similar to a Biological Assessment be prepared to determine whether the project may affect listed or proposed species and/or designated or proposed critical habitat. Recommended contents of a Biological Assessment are described at 50 CFR 402.12.

If a Federal agency determines, based on the Biological Assessment or BE, that listed species and/or designated critical habitat may be affected by the proposed project, the agency is required to consult with the Service pursuant to 50 CFR 402. In addition, the Service recommends that candidate species, proposed species and proposed critical habitat be addressed within the consultation. More information on the regulations and procedures for section 7 consultation, including the role of permit or license applicants, can be found in the "Endangered Species Consultation Handbook" at: http://www.fws.gov/endangered/esa-library/pdf/TOC-GLOS.PDF

Please be aware that bald and golden eagles are protected under the Bald and Golden Eagle Protection Act (16 U.S.C. 668 et seq.), and projects affecting these species may require development of an eagle conservation plan (http://www.fws.gov/windenergy/eagle_guidance.html). Additionally, wind energy projects should follow the wind energy guidelines (http://www.fws.gov/windenergy/) for minimizing impacts to migratory birds and bats.

Guidance for minimizing impacts to migratory birds for projects including communications towers (e.g., cellular, digital television, radio, and emergency broadcast) can be found at: http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/towers.htm; http://www.towerkill.com; and http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/comtow.html.

We appreciate your concern for threatened and endangered species. The Service encourages Federal agencies to include conservation of threatened and endangered species into their project planning to further the purposes of the Act. Please include the Consultation Tracking Number in the header of this letter with any request for consultation or correspondence about your project that you submit to our office.

Attachment(s):

▪ Official Species List ▪ USFWS National Wildlife Refuges and Fish Hatcheries

Official Species List

This list is provided pursuant to Section 7 of the Endangered Species Act, and fulfills the requirement for Federal agencies to "request of the Secretary of the Interior information whether any species which is listed or proposed to be listed may be present in the area of a proposed action".

This species list is provided by:

Virginia Ecological Services Field Office

6669 Short Lane

Gloucester, VA 23061-4410

(804) 693-6694

Project Summary

Consultation Code: 05E2VA00-2018-SLI-0325

Event Code: 05E2VA00-2018-E-04130

Project Name: EPA Approval of Virginia CWA Aquatic Life Ammonia and Cadmium

Criteria

Project Type: ** OTHER **

Project Description: Triennial Review Remaining Issues - state wide criteria

Project Location:

Approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/place/38.00322615589129N78.22543405781167W

Counties: Accomack, VA | Albemarle, VA | Alexandria, VA | Alleghany, VA | Amelia, VA | Amherst, VA | Appomattox, VA | Arlington, VA | Augusta, VA | Bath, VA | Bedford, VA | Bedford, VA | Bland, VA | Botetourt, VA | Bristol, VA | Brunswick, VA | Buchanan, VA | Buckingham, VA | Buena Vista, VA | Campbell, VA | Caroline, VA | Carroll, VA | Charles City, VA | Charlotte, VA | Charlottesville, VA | Chesapeake, VA | Chesterfield, VA | Clarke, VA | Colonial Heights, VA | Covington, VA | Craig, VA | Culpeper, VA | Cumberland, VA | Danville, VA | Dickenson, VA | Dinwiddie, VA | Emporia, VA | Essex, VA | Fairfax, VA | Fairfax, VA | Falls Church, VA | Fauquier, VA | Floyd, VA | Fluvanna, VA | Franklin, VA | Franklin, VA | Frederick, VA | Fredericksburg, VA | Galax, VA | Giles, VA | Gloucester, VA | Goochland, VA | Grayson, VA | Greene, VA | Greensville, VA | Halifax, VA | Hampton, VA | Hanover, VA | Harrisonburg, VA | Henrico, VA | Henry, VA | Highland, VA | Hopewell, VA | Isle of Wight, VA | James City, VA | King George, VA | King William, VA | King and Queen, VA | Lancaster, VA | Lee, VA | Lexington, VA | Loudoun, VA | Louisa, VA | Lunenburg, VA | Lynchburg, VA | Madison, VA | Manassas, VA | Manassas Park, VA | Martinsville, VA | Mathews, VA | Mecklenburg, VA | Middlesex, VA | Montgomery, VA | Nelson, VA | New Kent, VA | Newport News, VA | Norfolk, VA | Northampton, VA | Northumberland, VA | Norton, VA | Nottoway, VA | Orange, VA | Page, VA |

Patrick, VA | Petersburg, VA | Pittsylvania, VA | Poquoson, VA | Portsmouth, VA |

Powhatan, VA | Prince Edward, VA | Prince George, VA | Prince William, VA |

Pulaski, VA | Radford, VA | Rappahannock, VA | Richmond, VA | Richmond, VA |

Roanoke, VA | Roanoke, VA | Rockbridge, VA | Rockingham, VA | Russell, VA |

Salem, VA | Scott, VA | Shenandoah, VA | Smyth, VA | Southampton, VA |

Spotsylvania, VA | Stafford, VA | Staunton, VA | Suffolk, VA | Surry, VA | Sussex, VA

| Tazewell, VA | Virginia Beach, VA | Warren, VA | Washington, VA | Waynesboro,

VA | Westmoreland, VA | Williamsburg, VA | Winchester, VA | Wise, VA | Wythe, VA | York, VA

Endangered Species Act Species

There is a total of 73 threatened, endangered, or candidate species on this species list. Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species. See the "Critical habitats" section below for those critical habitats that lie wholly or partially within your project area under this office's jurisdiction. Please contact the designated USFWS office if you have questions.

Mammals

NAME	STATUS
Carolina Northern Flying Squirrel Glaucomys sabrinus coloratus No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/2657	Endangered
Gray Bat Myotis grisescens No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/6329	Endangered
Indiana Bat Myotis sodalis There is final critical habitat for this species. Your location overlaps the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/5949	Endangered
Northern Long-eared Bat Myotis septentrionalis No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/9045	Threatened
Virginia Big-eared Bat Corynorhinus (=Plecotus) townsendii virginianus There is final critical habitat for this species. Your location is outside the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/8369	Endangered

Birds

Piping Plover Charadrius melodus Threatened
Population: [Atlantic Coast and Northern Great Plains populations] - Wherever found, except those areas where listed as endangered. There is final critical habitat for this species. Your location is outside the critical habitat.
Species profile: https://ecos.fws.gov/ecp/species/6039

Red Knot Calidris canutus rufa
Threatened

No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/1864

Red-cockaded Woodpecker Picoides borealis
Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/7614

Roseate Tern Sterna dougallii Endangered
Population: northeast U.S. nesting pop.
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/2083

Reptiles

Hawksbill Sea Turtle Eretmochelys imbricata Endangered
There is final critical habitat for this species. Your location is outside the critical habitat.
Species profile: https://ecos.fws.gov/ecp/species/3656

Kemp's Ridley Sea Turtle Lepidochelys kempii Endangered
There is proposed critical habitat for this species. The location of the critical habitat is not available.
Species profile: https://ecos.fws.gov/ecp/species/5523

Leatherback Sea Turtle Dermochelys coriacea Endangered
There is final critical habitat for this species. Your location is outside the critical habitat.
Species profile: https://ecos.fws.gov/ecp/species/1493

Loggerhead Sea Turtle Caretta caretta Threatened
Population: Northwest Atlantic Ocean DPS
There is final critical habitat for this species. Your location is outside the critical habitat.
Species profile: https://ecos.fws.gov/ecp/species/1110

Amphibians

Shenandoah Salamander Plethodon shenandoah Endangered
No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/4097

Fishes

Blackside Dace Phoxinus cumberlandensis Threatened

No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/4775

Proposed Threatened

Candy Darter Etheostoma osburni
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/1396

Endangered

Duskytail Darter Etheostoma percnurum
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/891

Endangered

Roanoke Logperch Percina rex
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/1134

Threatened

Slender Chub Erimystax cahni
There is final critical habitat for this species. Your location overlaps the critical habitat.
Species profile: https://ecos.fws.gov/ecp/species/6637

Threatened

Spotfin Chub Erimonax monachus
Population: Wherever found, except where listed as an experimental population
There is final critical habitat for this species. Your location overlaps the critical habitat.
Species profile: https://ecos.fws.gov/ecp/species/1521

Yellowfin Madtom Noturus flavipinnis Experimental
Population: U.S.A. (TN, VA-specified portions of the Holston River and watershed; see 17.84(e) Population,
(1)(i)) Non- Essential
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/8565

Yellowfin Madtom Noturus flavipinnis
Threatened
Population: Wherever found, except where listed as an experimental population
There is final critical habitat for this species. Your location overlaps the critical habitat.
Species profile: https://ecos.fws.gov/ecp/species/8565

Clams

Appalachian Monkeyface (pearlymussel) Quadrula sparsa — Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/7154

Birdwing Pearlymussel Lemiox rimosus — Endangered
Population: Wherever found; Except where listed as Experimental Populations
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/6636

Cracking Pearlymussel Hemistena lata — Endangered
Population: Wherever found; Except where listed as Experimental Populations
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/4130

Cumberland Bean (pearlymussel) Villosa trabalis — Endangered
Population: Wherever found; Except where listed as Experimental Populations
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/6061

Cumberland Monkeyface (pearlymussel) Quadrula intermedia — Endangered
Population: Wherever found; Except where listed as Experimental Populations
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/6999

Cumberlandian Combshell Epioblasma brevidens — Endangered
Population: Wherever found; Except where listed as Experimental Populations
There is final critical habitat for this species. Your location overlaps the critical habitat.
Species profile: https://ecos.fws.gov/ecp/species/3119

Dromedary Pearlymussel Dromus dromas — Endangered
Population: Wherever found; Except where listed as Experimental Populations
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/6377

Dwarf Wedgemussel Alasmidonta heterodon — Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/784

Fanshell Cyprogenia stegaria — Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/4822

Finerayed Pigtoe Fusconaia cuneolus — Endangered
Population: Wherever found; Except where listed as Experimental Populations
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/3038

Fluted Kidneyshell Ptychobranchus subtentum There is final critical habitat for this species. Your location overlaps the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/1397	Endangered
Green Blossom (pearlymussel) Epioblasma torulosa gubernaculum No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/2098	Endangered
James Spinymussel Pleurobema collina No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/2212	Endangered
Littlewing Pearlymussel Pegias fabula No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/2572	Endangered
Oyster Mussel Epioblasma capsaeformis Population: Wherever found; Except where listed as Experimental Populations There is final critical habitat for this species. Your location overlaps the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/2099	Endangered
Pink Mucket (pearlymussel) Lampsilis abrupta No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/7829	Endangered
Purple Bean Villosa perpurpurea There is final critical habitat for this species. Your location overlaps the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/4125	Endangered
Rough Pigtoe Pleurobema plenum No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/6894	Endangered
Rough Rabbitsfoot Quadrula cylindrica strigillata There is final critical habitat for this species. Your location overlaps the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/5629	Endangered
Sheepnose Mussel Plethobasus cyphyus No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/6903	Endangered

Shiny Pigtoe Fusconaia cor — Endangered
Population: Wherever found; Except where listed as Experimental Populations
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/2573

Slabside Pearlymussel Pleuronaia dolabelloides — Endangered
There is final critical habitat for this species. Your location overlaps the critical habitat.
Species profile: https://ecos.fws.gov/ecp/species/1518

Snuffbox Mussel Epioblasma triquetra — Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/4135

Spectaclecase (mussel) Cumberlandia monodonta — Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/7867

Tan Riffleshell Epioblasma florentina walkeri (=E. walkeri) — Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/1247

Yellow Lance Elliptio lanceolata — Proposed Threatened
No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/4511

Snails

Virginia Fringed Mountain Snail Polygyriscus virginianus
Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/6905

Insects

Mitchell's Satyr Butterfly Neonympha mitchellii mitchellii — Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/8062

Northeastern Beach Tiger Beetle Cicindela dorsalis dorsalis — Threatened
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/8105

Rusty Patched Bumble Bee Bombus affinis — Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/9383

Arachnids

Spruce-fir Moss Spider Microhexura montivaga
Endangered
There is final critical habitat for this species. Your location is outside the critical habitat.
Species profile: https://ecos.fws.gov/ecp/species/4801

Crustaceans

Big Sandy Crayfish Cambarus callainus Threatened
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/8285

Lee County Cave Isopod Lirceus usdagalun Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/1550

Madison Cave Isopod Antrolana lira Threatened
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/4162

Flowering Plants

Eastern Prairie Fringed Orchid Platanthera leucophaea Threatened
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/601

Harperella Ptilimnium nodosum Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/3739

Michaux's Sumac Rhus michauxii Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/5217

Northeastern Bulrush Scirpus ancistrochaetus Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/6715

Peter's Mountain Mallow Iliamna corei Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/860

Roan Mountain Bluet Hedyotis purpurea var. montana Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/1087

Seabeach Amaranth Amaranthus pumilus Threatened
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/8549

Sensitive Joint-vetch Aeschynomene virginica Threatened
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/855

Shale Barren Rock Cress Arabis serotina Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/6018

Small Whorled Pogonia Isotria medeoloides Threatened
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/1890

Small-anthered Bittercress Cardamine micranthera Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/3462

Smooth Coneflower Echinacea laevigata Endangered
No critical habitat has been designated for this species.

Species profile: https://ecos.fws.gov/ecp/species/3473
Swamp Pink Helonias bullata Threatened
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/4333

Virginia Round-leaf Birch Betula uber
Threatened
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/2736

Virginia Sneezeweed Helenium virginicum Threatened
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/6297

Virginia Spiraea Spiraea virginiana Threatened
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/1728

Lichens

Rock Gnome Lichen Gymnoderma lineare Endangered
No critical habitat has been designated for this species.
Species profile: https://ecos.fws.gov/ecp/species/3933

Critical habitats
There are 10 critical habitats wholly or partially within your project area under this office's jurisdiction.

Cumberlandian Combshell Epioblasma brevidens Final
https://ecos.fws.gov/ecp/species/3119#crithab

Fluted Kidneyshell Ptychobranchus subtentum Final
https://ecos.fws.gov/ecp/species/1397#crithab

Indiana Bat Myotis sodalis Final
https://ecos.fws.gov/ecp/species/5949#crithab

Oyster Mussel Epioblasma capsaeformis Final
https://ecos.fws.gov/ecp/species/2099#crithab

Purple Bean Villosa perpurpurea Final
https://ecos.fws.gov/ecp/species/4125#crithab

Rough Rabbitsfoot Quadrula cylindrica strigillata Final
https://ecos.fws.gov/ecp/species/5629#crithab

Slabside Pearlymussel Pleuronaia dolabelloides Final
https://ecos.fws.gov/ecp/species/1518#crithab

Slender Chub Erimystax cahni Final
https://ecos.fws.gov/ecp/species/6637#crithab

Spotfin Chub Erimonax monachus Final
https://ecos.fws.gov/ecp/species/1521#crithab

Yellowfin Madtom Noturus flavipinnis Final
https://ecos.fws.gov/ecp/species/8565#crithab

USFWS National Wildlife Refuge Lands And Fish Hatcheries

Any activity proposed on lands managed by the National Wildlife Refuge system must undergo a 'Compatibility Determination' conducted by the Refuge. Please contact the individual Refuges to discuss any questions or concerns.

The following USFWS National Wildlife Refuge Lands and Fish Hatcheries lie fully or partially within your project area:

FACILITY NAME	ACRES
Back Bay National Wildlife Refuge Back Bay National Wildlife Refuge 1324 Sandbridge Road Virginia Beach, VA 23456-4023 (757) 301-7329 https://www.fws.gov/refuges/profiles/index.cfm?id=51510	8,700
Chincoteague National Wildlife Refuge Chincoteague National Wildlife Refuge P.O. Box 62 Chincoteague Island, VA 23336-0062 (757) 336-6122 https://www.fws.gov/refuges/profiles/index.cfm?id=51570	21,000
Eastern Shore Of Virginia National Wildlife Refuge Eastern Shore Of Virginia National Wildlife Refuge 5003 Hallet Circle Cape Charles, VA 23310-1128 (757) 331-2760 https://www.fws.gov/refuges/profiles/index.cfm?id=51650	1,370
Featherstone National Wildlife Refuge Featherstone National Wildlife Refuge C/o Potomac River Nwr Complex 12638 Darby Brook Court Woodbridge, VA 22192 (703) 490-4979 https://www.fws.gov/refuges/profiles/index.cfm?id=51612	333
Fisherman Island National Wildlife Refuge Fisherman Island National Wildlife Refuge C/o Eastern Shore Of Virginia Nwr 5003 Hallet Circle Cape Charles, VA 23310-1128 (757) 331-2760 https://www.fws.gov/refuges/profiles/index.cfm?id=51651	2,180

86,000

Great Dismal Swamp National Wildlife Refuge
Great Dismal Swamp National Wildlife Refuge
3100 Desert Road
Suffolk, VA 23434-8973
(757) 986-3705 https://www.fws.gov/refuges/profiles/index.cfm?id=51580

4,240

James River National Wildlife Refuge
James River National Wildlife Refuge
C/o Eastern Virginia Rivers Nwr, Southern Division
11116 Kimages Road
Charles City, VA 23030-2844
(804) 829-9020 https://www.fws.gov/refuges/profiles/index.cfm?id=51621

903

Mackay Island National Wildlife Refuge
Mackay Island National Wildlife Refuge
Post Office Box 39

Knotts Island, NC 27950-0039
(252) 429-3100 https://www.fws.gov/refuges/profiles/index.cfm?id=41660

4,280

Martin National Wildlife Refuge
Martin National Wildlife Refuge
C/o Blackwater Nwr
2145 Key Wallace Drive
Cambridge, MD 21613-9536
(410) 425-4971
https://www.fws.gov/refuges/profiles/index.cfm?id=51540

Mason Neck National Wildlife Refuge 3,80
Mason Neck National Wildlife Refuge
C/o Potomac River Nwr Complex
12638 Darby Brooke Court

Woodbridge, VA 22192 (703) 490-4979
https://www.fws.gov/refuges/profiles/index.cfm?id=51610
Nansemond National Wildlife Refuge 424
Nansemond National Wildlife Refuge
C/o Great Dismal Swamp Nwr
3100 Desert Road
Suffolk, VA 23434-8973
(757) 986-3705 https://www.fws.gov/refuges/profiles/index.cfm?id=51581

634

Occoquan Bay National Wildlife Refuge
Occoquan Bay National Wildlife Refuge
C/o Potomac River Nwr Complex
12638 Darby Brook Court
Woodbridge, VA 22192 (703) 490-4979
https://www.fws.gov/refuges/profiles/index.cfm?id=51611

3,060

Plum Tree Island National Wildlife Refuge
Plum Tree Island National Wildlife Refuge
C/o Eastern Virginia Rivers Nwr, Southern Division
11116 Kimages Road
Charles City, VA 23030-2844
(804) 829-9020 https://www.fws.gov/refuges/profiles/index.cfm?id=51512

1,300

Presquile National Wildlife Refuge
Presquile National Wildlife Refuge
C/o Eastern Virginia Rivers Nwr, Southern Division
11116 Kimages Road
Charles City, VA 23030-2844
(804) 829-9020
https://www.fws.gov/refuges/profiles/index.cfm?id=51623

Rappahannock River Valley National Wildlife Refuge 10,300
Rappahannock River Valley National Wildlife Refuge
P.O. Box 1030
Warsaw, VA 22572-1030
(804) 333-1470 https://www.fws.gov/refuges/profiles/index.cfm?id=51622

Wallops Island National Wildlife Refuge 372
Wallops Island National Wildlife Refuge
C/o Chincoteague Nwr
P.O. Box 62
Chincoteague Island, VA 23336-0062
(757) 336-6122 https://www.fws.gov/refuges/profiles/index.cfm?id=51571

Harrison Lake National Fish Hatchery 400
11110 Kimages Road
Charles City, VA 23030-2844
(804) 829-2421

https://www.fws.gov/offices/Directory/OfficeDetail.cfm?OrgCode=51210

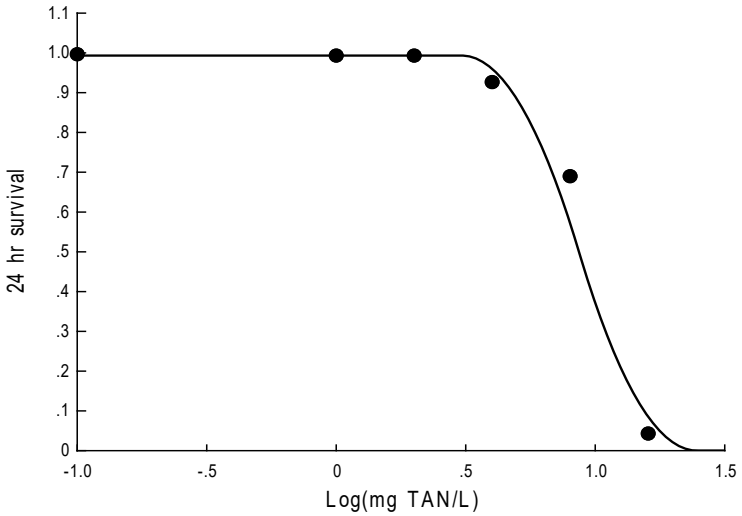
Appendix A

Test Information, C-R Data and Resulting TRAP models for Acute and Chronic Ammonia Toxicity Tests Considered Acceptable or Unacceptable for TAF and MAF Calculation

Appendix A.1

Test Information, C-R Data and Resulting TRAP models for Acute Ammonia Toxicity Tests Acceptable for TAF and MAF Calculation

Wang et al. 2007b	
Species: *Actinonaias ligamentina* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-2	
Test: #4 (May 2004)	
TAN, mg/L	**Proportion Surviving**
0.1	1.00
1	0.99
2	0.99
4	0.93
8	0.69
16	0.04

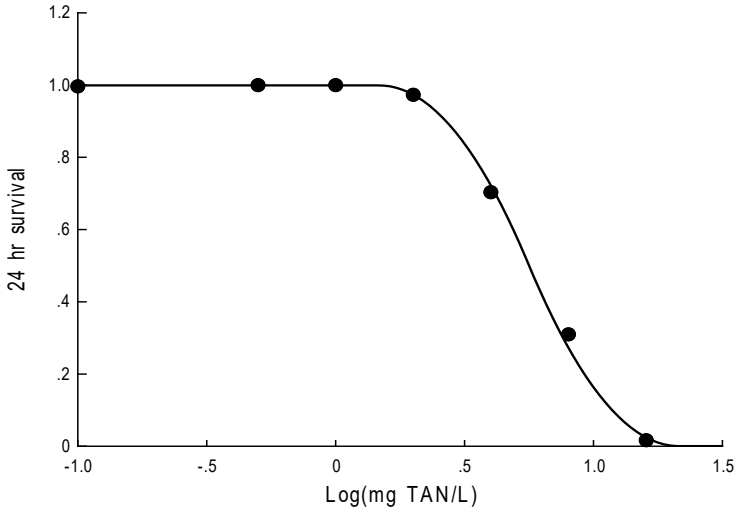


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	0.93857	0.009828	0.91925	0.9579
StDev	0.15	0.18521	0.008317	0.17024	0.20308
Y0	0.99	0.99306	0.002758	0.98521	0.99737
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**8.6811**	8.3032	9.0761	0.009828	0.93857
20	5.9133	5.5987	6.2456	0.012049	0.77183
10	4.873	4.5603	5.2071	0.014581	0.68779
5	**4.2498**	3.9383	4.5859	0.016693	0.62837
0	3.0543	2.7563	3.3845	0.022336	0.48491

LC50:LC5 = 2.043

Notes: Acceptable model fit.

Wang et al. 2007b	
Species: *Actinonaias ligamentina* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-3	
Test: #2 (repeat)	
TAN, mg/L	**Proportion Surviving**
0.1	1.00
0.5	1.00
1	1.00
2	0.97
4	0.70
8	0.31
16	0.02



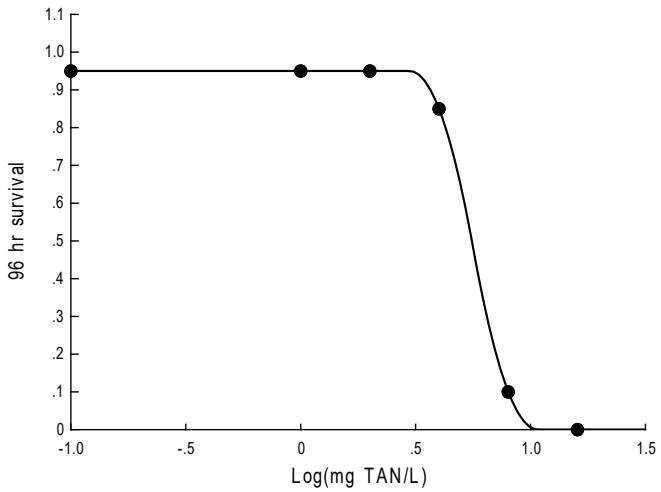
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.75	0.75079	1.09E-02	0.72933	0.77225
StDev	0.24	0.23728	8.23E-03	0.22218	0.2546
Y0	0.99	0.99888	1.11E-03	0.99382	0.99997

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**5.6337**	5.3621	5.9191	1.09E-02	0.75079
20	3.4449	3.2421	3.6602	1.34E-02	0.53717
10	2.6885	2.4997	2.8915	1.60E-02	0.42951
5	**2.2562**	2.0806	2.4466	1.78E-02	0.35338
0	1.4777	1.3299	1.6419	2.31E-02	0.16958

LC50:LC5 = 2.497

Notes: Acceptable model fit.

Wang et 2007b	
Species: *Epioblasma capsaeformis* (new juvenile)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-6	
Test: Single	
TAN, mg/L	**% Survival**
0.1	95
1	95
2	95
4	85
8	10
16	0



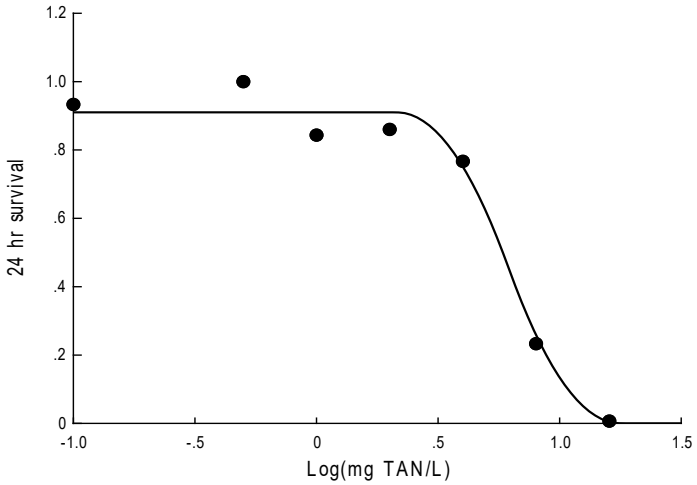
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.75	0.75255	0.034464	0.67656	0.82853
StDev	0.11	0.11353	0.025659	0.079324	0.19923
Y0	0.95	0.95	0.028137	0.86075	0.98957

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**5.6565**	4.7486	6.7379	0.034464	0.75255
20	4.4703	3.5024	5.7057	0.045464	0.65034
10	3.9703	2.9064	5.4236	0.053986	0.59882
5	**3.6509**	2.5026	5.326	0.060716	0.5624
0	2.9817	1.5767	5.6385	0.078497	0.47446

LC50:LC5 = 1.549

Notes: No errors.

Wang et al. 2007b	
Species: *Epioblasma capsaeformis* (glochidia)	
Test Endpoint: 6 hr Survival	
C-R Curve Label: Am-Acute-7	
Test: #1	
TAN, mg/L	**Proportion Surviving**
0.1	0.93
0.5	1.00
1	0.84
2	0.86
4	0.77
8	0.23
16	0.01



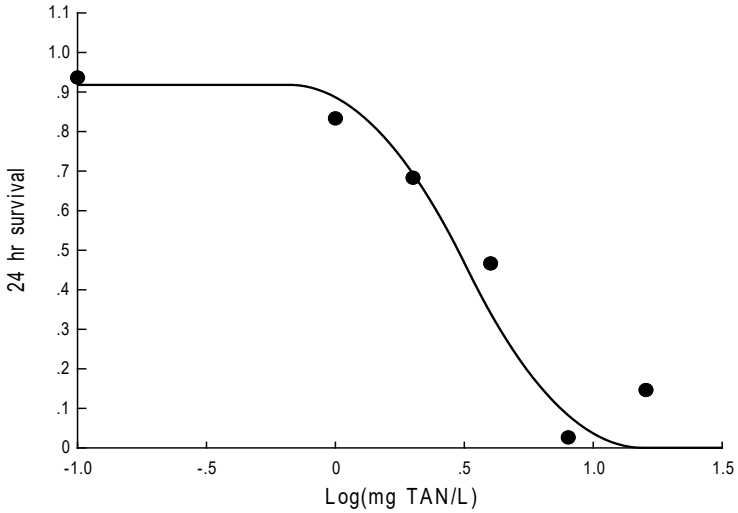
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.8	0.78992	0.013044	0.76421	0.81564
StDev	0.2	0.18742	0.009212	0.17098	0.2074
Y0	0.96667	0.90987	0.00825	0.89227	0.92543

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**6.1649**	5.8104	6.541	0.013044	0.78992
20	4.1801	3.8162	4.5787	0.020016	0.62119
10	3.4367	3.1033	3.806	0.022361	0.53614
5	**2.9923**	2.6691	3.3547	0.024973	0.47601
0	2.1421	1.8533	2.4758	0.031329	0.33083

LC50:LC5 = 2.060

Notes: Acceptable model fit. Acceptable noise at low level effects.

Wang et al. 2007b	
Species: *Epioblasma capsaeformis* (glochidia)	
Test Endpoint: 6 hr Survival	
C-R Curve Label: Am-Acute-8	
Test: #2	
TAN, mg/L	**Proportion Surviving**
0.1	0.94
1	0.83
2	0.68
4	0.47
8	0.03
16	0.15



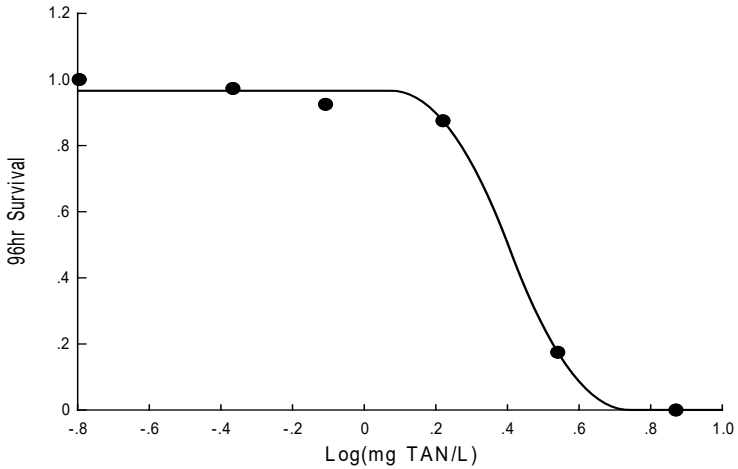
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.5	0.50716	0.018114	0.47148	0.54285
StDev	0.28	0.27994	0.017198	0.24991	0.31825
Y0	0.94	0.91793	0.014673	0.88407	0.94447

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**3.2149**	2.9613	3.4902	0.018114	0.50716
20	1.7994	1.5815	2.0474	0.028359	0.25513
10	1.3431	1.1433	1.5778	0.035207	0.12811
5	**1.0922**	0.90698	1.3152	0.040435	0.038292
0	0.6629	0.51582	0.85193	0.053785	-0.17855

LC50:LC5 = 2.944

Notes: Acceptable model fit.

Wang et al. 2007a	
Species: *Lampsilis abrupta* (2 month old)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-10	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.16	1.00
0.43	0.97
0.78	0.93
1.66	0.88
3.47	0.18
7.42	0



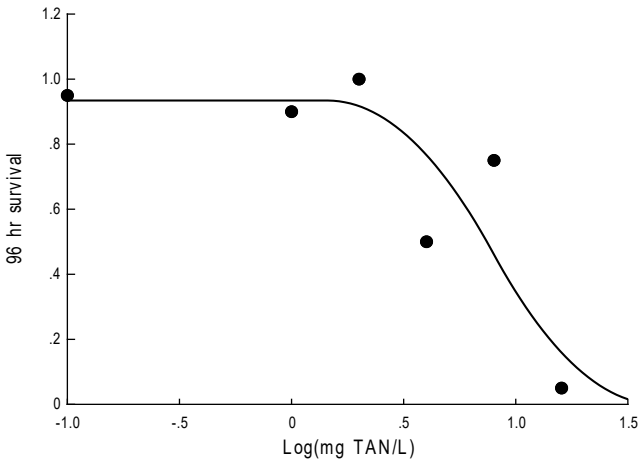
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.4	0.40814	0.02711	0.3523	0.46397
StDev	0.13	0.13554	0.023196	0.10176	0.20299
Y0	0.97	0.96581	0.0168	0.91478	0.99061

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**2.5594**	2.2506	2.9105	0.02711	0.40814
20	1.9324	1.6275	2.2946	0.035129	0.28611
10	1.6773	1.3506	2.0829	0.042577	0.2246
5	**1.5175**	1.1734	1.9623	0.048613	0.18112
0	1.1916	0.79606	1.7836	0.066543	0.076123

LC50:LC5 = 1.687

Notes: Acceptable model fit. Acceptable noise at low level effects.

Wang et al. 2007b	
Species: *Lampsilis fasciola* (<5 d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-12	
Test: Single	
TAN, mg/L	**Proportion Surviving**
0.1	0.95
1	0.90
2	1.00
4	0.50
8	0.75
16	0.05

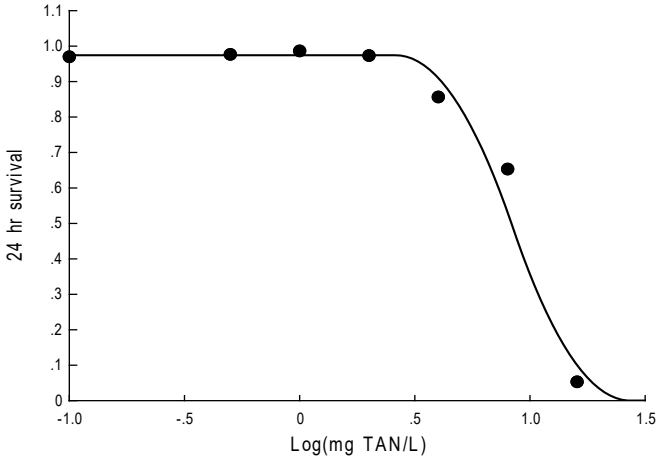


Log X50	0.85	0.89742	6.39E-02	0.76489	1.0299
StDev	0.125	0.30069	7.56E-02	0.2101	0.52769
Y0	0.95	0.93385	3.71E-02	0.81789	0.98629
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**7.8962**	5.8196	10.714	6.39E-02	0.89742
20	4.2336	2.5558	7.0128	0.10028	0.62671
10	3.0922	1.5358	6.2258	0.12962	0.49027
5	**2.4762**	1.0251	5.9816	0.15227	0.39379
0	1.4484	0.18444	11.374	0.27561	0.16088

LC50:LC5 = 3.189

Notes: Acceptable model fit. Acceptable noise at low level effects.

Wang et al. 2007b	
Species: *Lampsilis fasciola* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-13	
Test: #1	
TAN, mg/L	**Proportion Surviving**
0.1	0.97
0.5	0.98
1	0.99
2	0.97
4	0.86
8	0.65
16	0.05

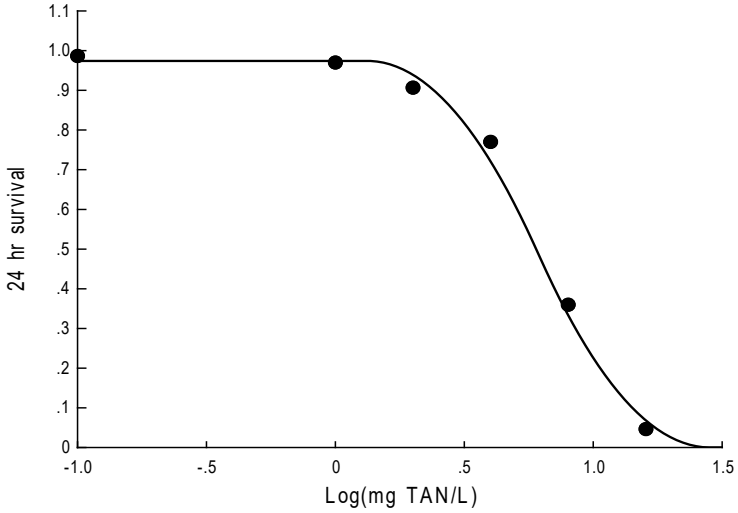


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.9	0.92607	0.011188	0.90406	0.94808
StDev	0.2	0.20774	0.010788	0.18858	0.23128
Y0	0.975	0.97421	0.004558	0.96363	0.98239
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**8.4347**	8.018	8.8731	0.011188	0.92607
20	5.4833	5.1181	5.8744	0.015175	0.73904
10	4.4134	4.0495	4.81	0.018886	0.64477
5	**3.7855**	3.4256	4.1832	0.021857	0.57812
0	2.6134	2.2794	2.9963	0.029602	0.4172

LC50:LC5 = 2.228

Notes: Acceptable model fit.

Wang et al. 2007b	
Species: *Lampsilis fasciola* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-14	
Test: #2	
TAN, mg/L	**Proportion Surviving**
0.1	0.99
1	0.97
2	0.91
4	0.77
8	0.36
16	0.05



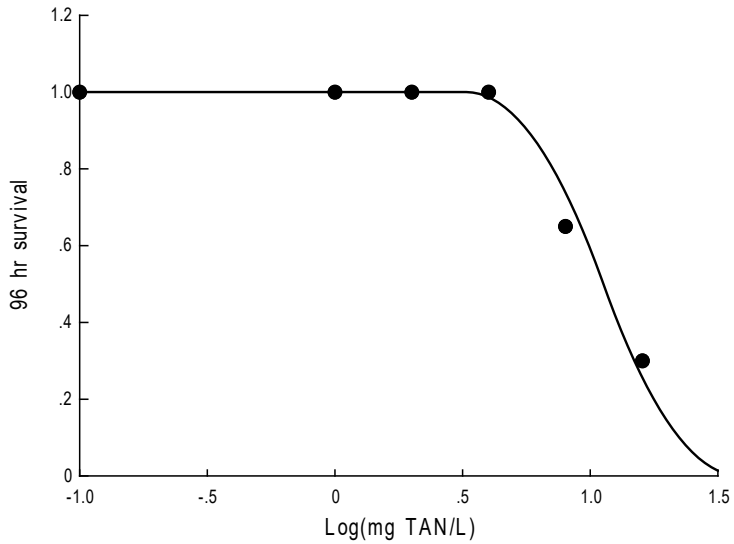
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.8	0.78769	0.013841	0.76048	0.8149
StDev	0.27	0.27148	0.012501	0.24903	0.29841
Y0	0.975	0.97397	0.006384	0.95819	0.98499

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**6.1333**	5.7607	6.5299	0.013841	0.78769
20	3.4937	3.2015	3.8124	0.019247	0.54328
10	2.6309	2.3628	2.9294	0.023628	0.4201
5	**2.1527**	1.9025	2.4359	0.027097	0.33299
0	1.3265	1.1245	1.5648	0.035932	0.12271

LC50:LC5 = 2.849

Notes: Acceptable model fit.

Wang et 2007b	
Species: *Lampsilis rafinesqueana* (<5-d old juvenile)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-16	
Test: #2	
TAN, mg/L	**Proportion Surviving**
0.1	1.00
1	1.00
2	1.00
4	1.00
8	0.65
16	0.30



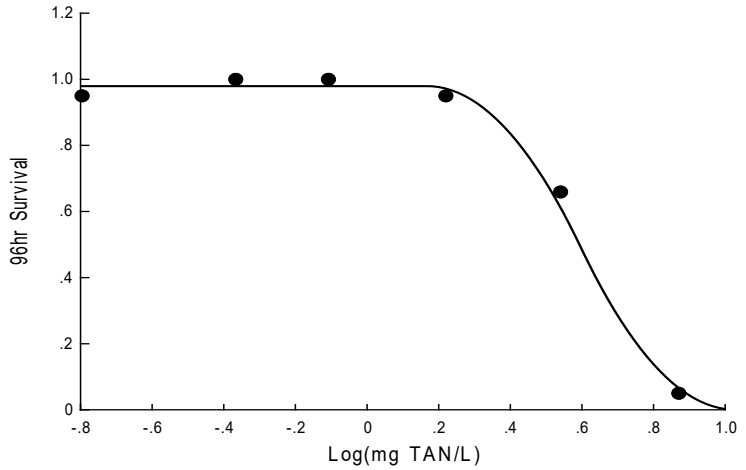
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.05	1.0514	0.049466	0.94814	1.1548
StDev	0.22	0.21914	0.040601	0.16127	0.34185
Y0	1	0.9999	0.001302	0.93921	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**11.258**	8.8744	14.281	0.049466	1.0514
20	7.1476	5.6646	9.0188	0.046632	0.85416
10	5.685	4.2663	7.5754	0.054905	0.75473
5	**4.8352**	3.4138	6.8486	0.063538	0.68442
0	3.271	1.8264	5.858	0.090157	0.51468

LC50:LC5 = 2.328

Notes: Acceptable model fit.

Wang et al. 2007a	
Species: *Lampsilis siliquoidea* (2 month old)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-21	
Test: Single	
TAN, mg/L	**Proportion Surviving**
0.16	0.95
0.43	1.00
0.78	1.00
1.66	0.95
3.47	0.66
7.42	0.05

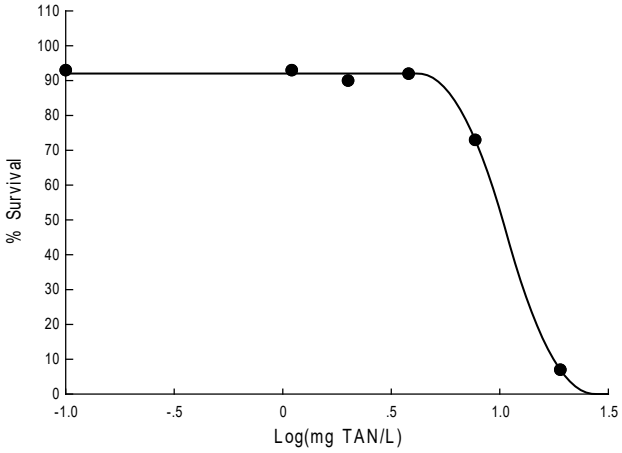


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.6	0.59762	0.029248	0.53831	0.65693
StDev	0.175	0.17581	0.02571	0.13689	0.24582
Y0	0.975	0.97917	0.012371	0.93808	0.99605
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**3.9593**	3.4539	4.5387	0.029248	0.59762
20	2.75	2.261	3.3448	0.041028	0.43934
10	2.2886	1.7887	2.9281	0.0502	0.35956
5	**2.0098**	1.5037	2.6862	0.057487	0.30315
0	1.4688	0.96539	2.2348	0.07565	0.16697

LC50:LC5 = 1.970

Notes: Acceptable model fit.

Wang et al. 2008	
Species: *Lampsilis siliquoidea* (7 d old juvenile)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-22	
Test: Experiment 1- pH=7.5	
TAN, mg/L	**% Survival**
Control (0.1)	93
1.1	93
2	90
3.8	92
7.7	73
19	7



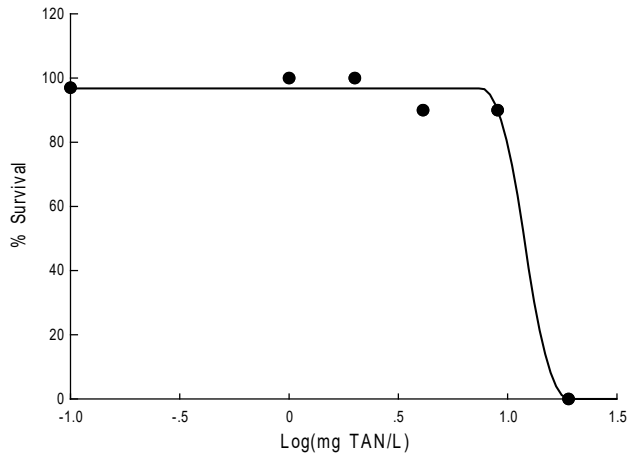
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	1.0314	0.008905	1.0031	1.0597
S	2.5	2.4657	0.11927	2.0862	2.8453
Y0	93	92	0.70711	89.75	94.25

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**10.75**	10.071	11.475	0.008905	1.0314
20	7.6268	7.0596	8.2396	0.010547	0.88234
10	6.4153	5.7742	7.1275	0.014367	0.80722
5	**5.6767**	4.6074	6.9941	0.02848	0.75409
0	4.2252	3.4558	5.1659	0.027431	0.62585

LC50:LC5 = 1.894

Notes: Acceptable model fit.

Wang et al. 2008	
Species: *Lampsilis siliquoidea* (7 d old juvenile)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-27	
Test: Experiment 2- pH=8.0	
TAN, mg/L	**% Survival**
Control	97
1	100
2	100
4.1	90
9	90
19	0



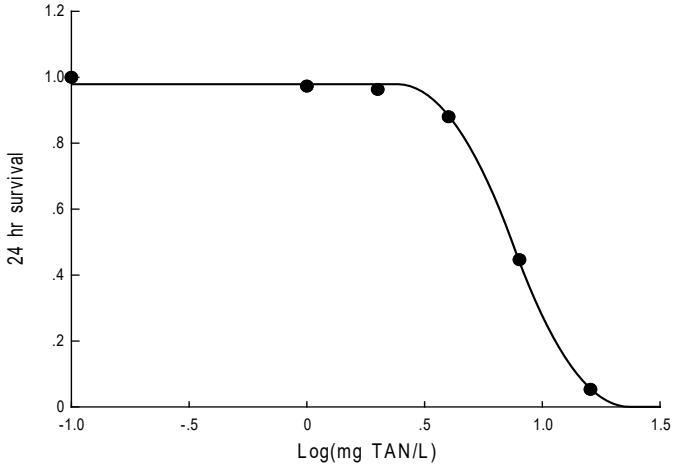
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.94835	1.0794	2.1634	-5.8056	7.9643
S	1.7806	5.0067	86.564	-270.48	280.49
Y0	99	96.75	2.3585	89.244	104.26

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**12.005**			2.1634	1.0794
20	10.138	8.2192	12.505	0.028634	1.006
10	9.3102	7.6099	11.39	0.027518	0.96896
5	**8.7659**	7.0464	10.905	0.029797	0.94279
0	7.5794	5.8344	9.8462	0.035706	0.87963

LC50:LC5 = 1.370

Notes: Acceptable model fit. Acceptable noise at low level effects.

Wang et al. 2007b	
Species: *Lampsilis siliquoidea* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-32	
Test: #7 (September 2004)	
TAN, mg/L	**Proportion surviving**
0.1	1.00
1	0.97
2	0.96
4	0.88
8	0.45
16	0.05



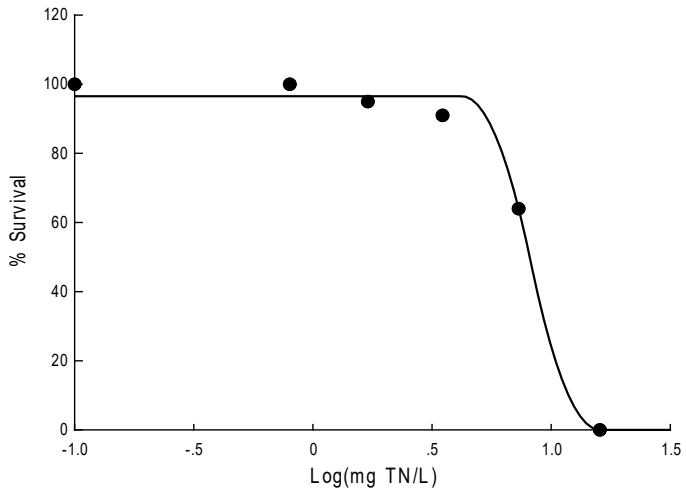
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.88	0.87718	0.010836	0.85587	0.8985
StDev	0.2	0.20119	0.009775	0.18371	0.22236
Y0	0.99	0.97877	0.004793	0.96712	0.98713

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**7.5367**	7.1758	7.9158	0.010836	0.87718
20	4.9666	4.6296	5.3281	0.015477	0.69606
10	4.025	3.69	4.3904	0.019086	0.60477
5	**3.4691**	3.1373	3.8361	0.022024	0.54022
0	2.4232	2.1222	2.7668	0.028782	0.38438

LC50:LC5 = 2.173

Notes: Acceptable model fit.

Wang et al. 2017	
Species: *Margaritifera falcata*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-34	
Test: Single	
TN, mg/L	**% Survival**
0.1	100
0.8	100
1.7	95
3.5	91
7.3	64
16	0

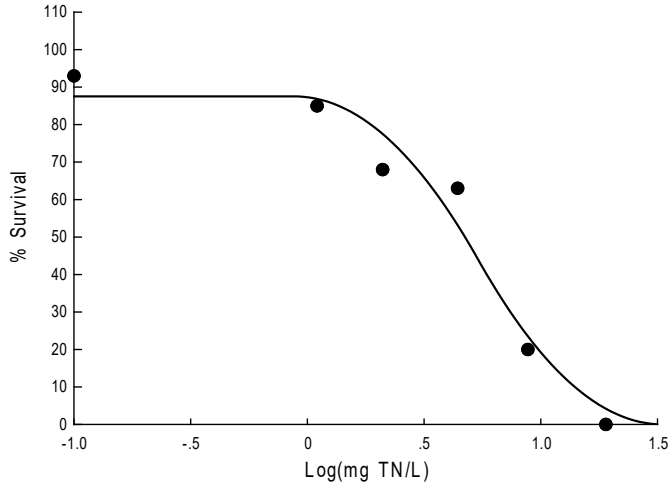


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	0.91515	5.1505	-15.476	17.306
S	2.5	3.4592	343.77	-1090.6	1097.5
Y0	98.333	96.5	2.1794	89.564	103.44
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**8.2253**			5.1505	0.91515
20	6.4402	5.2384	7.9177	0.028186	0.8089
10	5.6931	4.5833	7.0716	0.02959	0.75535
5	**5.2178**	4.1803	6.5127	0.030252	0.71748
0	4.2274	3.3245	5.3755	0.032788	0.62607

LC50:LC5 = 1.576

Notes: Acceptable model fit. Acceptable noise at low level effects.

Wang et al. 2017	
Species: *Megalonaias nervosa*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-35	
Test: Single	
TAN, mg/L	**% Survival**
0.1	93
1.1	85
2.1	68
4.4	63
8.8	20
19	0



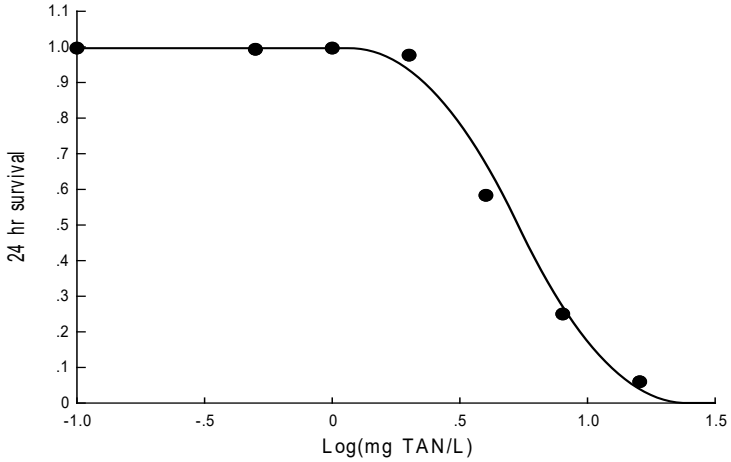
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.75	0.73401	0.080828	0.47678	0.99124
S	1.5	1.2681	0.37768	0.066098	2.47
Y0	89	87.512	7.1908	64.628	110.4

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**5.4202**	2.9977	9.8004	0.080828	0.73401
20	2.7808	1.0003	7.73	0.13952	0.44416
10	1.9865	0.47138	8.3713	0.1963	0.29808
5	**1.566**	0.24759	9.9044	0.25171	0.19478
0	0.88187	0.090045	8.6367	0.31138	-0.0546

LC50:LC5 = 3.461

Notes: Acceptable model fit. Acceptable noise at low level effects. New acute value added since 2013 ALC document.

Wang et al. 2007b	
Species: *Venustaconcha ellipsiformis* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-40	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.1	1.00
0.5	0.99
1	1.00
2	0.98
4	0.58
8	0.25
16	0.06



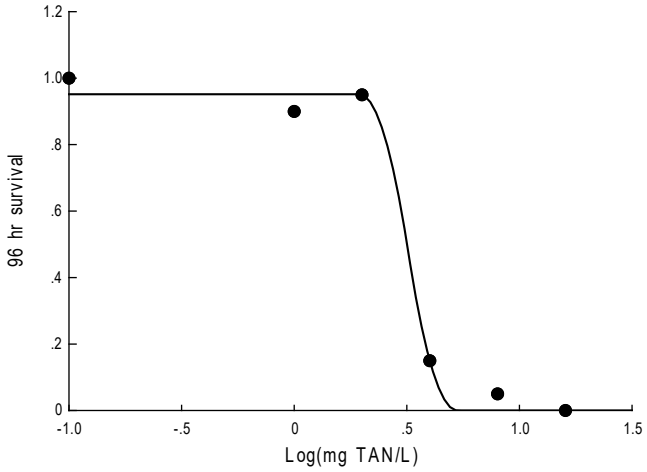
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.73	0.72917	0.012311	0.70498	0.75336
StDev	0.27	0.26901	0.010504	0.24991	0.29131
Y0	0.99	0.99604	0.002091	0.98937	0.99902

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**5.3601**	5.0697	5.6671	0.012311	0.72917
20	3.0689	2.8519	3.3023	0.016182	0.48698
10	2.3169	2.1193	2.533	0.019642	0.36491
5	**1.8993**	1.7137	2.1051	0.022613	0.2786
0	1.1755	1.0274	1.345	0.029442	0.070222

LC50:LC5 = 2.822

Notes: Acceptable model fit.

Wang et al. 2007b	
Species: *Villosa iris* (2 month old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-41	
Test: #1	
TAN, mg/L	**Proportion surviving**
0.1	1.00
1	0.90
2	0.95
4	0.15
8	0.05
16	0



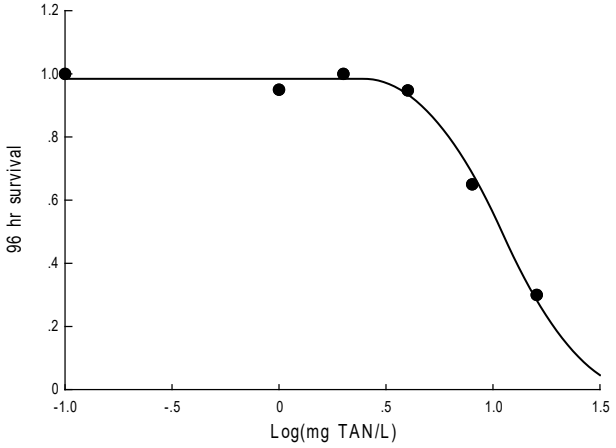
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.61275	0.50693	0.088136	0.31056	0.70331
StDev	0.1	0.088552	0.078816	0.061873	0.1554
Y0	0.95	0.95122	0.034059	0.83256	0.99427

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**3.2132**	2.0443	5.0503	0.088136	0.50693
20	2.6743	1.1454	6.2443	0.15626	0.42721
10	2.438	0.79667	7.4608	0.19134	0.38703
5	**2.2836**	0.58506	8.9134	0.2163	0.35862
0	1.95	0.19949	19.06	0.27698	0.29003

LC50:LC5 = 1.407

Notes: Large SE for StDev, but acceptable model fit. Acceptable noise at low level effects.

Wang et al. 2007b	
Species: *Villosa iris* (2 month old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-42	
Test: #2	
TAN, mg/L	**Proportion surviving**
0.1	1.00
1	0.95
2	1.00
4	0.95
8	0.65
16	0.30

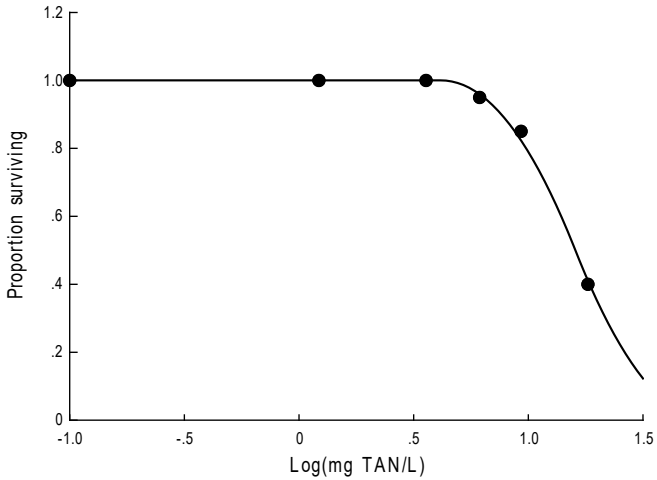


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.05	1.0467	0.059845	0.92174	1.1716
StDev	0.27	0.26597	0.065	0.18584	0.46676
Y0	0.98	0.98412	0.015963	0.91316	0.99963
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**11.135**	8.351	14.846	0.059845	1.0467
20	6.4154	4.5375	9.0704	0.068312	0.80722
10	4.8589	3.003	7.8618	0.088451	0.68654
5	**3.9921**	2.1499	7.4129	0.106	0.6012
0	2.4842	0.77312	7.982	0.15465	0.39518

LC50:LC5 = 2.789

Notes: Acceptable model fit.

Scheller et al 1997	
Species: *Villosa iris*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-43	
Test: 5-d old juveniles	
TAN, mg/L	**Proportion surviving**
Control	1.00
1.22	1.00
3.58	1.00
6.13	0.95
9.29	0.85
18.18	0.40



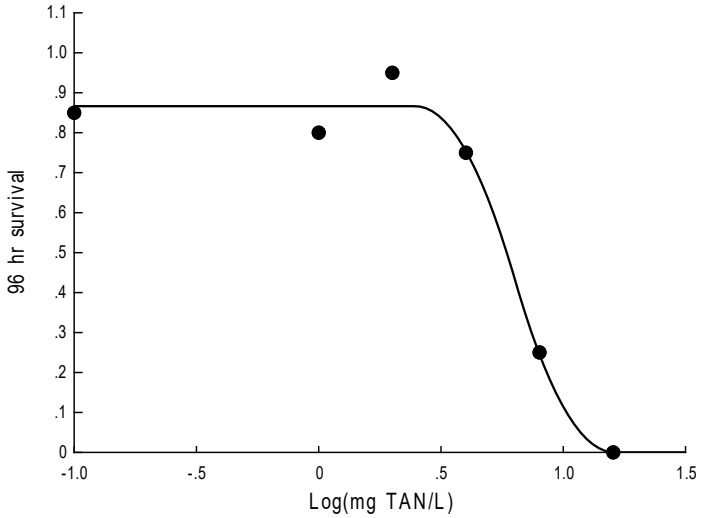
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.2	1.2051	0.05971	1.0785	1.3317
S	0.24	0.23856	0.056116	0.16668	0.41865
Y0	1	0.9999	0.001291	0.94017	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**16.036**	11.981	21.464	0.05971	1.2051
20	9.7799	7.5985	12.587	0.04898	0.99033
10	7.6224	5.4563	10.648	0.060406	0.88209
5	**6.3907**	4.13	9.8889	0.073434	0.80555
0	4.176	1.7273	10.097	0.11456	0.62076

LC50:LC5 = 2.509

Notes: Acceptable model fit.

Wang et 2007b	
Species: *Villosa iris* (<5-d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-44	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.1	0.85
1	0.80
2	0.95
4	0.75
8	0.25
16	0

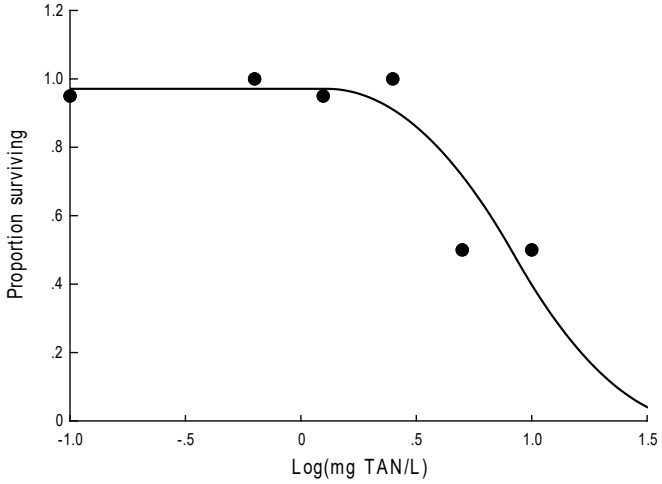


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.8	0.80187	0.051785	0.68692	0.91682
StDev	0.17	0.16609	0.040031	0.11605	0.29147
Y0	0.875	0.86624	0.04369	0.75437	0.94
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**6.3368**	4.8632	8.2569	0.051785	0.80187
20	4.491	3.0289	6.6588	0.072866	0.65234
10	3.7755	2.2949	6.2114	0.085519	0.57698
5	**3.3396**	1.8435	6.0497	0.094785	0.52369
0	2.4834	0.95129	6.4828	0.11716	0.39504

LC50:LC5 = 1.897

Notes: Acceptable model fit. Acceptable noise at low level effects.

Scheller 1997	
Species: *Villosa iris*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-46	
Test: <3-d old juveniles	
TAN, mg/L	**Proportion surviving**
Control	0.95
0.63	1.00
1.25	0.95
2.5	1.00
5	0.50
10	0.50



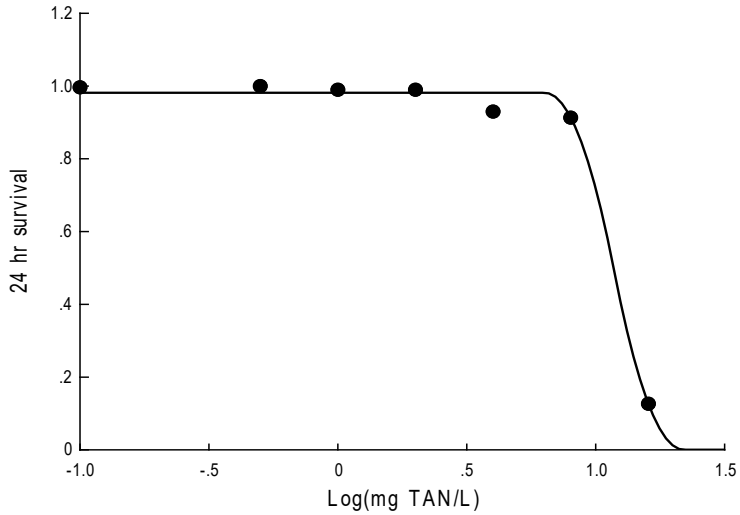
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.9	0.92326	0.081508	0.75087	1.0956
S	0.3	0.33081	0.099296	0.23114	0.58054
Y0	0.975	0.97062	0.021752	0.89091	0.99708

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**8.3803**	5.6347	12.464	0.081508	0.92326
20	4.2212	2.7089	6.5777	0.086312	0.62543
10	2.9877	1.5575	5.7309	0.11802	0.47533
5	**2.3399**	0.98411	5.5634	0.14611	0.36919
0	1.297	0.23122	7.2759	0.22453	0.11295

LC50:LC5 = 3.581

Notes: Acceptable model fit. Acceptable noise at low level effects.

Wang et al. 2007b	
Species: *Villosa iris* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-48	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.1	1.00
0.5	1.00
1	0.99
2	0.99
4	0.93
8	0.91
16	0.13

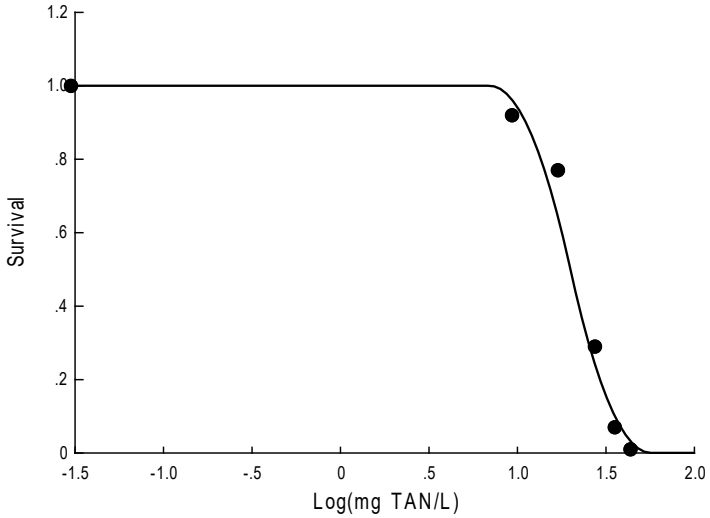


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.05	1.0718	0.007919	1.0562	1.0875
StDev	0.11	0.10975	0.005819	0.09943	0.12247
Y0	0.99	0.98133	0.003495	0.97313	0.98756
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**11.799**	11.382	12.231	0.007919	1.0718
20	9.3979	8.9922	9.8218	0.009688	0.97303
10	8.3798	7.9543	8.8279	0.0114	0.92323
5	**7.7271**	7.2862	8.1947	0.012812	0.88802
0	6.3534	5.8808	6.864	0.016671	0.80301

LC50:LC5 = 1.527

Notes: Acceptable model fit. Acceptable noise at low level effects.

Anderson and Buckley 1998	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Am-Acute-49	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.03	1.00
9.31	0.92
16.91	0.77
27.42	0.29
35.48	0.07
43.55	0.01



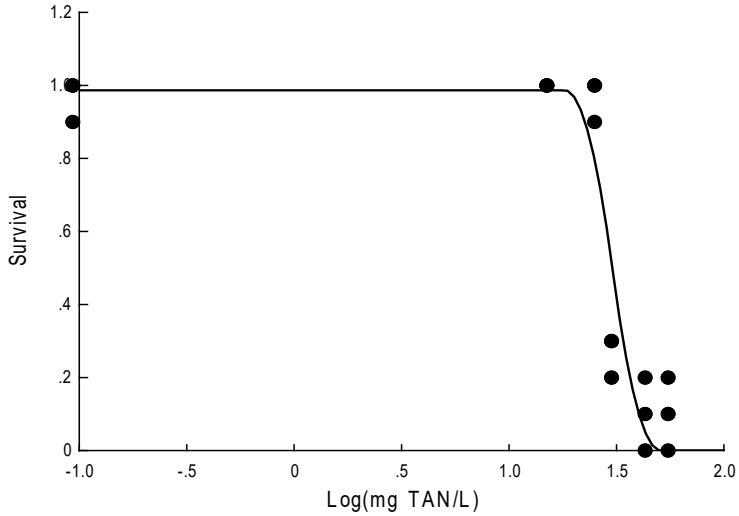
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.3	1.299	0.013526	1.2724	1.3257
StDev	0.19	0.18561	0.010662	0.16686	0.20915
Y0	1	0.9999	0.0010204	0.96358	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**19.909**	18.722	21.17	0.013526	1.299
20	13.55	12.454	14.742	0.018504	1.1319
10	11.161	10.082	12.356	0.022222	1.0477
5	**9.7311**	8.6721	10.919	0.025079	0.98816
0	6.9886	6.0123	8.1234	0.032328	0.84439

LC50:LC5 = 2.046

Notes: Acceptable model fit.

Sarda 1994	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Am-Acute-50	
Test: 2/22/93 Recon hard water	
TAN, mg/L	**Proportion surviving**
low	1.00
low	0.90
low	1.00
13.5	1.00
13.5	1.00
13.5	1.00
20.4	1.00
20.4	0.90
20.4	1.00
28	0.30
28	0.20
28	0.30
40	0.20
40	0.10
40	0
52	0.20
52	0
52	0.10



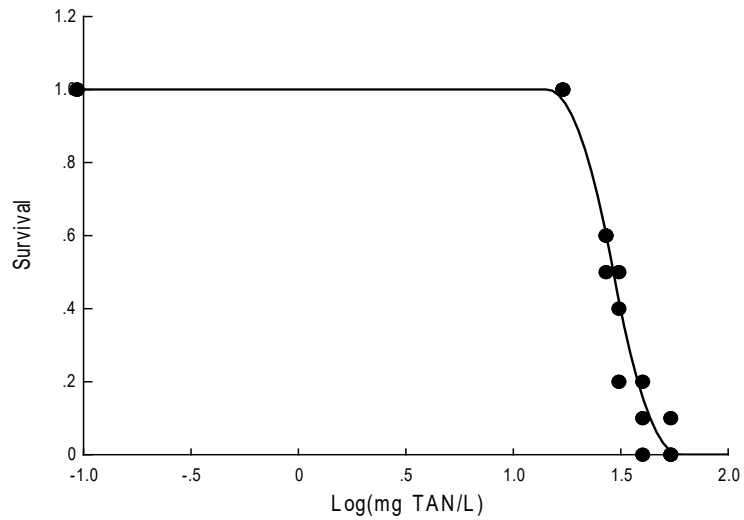
LC50:LC5 = 1.419

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.4825	0.014583	1.453	1.512
StDev	0.075	0.090662	0.014742	0.068909	0.13256
Y0	1	0.9865	0.014882	0.91597	0.99984

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**30.373**	28.378	32.508	0.014583	1.4825
20	25.169	22.745	27.851	0.021153	1.4009
10	22.894	20.069	26.116	0.026561	1.3597
5	**21.411**	18.042	25.408	0.033364	1.3306
0	18.214	14.357	23.107	0.041142	1.2604

Notes: Acceptable model fit.

Sarda 1994	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Am-Acute-51	
Test: 2/25/93 Recon hard water	
TAN, mg/L	**Proportion surviving**
low	1.00
low	1.00
low	1.00
15.2	1.00
15.2	1.00
15.2	1.00
25.3	0.60
25.3	0.60
25.3	0.50
29.6	0.50
29.6	0.40
29.6	0.20
39	0.20
39	0.10
39	0
50.2	0.10
50.2	0
50.2	0



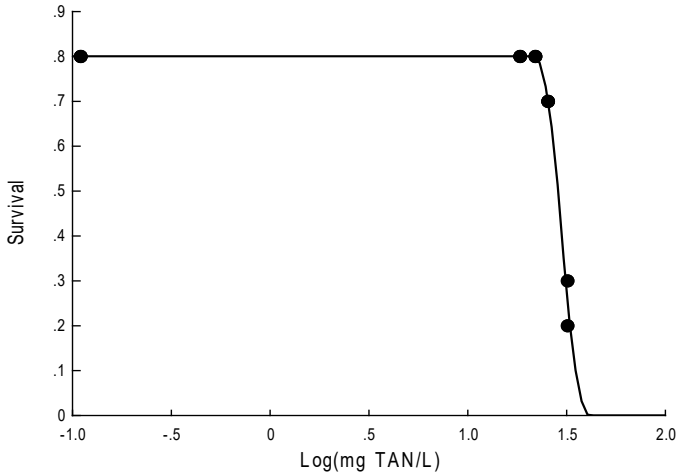
LC50:LC5 = 1.628

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.4658	0.015815	1.4342	1.4974
StDev	0.125	0.12632	0.013111	0.10504	0.15847
Y0	1	0.9999	0.001825	0.88418	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**29.23**	27.179	31.436	0.015815	1.4658
20	22.496	20.35	24.869	0.021558	1.3521
10	19.715	17.434	22.295	0.026081	1.2948
5	**17.958**	15.594	20.681	0.029546	1.2543
0	14.336	11.839	17.359	0.038297	1.1564

Notes: Acceptable model fit.

Hazel et al. 1979	
Species: *Stenelmis sexlineata*	
Test Endpoint: 4 day Survival	
C-R Curve Label: Am-Acute-53	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.11	0.8
0.11	0.8
18.4	0.8
18.4	0.8
22	0.8
22	0.8
25.5	0.7
25.5	0.7
32	0.3
32	0.2



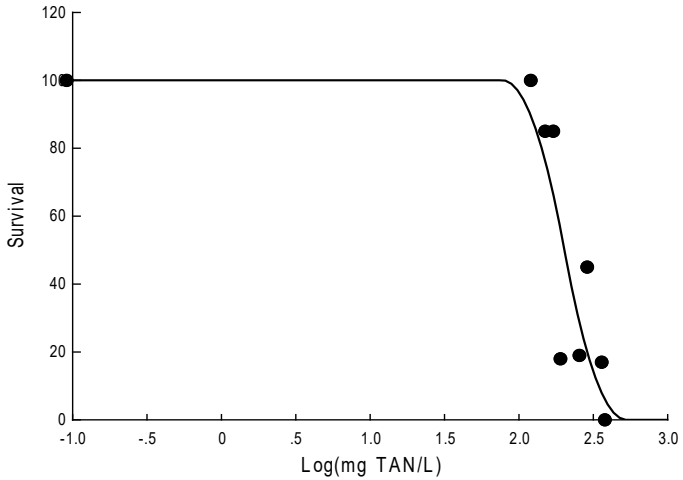
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.476	0.019937	1.4316	1.5204
StDev	0.05	0.05675	0.025296	0.039652	0.099593
Y0	0.8	0.80019	0.053584	0.67142	0.89534

LC50:LC5 = 1.245

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**29.923**	27.014	33.146	0.019937	1.476
20	26.602	22.229	31.835	0.03309	1.4249
10	25.071	19.503	32.228	0.042963	1.3992
5	**24.041**	17.491	33.045	0.050525	1.381
0	21.727	12.195	38.709	0.070165	1.337

Notes: Acceptable model fit.

Wicks et al. 2002	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 4 day Survival	
C-R Curve Label: Am-Acute-56	
Test: Resting Fish	
TAN, mg/L	**% Survival**
0.05	100
120	100
150	85
170	85
190	18
255	19
287.5	45
360	17
378	0



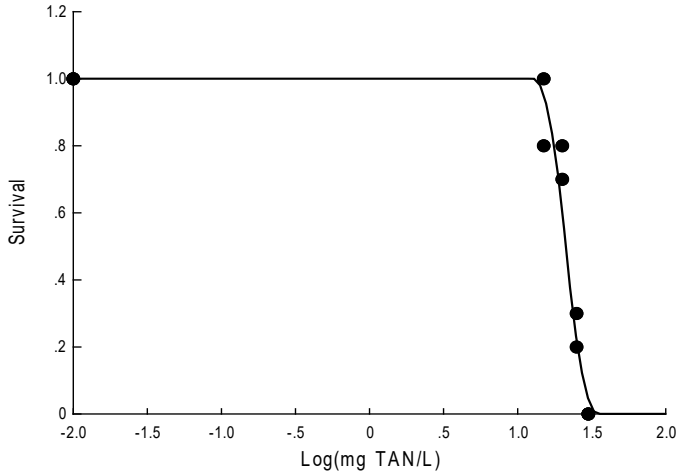
LC50:LC5 = 1.925

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.75	2.3058	0.044845	2.1998	2.4119
S	5	2.4047	0.84223	0.41319	4.3963
Y0	100	100			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**202.23**	158.41	258.16	0.044845	2.3058
20	142.23	96.037	210.65	0.072129	2.153
10	119.11	67.103	211.44	0.1054	2.076
5	**105.07**	47.994	230.04	0.14391	2.0215
0	77.624	23.97	251.37	0.21581	1.89

Notes: Acceptable model fit.

Hazel et al. 1979	
Species: *Cyprinella lutrensis*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-58	
Test: #2	
TAN, mg/L	**Proportion surviving**
0.01	1.0
0.01	1.0
15	1.0
15	0.8
20	0.7
20	0.8
25	0.3
25	0.2
30	0.0
30	0.0



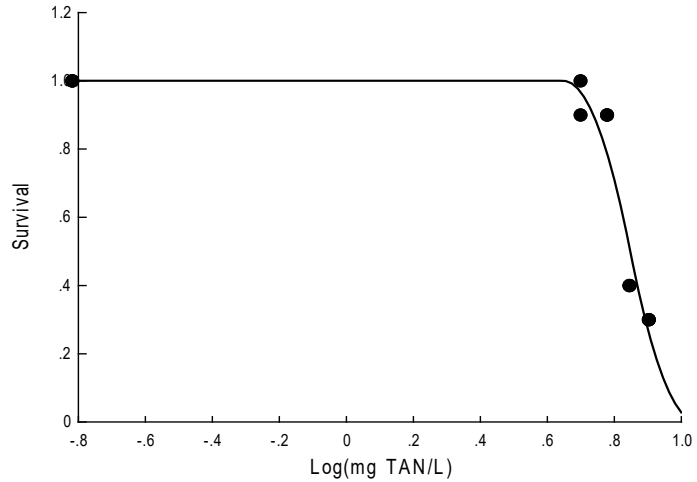
LC50:LC5 = 1.406

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.3167	1.325	0.01535	1.2938	1.3563
StDev	0.090628	0.088289	0.012934	0.068716	0.12353
Y0	1	0.9999	0.002236	0.83142	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**21.136**	19.67	22.712	0.01535	1.325
20	17.601	15.973	19.395	0.020269	1.2455
10	16.05	14.222	18.113	0.024542	1.2055
5	**15.037**	12.972	17.43	0.029161	1.1772
0	12.846	10.471	15.76	0.036691	1.1088

Notes: Acceptable model fit.

Hazel et al. 1979	
Species: *Cyprinella lutrensis*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-59	
Test: #1	
TAN, mg/L	**Proportion surviving**
0.14	1.0
0.15	1.0
5	0.9
5	1.0
6	0.9
6	0.9
7	0.4
7	0.4
8	0.3
8	0.3



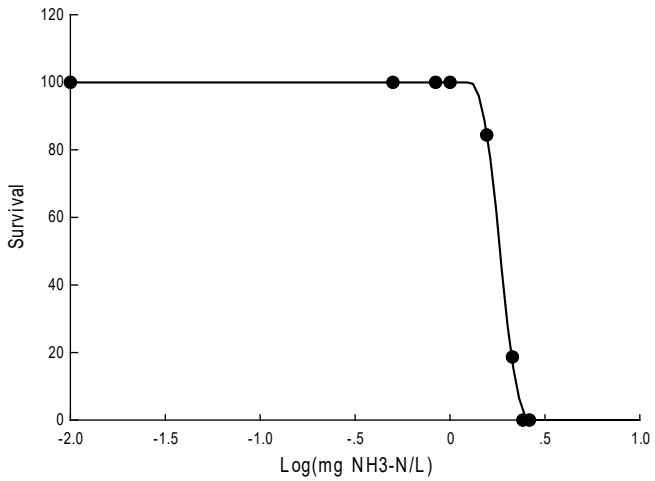
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.95	0.84759	0.014521	0.81799	0.87719
StDev	0.1	0.081393	0.015394	0.059578	0.12842
Y0	1	0.9999	0.002236	0.83143	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**7.0403**	6.5765	7.5369	0.014521	0.84759
20	5.9472	5.5119	6.417	0.015609	0.77431
10	5.4624	4.9274	6.0554	0.020159	0.73738
5	**5.1436**	4.5177	5.8562	0.024192	0.71127
0	4.4486	3.5537	5.5687	0.035327	0.64822

LC50:LC5 = 1.369

Notes: Acceptable model fit.

Hasan and MacIntosh 1986	
Species: *Cyprinus carpio*	
Test Endpoint: 168 and 96 hr Survival	
C-R Curve Label: Am-Acute-62	
Test: Trial 2	
NH3-N, mg/L	**% Survival**
0	100
0.5	100
0.84	100
1	100
1.56	84.4
2.13	18.7
2.42	0
2.62	0



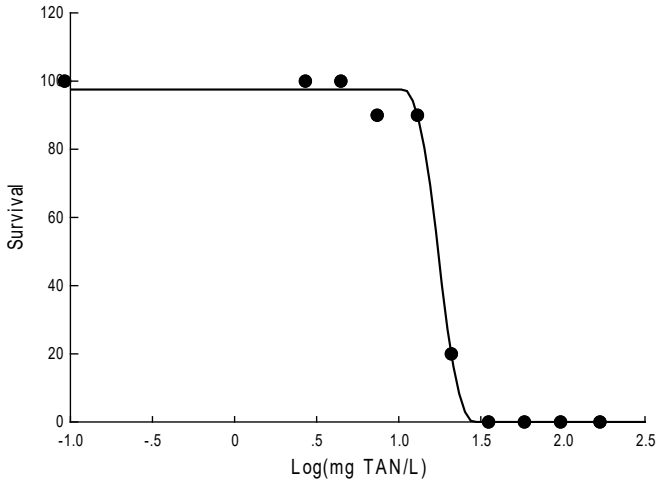
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.22915	0.26367	0.002829	0.25639	0.27094
S	4.8541	6.389	0.23968	5.7729	7.0051
Y0	100	99.947	0.69899	98.15	101.74

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.8351**	1.8046	1.8661	0.002829	0.26367
20	1.6075	1.5704	1.6453	0.003935	0.20614
10	1.5036	1.4624	1.5461	0.0047	0.17714
5	**1.4343**	1.391	1.4789	0.005175	0.15664
0	1.2798	1.2336	1.3277	0.006207	0.10715

LC50:LC5 = 1.279

Notes: Acceptable model fit.

Buhl 2002	
Species: *Hybognathus amarus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-63	
Test: Single	
TAN, mg/L	**% Survival**
<0.10	100
2.7	100
4.44	100
7.38	90
13	90
20.9	20
35.2	0
58.2	0
96.7	0
168	0



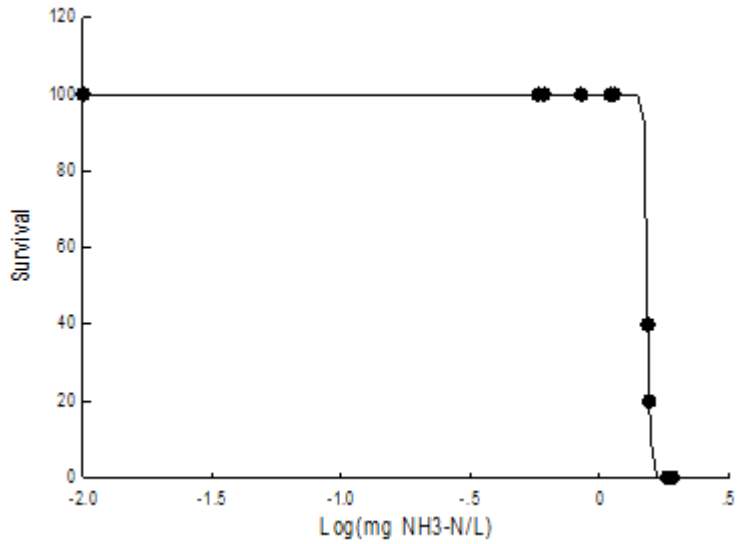
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.25	1.2435	0.010493	1.2187	1.2683
S	4.75	4.6908	0.5141	3.4751	5.9064
Y0	100	97.5	1.6366	93.63	101.37

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**17.519**	16.546	18.549	0.010493	1.2435
20	14.627	13.439	15.92	0.015562	1.1652
10	13.356	12.043	14.811	0.018996	1.1257
5	**12.524**	11.127	14.096	0.021721	1.0977
0	10.723	7.7315	14.873	0.060077	1.0303

LC50:LC5 = 1.399

Notes: Acceptable model fit. Acceptable noise at low level effects.

Swigert and Spacie 1983	
Species: *Pimephales promelas*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-69	
Test: 0.2 g fish	
NH3-N, mg/L	**% Survival**
Control (0.01)	100
Control (0.01)	100
0.58	100
0.61	100
0.85	100
0.85	100
1.1	100
1.14	100
1.54	40
1.56	20
1.83	0
1.91	0



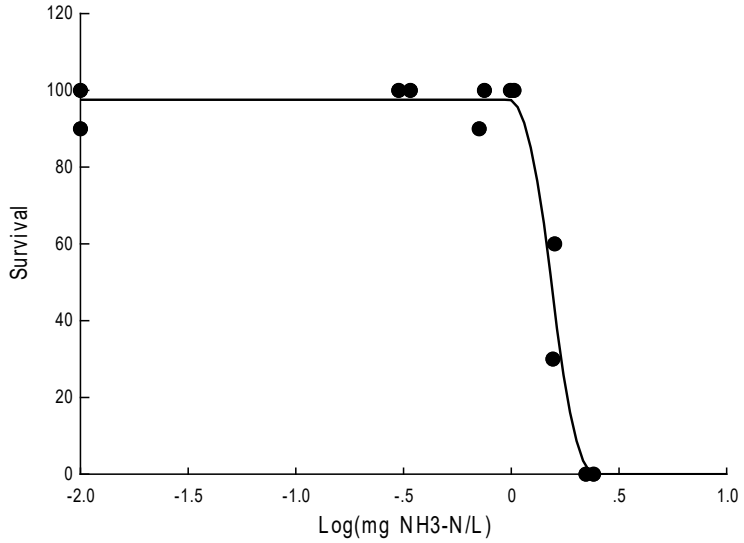
LC50:LC5 = 1.034

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.14	0.18526	0	0.18526	0.18526
S	20	46.748	0	46.748	46.748
Y0	100	100	0	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.532**	1.532	1.532	0	0.18526
20	1.5045	1.5045	1.5045	0	0.1774
10	1.4909	1.4909	1.4909	0	0.17344
5	**1.4813**	1.4813	1.4813	0	0.17064
0	1.4584	1.4584	1.4584	0	0.16387

Notes: Representative curve slope due to model steepness. Acceptable.

Swigert and Spacie 1983	
Species: *Pimephales promelas*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-70	
Test: 0.5 g fish	
NH3-N, mg/L	**% Survival**
Control (0.01)	90
Control (0.01)	100
0.3	100
0.34	100
0.71	90
0.75	100
0.99	100
1.03	100
1.56	30
1.59	60
2.22	0
2.41	0



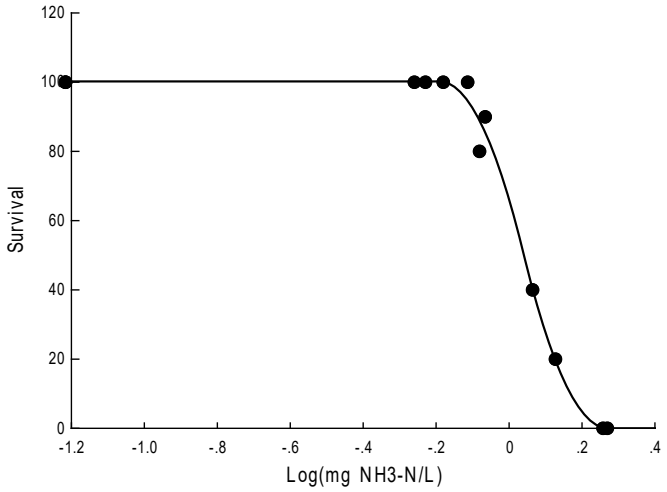
LC50:LC5 = 1.365

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.18	0.18865	1.51E-02	0.15445	0.22284
S	5	5.0605	2.5711	-0.75577	10.877
Y0	98	97.528	3.3256	90.005	105.05

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.544**	1.4271	1.6705	1.51E-02	0.18865
20	1.3062	0.98116	1.739	5.49E-02	0.11602
10	1.2006	0.88198	1.6344	5.92E-02	7.94E-02
5	**1.1312**	0.84558	1.5132	5.59E-02	5.35E-02
0	0.97957	0.66052	1.4527	7.57E-02	-8.96E-03

Notes: Large SE for steepness (S), but acceptable model fit.

Reinbold and Pescitelli 1982c	
Species: *Catostomus commersonii*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-71	
Test: #2	
NH3-N, mg/L	**% Survival**
Control (0.05)	100
Control (0.05)	100
0.55	100
0.59	100
0.66	100
0.77	100
0.83	80
0.86	90
1.16	40
1.34	20
1.81	0
1.86	0

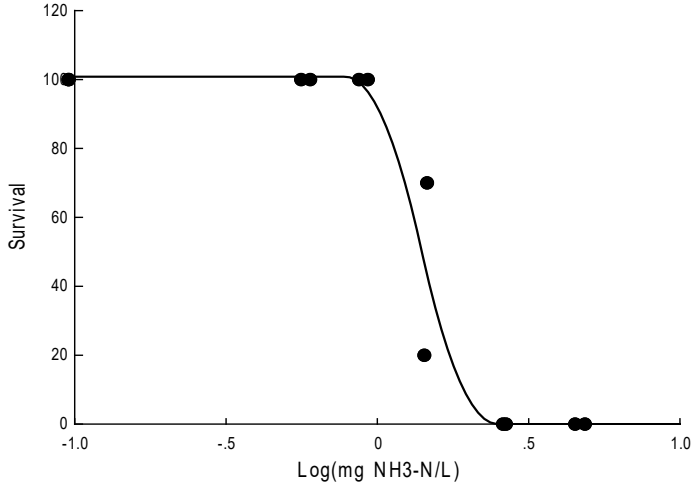


LC50:LC5 = 1.439

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.05	0.040488	0.0072965	0.023983	0.056994
S	4.2	4.3295	0.37218	3.4876	5.1714
Y0	100	100.21	1.7137	96.329	104.08
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.0977**	1.0568	1.1402	0.007297	0.040488
20	0.90281	0.85363	0.95482	0.010753	-0.0444
10	0.81811	0.76368	0.87641	0.013217	-0.08719
5	**0.76305**	0.70701	0.82355	0.014647	-0.11744
0	0.64493	0.58706	0.70852	0.018052	-0.19048

Notes: Acceptable model fit.

Reinbold and Pescitelli 1982d	
Species: *Ictalurus punctatus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-74	
Test: #1	
NH3-N, mg/L	**% Survival**
Control (0.05)	100
Control (0.05)	100
0.56	100
0.6	100
0.87	100
0.93	100
1.43	20
1.46	70
2.6	0
2.66	0
4.5	0
4.85	0

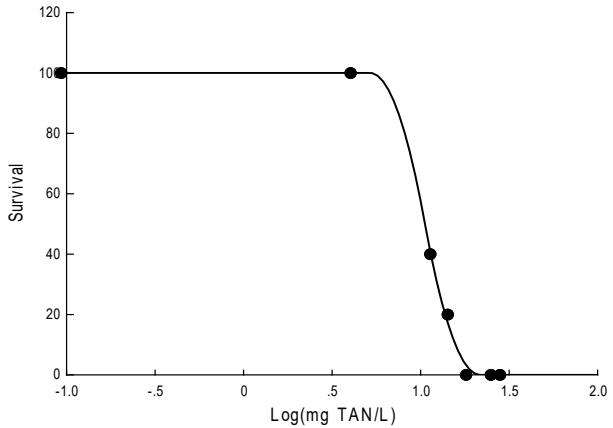


LC50:LC5 = 1.485

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.15	0.14627	0.025362	0.088898	0.20365
S	4	3.9804	2.1789	-0.94846	8.9094
Y0	100	100.79	6.2664	86.61	114.96
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.4005**	1.2272	1.5983	0.025362	0.14627
20	1.1322	0.82097	1.5615	0.061713	0.053935
10	1.0172	0.65115	1.5889	0.085632	0.007397
5	**0.94295**	0.551	1.6137	0.10315	-0.02551
0	0.78532	0.36279	1.6999	0.14826	-0.10496

Notes: Large SE for steepness, but acceptable model fit.

Jude 1973	
Species: *Lepomis gibbosus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-77	
Test: Single	
TAN, mg/L	**% Survival**
0.08	100
4.02	100
11.34	40
14.23	20
18.07	0
24.95	0
28.1	0



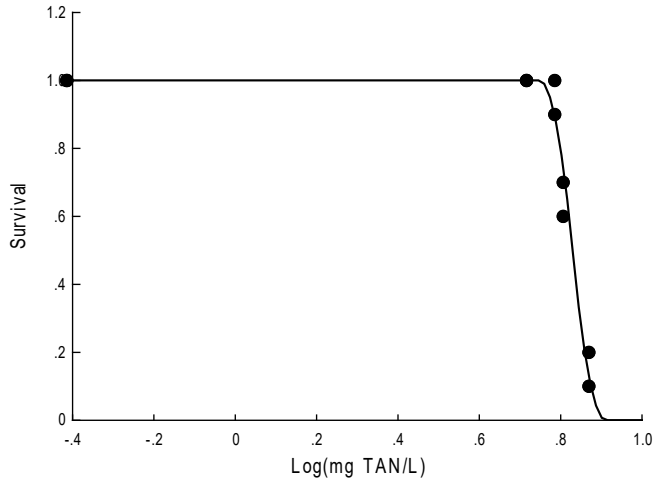
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	1.0251	0.0095797	0.9985	1.0517
S	3.2	3.2268	0.33642	2.2927	4.1608
Y0	100	100	1.5299	95.752	104.25

LC50:LC5 = 1.629

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**10.595**	9.9655	11.264	0.00958	1.0251
20	8.1506	6.9328	9.5823	0.025313	0.91119
10	7.1414	5.327	9.5737	0.045848	0.85378
5	**6.5041**	4.2757	9.8939	0.065615	0.81319
0	5.1902	3.4107	7.8983	0.065676	0.71519

Notes: Acceptable model fit.

Hazel et al. 1979	
Species: *Lepomis macrochirus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-80	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.3	1.0
0.3	1.0
5.2	1.0
5.2	1.0
6.1	0.9
6.1	0.6
6.4	0.7
6.4	0.1
7.4	0.2
7.4	1.0



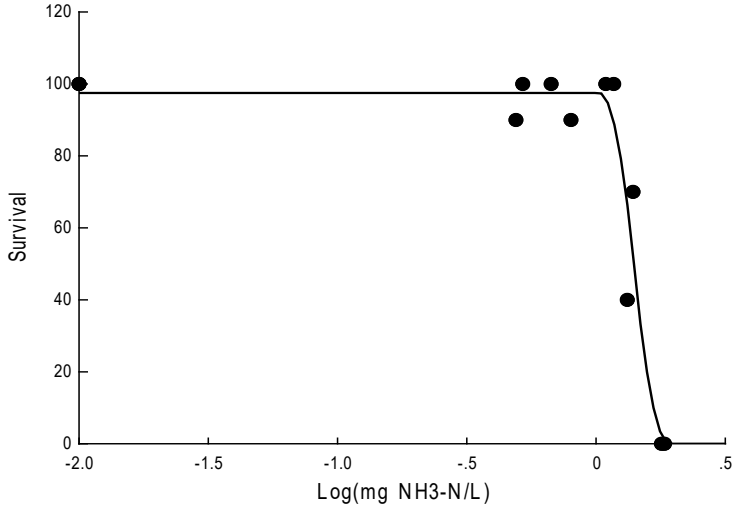
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.9	0.82941	0.007024	0.81486	0.84397
StDev	0.05	0.033202	0.00645	0.024131	0.053194
Y0	1	0.9999	0.001581	0.91171	1

LC50:LC5 = 1.137

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**6.7517**	6.5292	6.9818	0.007024	0.82941
20	6.3026	6.0621	6.5527	0.007839	0.79952
10	6.0878	5.7878	6.4032	0.009662	0.78446
5	**5.9403**	5.5826	6.3208	0.011279	0.7738
0	5.5987	5.0429	6.2158	0.015811	0.74809

Notes: Acceptable model fit.

Swigert and Spacie 1983	
Species: *Lepomis macrochirus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-83	
Test: July 20, 1982 test	
NH3-N, mg/L	**% Survival**
Control (0.01)	100
Control (0.01)	100
0.49	90
0.52	100
0.67	100
0.8	90
1.09	100
1.17	100
1.32	40
1.39	70
1.79	0
1.84	0



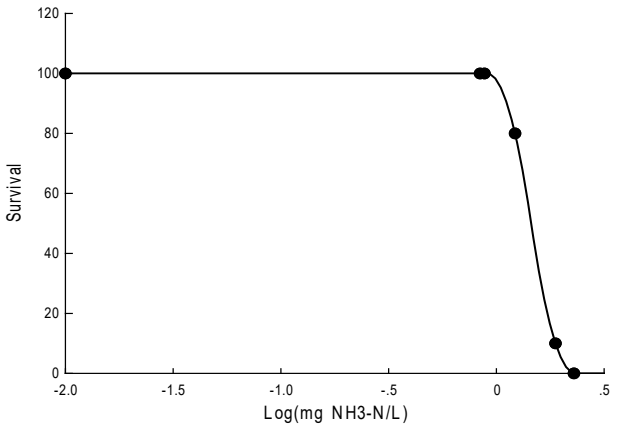
LC50:LC5 = 1.237

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.15	0.14828	0.01426	0.11602	0.18053
S	12	7.4072	2.7369	1.2158	13.599
Y0	100	97.474	4.711	86.817	108.13

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.4069**	1.3062	1.5154	0.01426	0.14828
20	1.255	1.1261	1.3988	0.020815	0.098656
10	1.1848	1.0021	1.4008	0.032144	0.073648
5	**1.1375**	0.94655	1.367	0.035285	0.055964
0	1.031	0.86267	1.2323	0.034228	0.013272

Notes: No errors. Good interpolation through pre-threshold values. Falling limb well characterized. Acceptable.

Swigert and Spacie 1983	
Species: *Lepomis macrochirus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-84	
Test: Sept 28,1982 test	
TAN, mg/L	**% Survival**
Control (0.01)	100
0.84	100
0.88	100
1.22	80
1.88	10
2.29	0



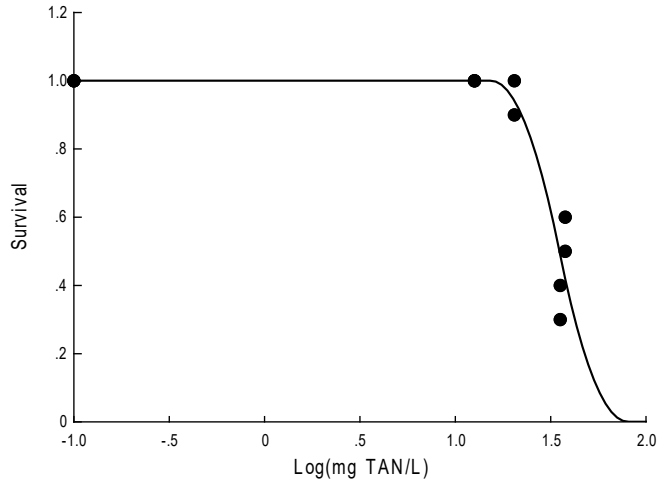
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.16	0.16135	6.1007E-05	0.16116	0.16155
S	4.5	4.9011	0.0031973	4.8909	4.9113
Y0	100	100	0.012405	99.96	100.04

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.450**	1.4493	1.4506	0.000061007	0.16135
20	1.22	1.2193	1.2207	0.00007625	0.086362
10	1.1183	1.1176	1.1191	0.000092008	0.048566
5	**1.0516**	1.0508	1.0524	0.00010159	0.021841
0	0.9064	0.9056	0.90719	0.00011968	-0.042681

LC50:LC5 = 1.379

Notes: Acceptable model fit.

Hazel et al. 1979	
Species: *Etheostoma spectabile*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-85	
Test: Single	
TAN, mg/L	**Proportion surviving**
0	1.0
0	1.0
12.6	1.0
12.6	1.0
20.4	0.9
20.4	1.0
35.5	0.3
35.5	0.4
37.7	0.5
37.7	0.6



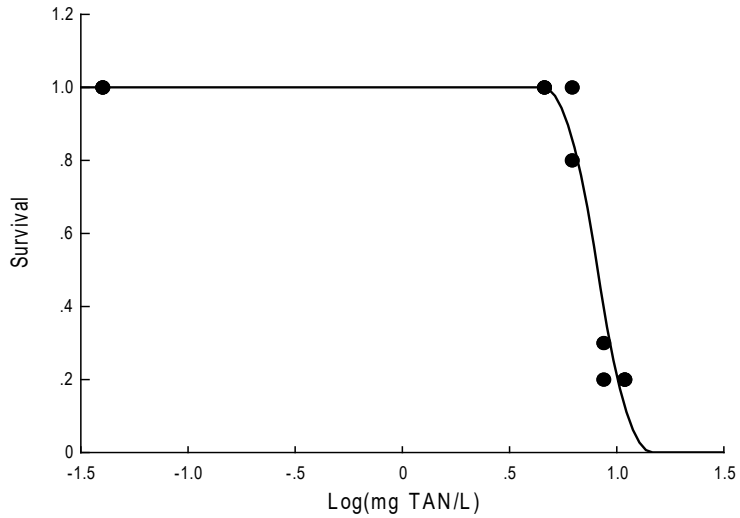
LC50:LC5 = 1.760

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.5459	0.027914	1.4887	1.6032
StDev	0.15	0.14665	0.036114	0.10247	0.25736
Y0	1	0.9999	0.001581	0.91171	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**35.151**	30.812	40.101	0.027914	1.5459
20	25.936	21.797	30.862	0.034964	1.4139
10	22.252	17.311	28.603	0.047094	1.3474
5	**19.967**	14.412	27.664	0.057041	1.3003
0	15.372	8.2939	28.489	0.083786	1.1867

Notes: Acceptable model fit.

Hazel et al. 1979	
Species: *Etheostoma spectabile*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-86	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.04	1.0
0.04	1.0
4.6	1.0
4.6	1.0
6.2	0.8
6.2	1.0
8.7	0.2
8.7	0.3
10.9	0.2
10.9	0.2



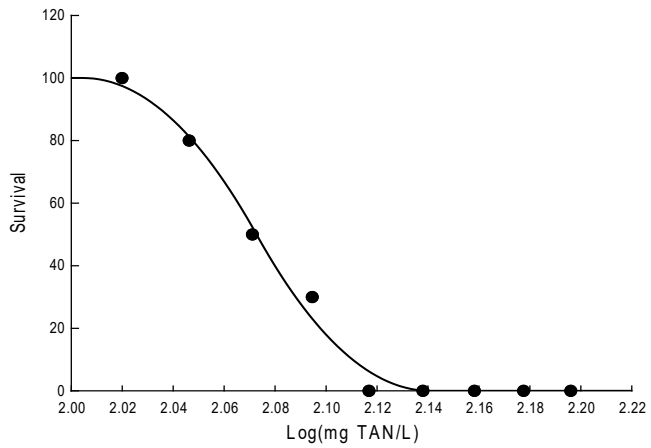
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.9	0.9112	0.01918	0.87198	0.95042
StDev	0.1	0.10365	0.016034	0.0797	0.14828
Y0	1	0.9999	0.002124	0.84648	1

LC50:LC5 = 1.491

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**8.1508**	7.4471	8.921	0.01918	0.9112
20	6.5748	5.8953	7.3326	0.022607	0.81788
10	5.9	5.1534	6.7546	0.027153	0.77085
5	**5.465**	4.6601	6.409	0.030998	0.73759
0	4.5426	3.5794	5.7649	0.041609	0.6573

Notes: Acceptable model fit.

Rani et al. 1998	
Species: *Oreochromis mossambicus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-87	
Test: Single	
TAN, mg/L	**% Survival**
105	100
111	80
118	50
124	30
131	0
137	0
144	0
150	0
157	0



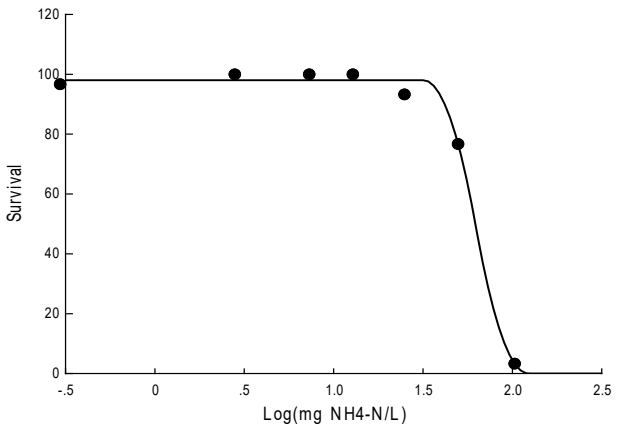
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2	2.0727	0.001841	2.0684	2.0771
S	15	14.672	1.2792	11.647	17.697
Y0	100	100			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**118.22**	117.04	119.41	0.0018408	2.0727
20	111.6	109.81	113.41	0.0029589	2.0477
10	108.4	106.08	110.76	0.0039639	2.035
5	**106.19**	103.62	108.83	0.0045037	2.0261
0	101.05	98.395	103.78	0.0048933	2.0045

LC50:LC5 = 1.113

Notes: Acceptable model fit despite no true control.

Schuytema and Nebeker 1999a	
Species: *Pseudacris regilla*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-89	
Test: ammonium chloride	
NH-4 N, mg/L	**% Survival**
0.2	97
2.8	100
7.3	100
12.8	100
24.9	93
49.7	77
102.9	3



	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.7	1.7959	0.014658	1.7553	1.8366
S	3	3.4208	0.40246	2.3034	4.5382
Y0	99	98	1.3375	94.286	101.71
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**62.51**	56.918	68.651	0.014658	1.7959
20	48.81	44.415	53.639	0.014758	1.6885
10	43.088	33.357	55.657	0.04004	1.6344
5	**39.451**	26.109	59.611	0.064566	1.5961
0	31.887	26.562	38.28	0.028581	1.5036

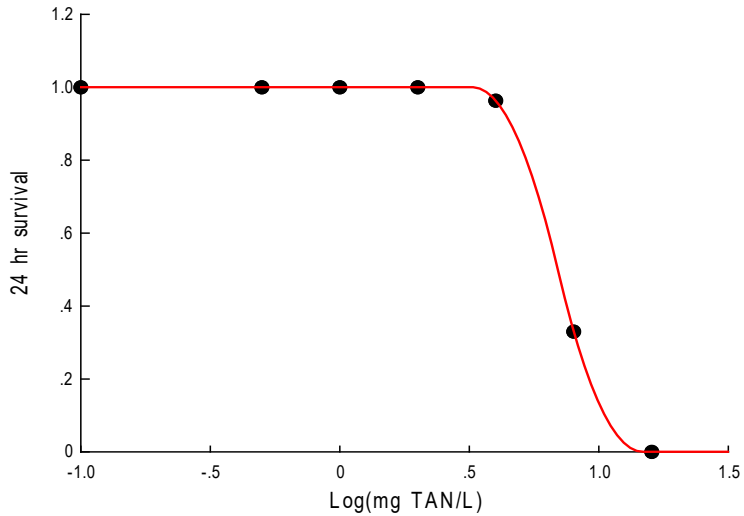
LC50:LC5 = 1.584

Notes: No TRAP flags or errors. Acceptable noise at low level effects.

Appendix A.2

Test Information, C-R Data and Resulting TRAP models for Acute Ammonia Toxicity Tests Considered Unacceptable for TAF and MAF Calculation

Wang et al. 2007b	
Species: *Actinonaias ligamentina* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-1	
Test: #1	
TAN, mg/L	**Proportion Surviving**
0.1	1.00
0.5	1.00
1	1.00
2	1.00
4	0.96
8	0.33
16	0



	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.84	0.8415	0.009133	0.8235	0.85951
StDev	0.14	0.13399	0.007631	0.12056	0.15082
Y0	0.99	0.9999	0.000289	0.99672	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**6.9423**	6.6604	7.2361	0.009133	0.8415
20	5.2586	5.043	5.4834	0.009195	0.72087
10	4.5717	4.3496	4.805	0.01089	0.66007
5	**4.1408**	3.9093	4.3859	0.012533	0.61708
0	3.2606	3.0058	3.5369	0.017502	0.51329

LC50:LC5 = 1.677

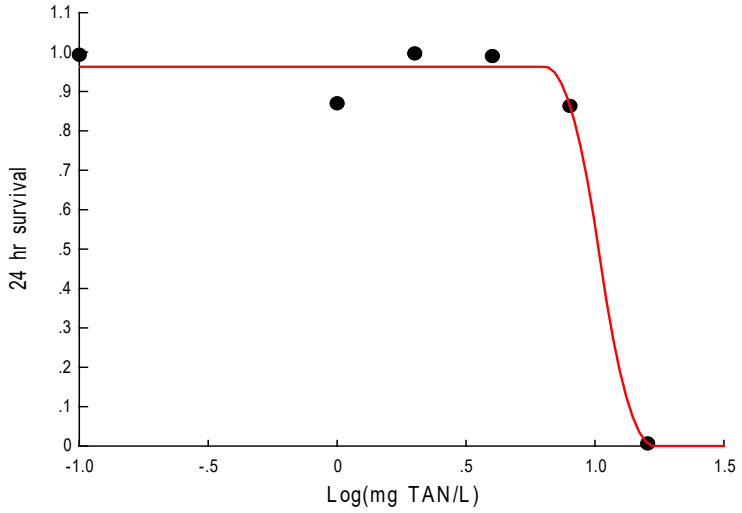
Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Actinonaias ligamentina* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-4	
Test: #3 (March 2004)	
TAN, mg/L	**Proportion Surviving**
0.1	0.99
1	0.87
2	1.00
4	0.99
8	0.86
16	0.01

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	1.0181	0.00696	1.0044	1.0319
StDev	0.086	0.085989	0.00377	0.079193	0.094072
Y0	0.97	0.9625	0.005484	0.95014	0.97252

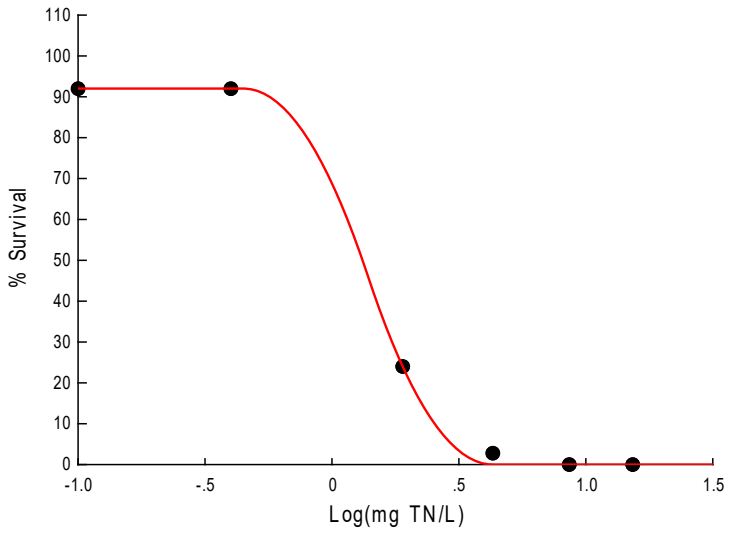
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**10.426**	10.101	10.761	0.00696	1.0181
20	8.7234	8.3821	9.0787	0.008758	0.94069
10	7.9739	7.6213	8.3427	0.009897	0.90167
5	**7.4831**	7.1208	7.8637	0.010835	0.87408
0	6.4191	6.038	6.8242	0.013266	0.80747

Notes: TRAP flagged for IP (No Unique Solution).



LC50:LC5 = 1.393

Wang et al. 2017	
Species: *Amblema plicata*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-5	
Test: Single	
TAN, mg/L	**% Survival**
0.1	92
0.4	92
1.9	24
4.3	2.8
8.6	0
15.3	0



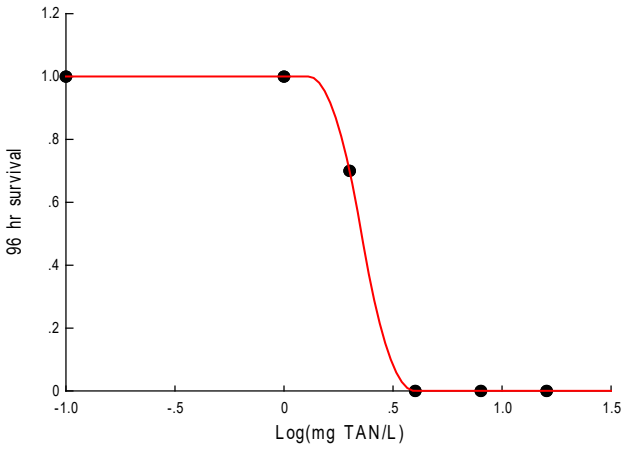
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.179	0.14245			
S	1.83	2.0373			
Y0	92	92			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.3882**				0.14245
20	0.9163				-0.03796
10	0.74321				-0.12889
5	**0.64094**				-0.19318
0	0.44832				-0.34841

Notes: TRAP flagged for IP (No Unique Solution).

LC50:LC5 = 2.166

Wang et al. 2007b	
Species: *Lampsilis abrupta* (2-mo old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-9	
Test: Single	
TAN, mg/L	**Proportion Surviving**
0.1	1.0
1	1.0
2	0.70
4	0.0
8	0.0
16	0.0

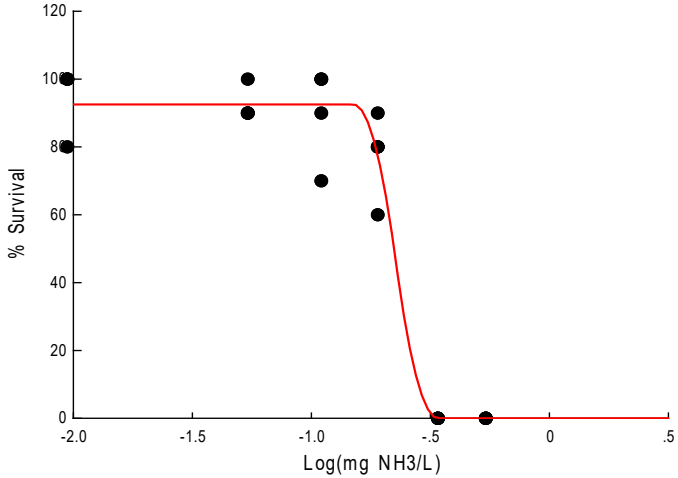


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.35	0.35571			
StDev	0.1	0.099014			
Y0	1	0.9999			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**2.2684**				0.35571
20	1.8474				0.26657
10	1.6659				0.22164
5	**1.5484**				0.18987
0	1.2977				0.11318

LC50:LC5 = 1.465

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

Mummert et al. 2003	
Species: *Lampsilis fasciola* (2-5 d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-11	
Test: Single	
NH3, mg/L	**% Survival**
0.01	100
0.01	100
0.01	100
0.01	80
0.054	100
0.054	90
0.054	90
0.054	90
0.11	100
0.11	100
0.11	90
0.11	70
0.19	90
0.19	80
0.19	80
0.19	60
0.34	0
0.34	0
0.34	0
0.34	0
0.54	0
0.54	0
0.54	0
0.54	0



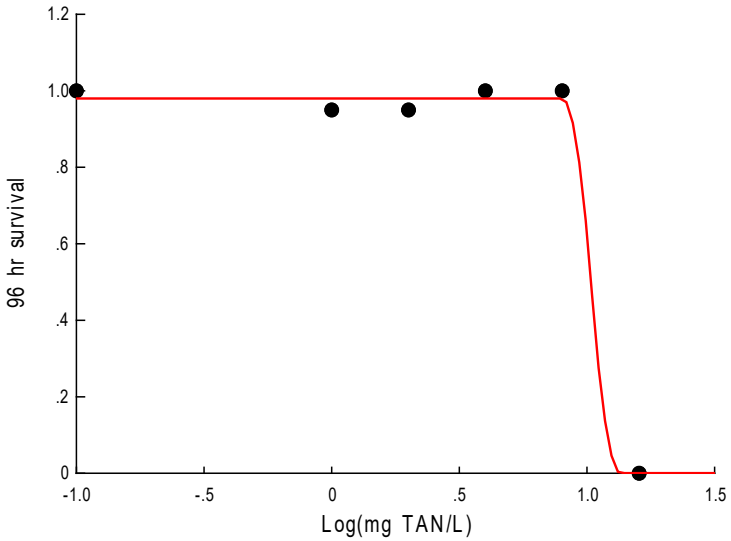
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.65	-0.64503	0.81873	-2.3477	1.0576
S	5	5.6485	60.674	-120.53	131.83
Y0	92.5	92.5	2.4398	87.426	97.574

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**0.22645**	0.0044907	11.419	0.81873	-0.64503
20	0.19494	0.181	0.20995	0.015495	-0.7101
10	0.18076	0.16626	0.19653	0.017466	-0.74289
5	**0.17136**	0.15629	0.18789	0.019225	-0.76608
0	0.15064	0.13494	0.16817	0.022988	-0.82207

LC50:LC5 = 1.321

Notes: TRAP flagged for IP (No Unique Solution).

Wang et 2007b	
Species: *Lampsilis rafinesqueana* (<5-d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-15	
Test: #1	
TAN, mg/L	**Proportion Surviving**
0.1	1.00
1	0.95
2	0.95
4	1.00
8	1.00
16	0

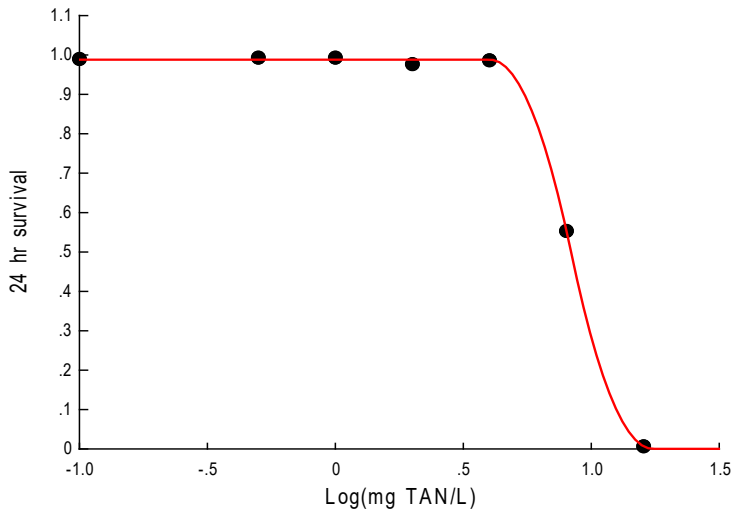


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	1.017			
StDev	0.07	0.046441			
Y0	0.98	0.9798			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**10.399**				1.017
20	9.4432				0.97512
10	8.9955				0.95402
5	**8.6917**				0.93911
0	8				0.90309

LC50:LC5 = 1.196

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Lampsilis rafinesqueana* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-17	
Test: NMAm1d	
TAN, mg/L	**Proportion Surviving**
0.1	0.99
0.5	0.99
1	0.99
2	0.98
4	0.99
8	0.55
16	0.01



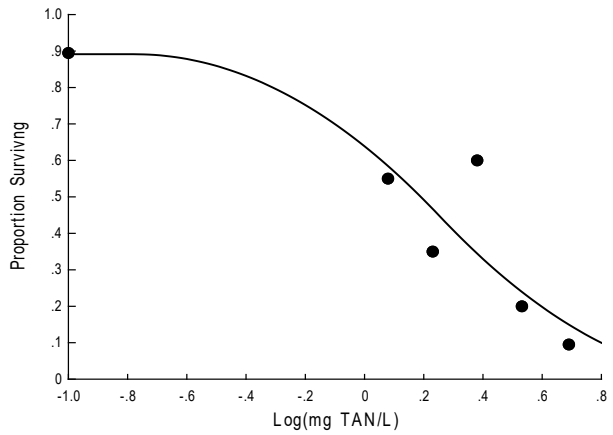
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.92	0.92278	9.26E-03	0.90452	0.94104
StDev	0.13	0.12983	7.08E-03	0.11731	0.14535
Y0	0.99	0.988	2.81E-03	0.9811	0.99287

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**8.3711**	8.0265	8.7306	0.0093	0.92278
20	6.3959	5.9872	6.8324	0.0145	0.8059
10	5.5846	5.1797	6.0212	0.0165	0.74699
5	**5.0739**	4.6624	5.5217	0.0184	0.70534
0	4.0251	3.6152	4.4815	0.0231	0.60478

LC50:LC5 = 1.650

Notes: TRAP flagged for IP (No Unique Solution).

Myers-Kinzie 1998	
Species: *Lampsilis siliquoidea* (juvenile)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-18	
Test: 5-d old	
TAN, mg/L	**Proportion Surviving**
0.1	0.895
1.2	0.55
1.7	0.35
2.4	0.60
3.4	0.20
4.9	0.10

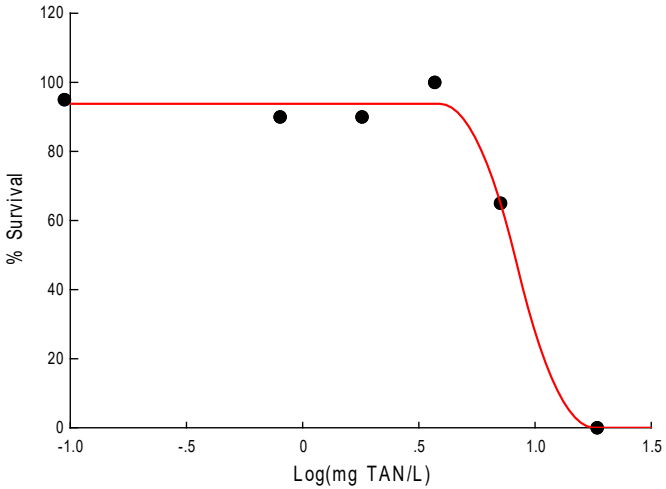


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.3	0.25554	0.088737	0.071783	0.4393
S	0.4	0.4216	0.13558	0.29458	0.73989
Y0	0.895	0.89106	0.071321	0.6646	0.98568
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.8011**	1.1797	2.7497	0.088735	0.25553
20	0.75155	0.29505	1.9143	0.186	-0.12404
10	0.48379	0.12728	1.8388	0.24763	-0.31534
5	**0.35431**	0.064686	1.9407	0.29402	-0.45062
0	0.16704	0.00388	7.1906	0.50392	-0.77719

LC50:LC5 = 5.083

Notes: Not core data. No effect within area of concern.

Miao et al. 2010	
Species: *Lampsilis siliquoidea* (3 mo old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-19	
Test: Single	
TAN, mg/L	**% Survival**
<0.1	95
0.8	90
1.8	90
3.7	100
7.1	65
18.5	0



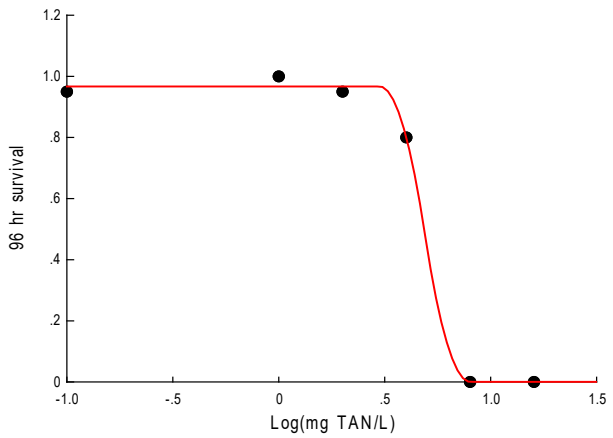
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	0.92541	5.962	-18.048	19.899
S	1.5	2.9245	235.14	-745.41	751.26
Y0	93.75	93.75	2.3936	86.133	101.37

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**8.4218**			5.962	0.92541
20	6.3056	4.9165	8.0872	3.40E-02	0.79973
10	5.4499	4.1284	7.1943	3.79E-02	0.73639
5	**4.9158**	3.6801	6.5665	3.95E-02	0.6916
0	3.8323	2.7802	5.2826	4.38E-02	0.58346

LC50:LC5 = 1.713

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Lampsilis siliquoidea* (2-mo old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-20	
Test: Single	
TAN, mg/L	**Proportion Surviving**
0.1	0.95
1	1.00
2	0.95
4	0.80
8	0.00
16	0.00

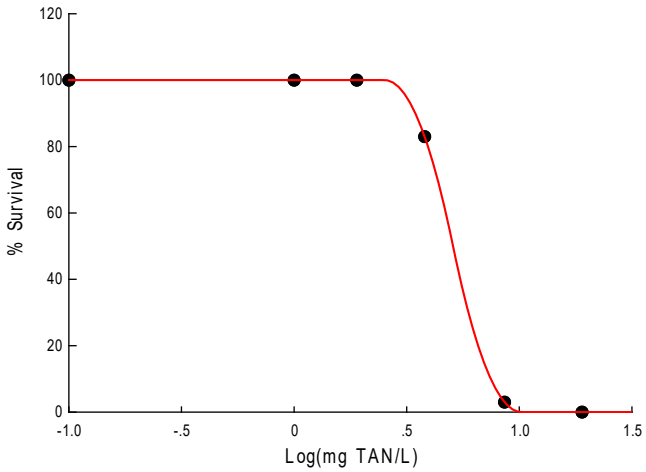


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.7	0.69001			
StDev	0.1	0.086988			
Y0	0.96667	0.96667			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**4.8979**				0.69001
20	4.0897				0.61169
10	3.7344				0.57222
5	**3.502**				0.54431
0	2.9987				0.47693

LC50:LC5 = 1.399

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

Wang et al. 2008	
Species: *Lampsilis siliquoidea* (7-d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-23	
Test: Experiment 1- pH=8.0	
TAN, mg/L	**% Survival**
Control (0.1)	100
1	100
1.9	100
3.8	83
8.6	3
19	0



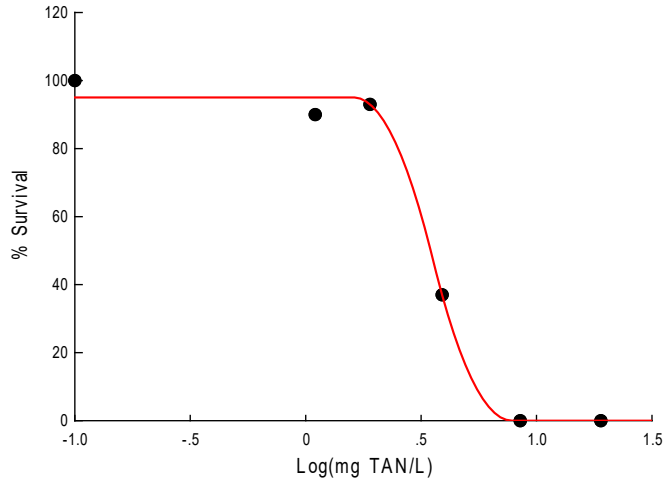
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.7	0.70597	0	0.70597	0.70597
S	3.3	3.3039	0	3.3039	3.3039
Y0	100	100	0	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**5.0812**	5.0812	5.0812	0	0.70597
20	3.933	3.933	3.933	0	0.59472
10	3.4567	3.4567	3.4567	0	0.53866
5	**3.1551**	3.1551	3.1551	0	0.49901
0	2.531	2.531	2.531	0	0.4033

LC50:LC5 = 1.610

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2008	
Species: *Lampsilis siliquoidea* (7-d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-24	
Test: Experiment 1- pH=8.5	
TAN, mg/L	**% Survival**
Control (0.1)	100
1.1	90
1.9	93
3.9	37
8.5	0
19	0



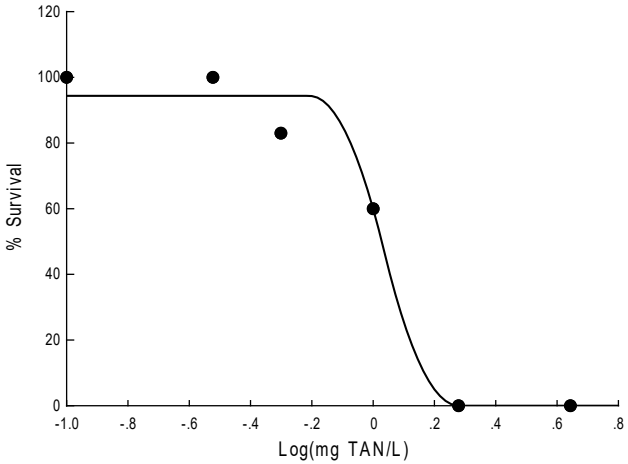
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.55	0.55086	0.020101	0.48689	0.61483
S	3	2.9209	0.80711	0.35231	5.4895
Y0	94.333	95	2.8868	85.813	104.19

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**3.5552**	3.0683	4.1194	0.020101	0.55086
20	2.6609	1.868	3.7904	0.048282	0.42503
10	2.2994	1.4295	3.6985	0.06486	0.36161
5	**2.0738**	1.1808	3.6422	0.076859	0.31677
0	1.6162	0.73678	3.5454	0.1072	0.2085

LC50:LC5 = 1.714

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2008	
Species: *Lampsilis siliquoidea* (7-d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-25	
Test: Experiment 1- pH=9.0	
TAN, mg/L	**% Survival**
Control (0.1)	100
0.3	100
0.5	83
1	60
1.9	0
4.4	0

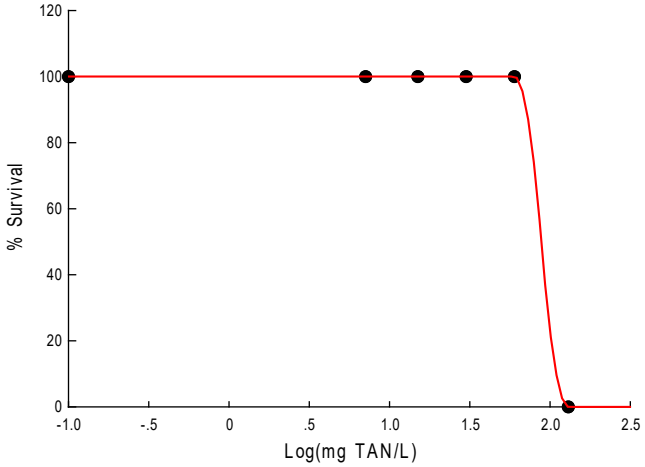


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.03	0.035716	2.8802	-9.1305	9.2019
S	2.5	4.1108	331.5	-1050.9	1059.1
Y0	100	94.333	4.6268	79.609	109.06
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.0857**			2.8802	0.035716
20	0.8837	0.61346	1.273	0.049811	-0.05369
10	0.79661	0.55448	1.1445	0.049446	-0.09876
5	**0.74025**	0.51427	1.0655	0.049706	-0.13062
0	0.62009	0.42061	0.91418	0.052971	-0.20755

LC50:LC5 = 1.467

Notes: Poor model fit.

Wang et al. 2008	
Species: *Lampsilis siliquoidea* (7-d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-26	
Test: Experiment 2- pH=6.6	
TAN, mg/L	**% Survival**
Control (0.1)	100
7.1	100
15	100
30	100
60	100
130	0



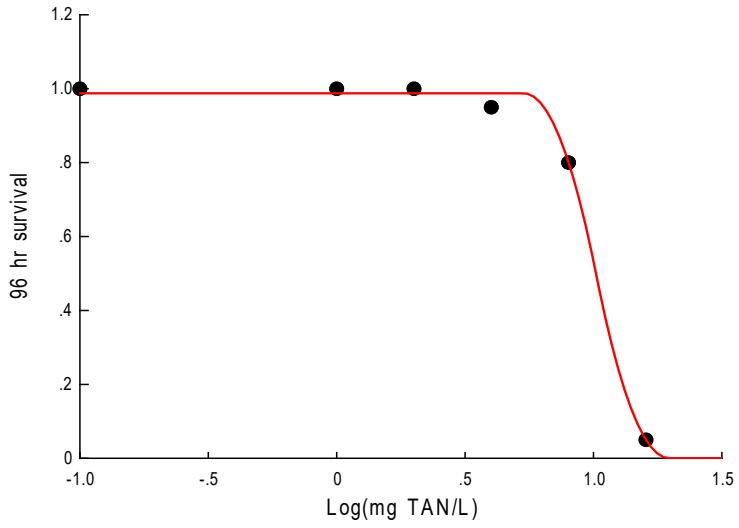
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.946	1.946	1.31E-07	1.946	1.946
S	5.795	5.9561	4.64E-06	5.956	5.9561
Y0	100	100	1.60E-11	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**88.318**				1.946
20	76.619				1.8843
10	71.324				1.8532
5	**67.802**				1.8312
0	60				1.7782

LC50:LC5 = 1.303

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Lampsilis siliquoidea* (<5 d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-28	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.1	1.00
1	1.00
2	1.00
4	0.95
8	0.80
16	0.05

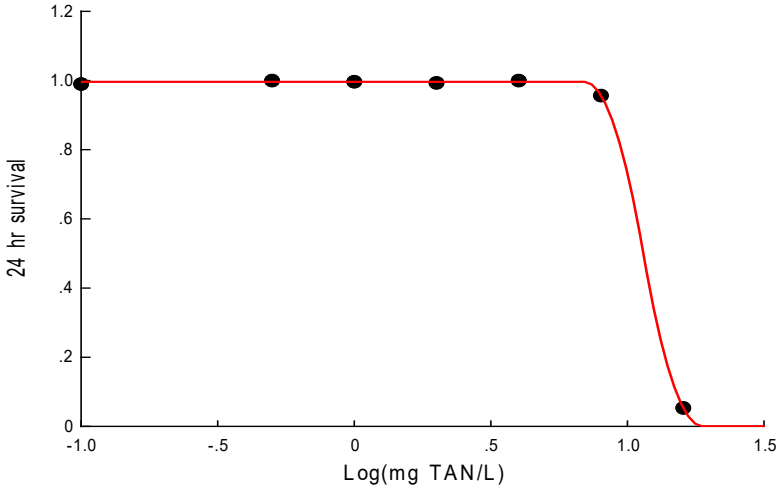


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	1.0115	0.031069	0.94473	1.0782
StDev	0.1	0.11531	0.023183	0.08303	0.18856
Y0	1	0.9875	0.012422	0.93231	0.99968
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**10.268**	8.8051	11.973	0.031069	1.0115
20	8.0847	6.5359	10	0.041149	0.90766
10	7.1671	5.4829	9.3687	0.048929	0.85534
5	**6.5818**	4.7347	9.1496	0.056827	0.81835
0	5.3583	3.2411	8.8587	0.070743	0.72903

LC50:LC5 = 1.560

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Lampsilis siliquoidea* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-29	
Test: #1	
TAN, mg/L	**Proportion surviving**
0.1	0.99
0.5	1.00
1	1.00
2	0.99
4	1.00
8	0.96
16	0.05



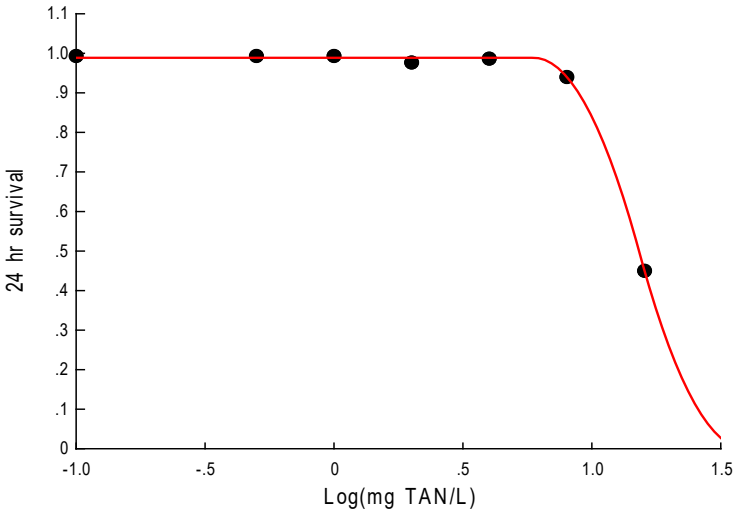
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.07	1.0586	6.28E-03	1.0462	1.071
StDev	8.80E-02	8.83E-02	3.69E-03	8.16E-02	9.62E-02
Y0	0.999	0.996	1.63E-03	0.99131	0.99853

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**11.444**	11.122	11.775	6.28E-03	1.0586
20	9.5298	9.2228	9.847	7.20E-03	0.97908
10	8.6901	8.3736	9.0185	8.14E-03	0.93902
5	**8.1414**	7.8158	8.4805	8.94E-03	0.9107
0	6.9552	6.6074	7.3213	1.12E-02	0.84231

LC50:LC5 = 1.406

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Lampsilis siliquoidea* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-30	
Test: #3	
TAN, mg/L	**Proportion surviving**
0.1	0.99
0.5	0.99
1	0.99
2	0.98
4	0.99
8	0.94
16	0.45



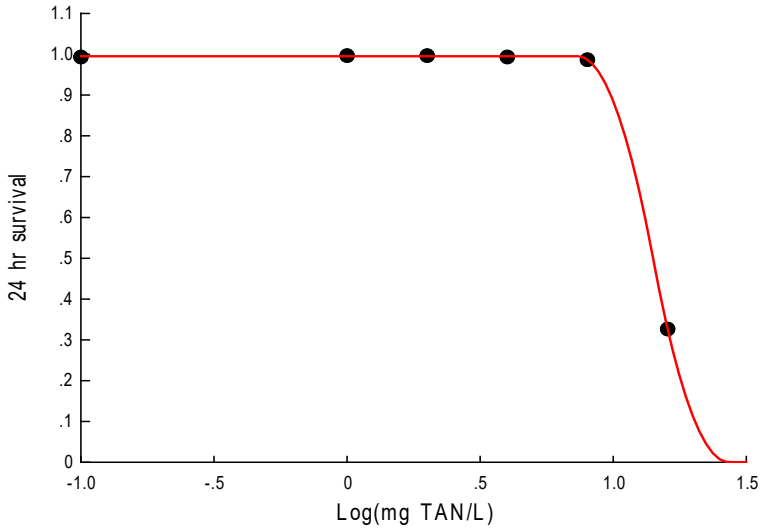
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.19	1.1852	0.011813	1.1619	1.2085
StDev	0.17	0.16785	0.012412	0.14665	0.19628
Y0	0.99	0.98867	0.002733	0.98192	0.99338

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**15.319**	14.519	16.163	0.011813	1.1852
20	10.817	10.239	11.428	0.012027	1.0341
10	9.0772	8.4582	9.7415	0.015366	0.95795
5	**8.0186**	7.363	8.7325	0.018436	0.9041
0	5.944	5.2237	6.7637	0.027318	0.77408

LC50:LC5 = 1.910

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Lampsilis siliquoidea* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-31	
Test: #4 (April 2004)	
TAN, mg/L	**Proportion surviving**
0.1	0.99
1	1.00
2	1.00
4	0.99
8	0.99
16	0.33

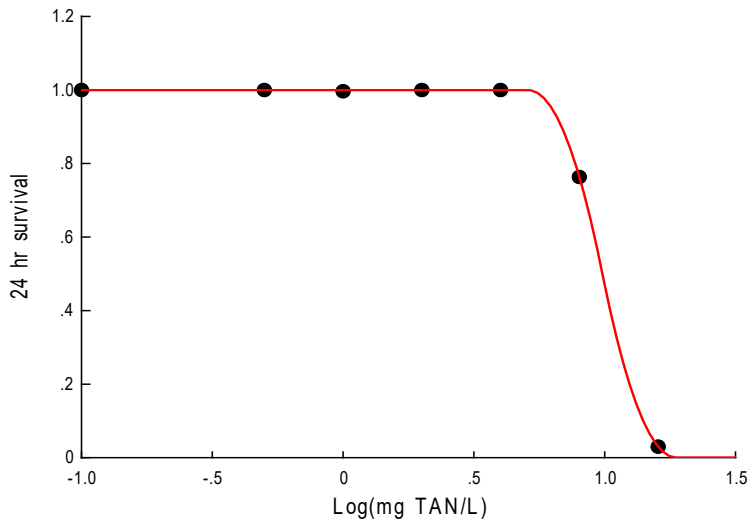


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.15	1.1502	0.008313	1.1339	1.1666
StDev	0.12	0.1159	0.006908	0.1038	0.13123
Y0	0.99	0.995	0.002036	0.98915	0.99816
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**14.133**	13.61	14.677	0.008313	1.1502
20	11.115	10.651	11.599	0.009362	1.0459
10	9.8471	9.3567	10.363	0.01116	0.99331
5	**9.039**	8.5254	9.5836	0.012727	0.95612
0	7.351	6.7851	7.964	0.017182	0.86634

LC50:LC5 = 1.564

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Lampsilis siliquoidea* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-33	
Test: #2 (repeat)	
TAN, mg/L	**Proportion surviving**
0.1	1.00
0.5	1.00
1	1.00
2	1.00
4	1.00
8	0.76
16	0.03



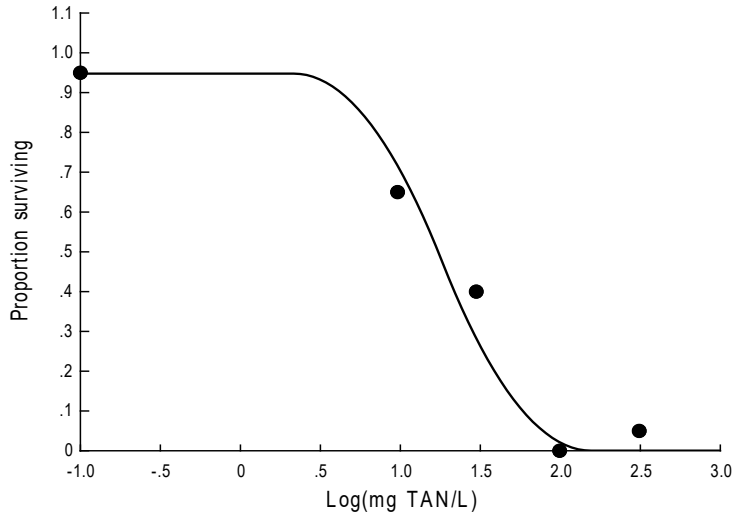
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.99	0.99123	0.007862	0.97573	1.0067
StDev	0.11	0.11506	0.005802	0.10473	0.12768
Y0	0.99	0.99933	0.000666	0.99629	0.99998

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**9.8**	9.4565	10.156	0.007862	0.99123
20	7.7203	7.3566	8.1021	0.010607	0.88764
10	6.8459	6.4617	7.2529	0.012653	0.83543
5	**6.288**	5.8927	6.7097	0.014179	0.79851
0	5.1213	4.7112	5.5672	0.018051	0.70938

LC50:LC5 = 1.559

Notes: TRAP flagged for IP (No Unique Solution).

Scheller et al 1997	
Species: *Pyganodon grandis* (adult)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-36	
Test: pH 7.71 test	
TAN, mg/L	**Proportion surviving**
0.1	0.95
9.6	0.65
29.8	0.4
99	0
311.1	0.05



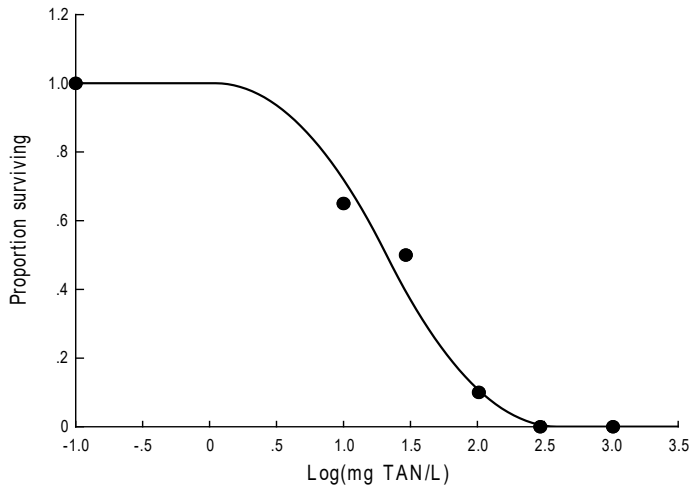
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.25	1.2628	0.096872	1.0568	1.4689
S	0.38	0.37956	0.079223	0.27049	0.6355
Y0	0.95	0.94769	0.049676	0.74857	0.99846

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**18.316**	11.396	29.437	0.096872	1.2628
20	8.3391	3.9215	17.733	0.14697	0.92112
10	5.6091	1.5992	19.674	0.22977	0.7489
5	**4.2376**	1.3118	13.689	0.20189	0.62712
0	2.1534	0.33035	14.037	0.25878	0.33311

LC50:LC5 = 4.322

Notes: No effect within area of concern.

Scheller et al 1997	
Species: *Pyganodon grandis* (adult)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-37	
Test: pH 7.5 test	
TAN, mg/L	**Proportion surviving**
0.1	1.00
10	0.65
29.2	0.50
102.5	0.10
294.7	0.00
1030	0.00

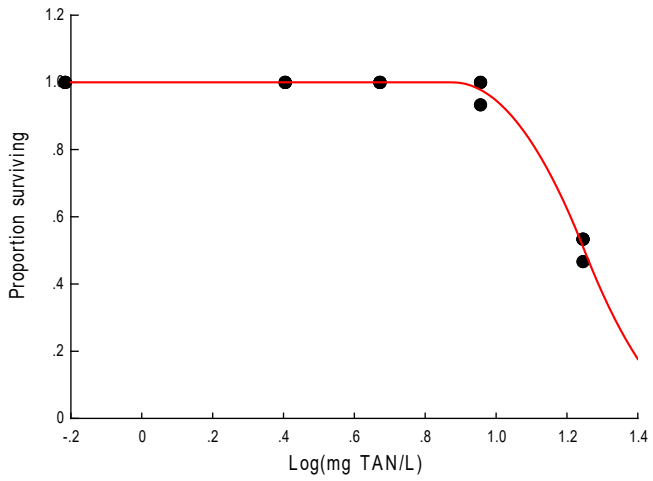


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.3	1.3218	0.10493	1.1055	1.538
S	0.5	0.52211	0.087665	0.39381	0.7748
Y0	1	0.9999	0.002236	0.83139	1
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**20.977**	12.751	34.511	0.10493	1.3218
20	7.1072	2.8819	17.528	0.18475	0.8517
10	4.119	1.4946	11.352	0.19972	0.61479
5	**2.8008**	0.85189	9.2081	0.22588	0.44727
0	1.1037	0.19577	6.2223	0.28801	4.29E-02

LC50:LC5 = 7.490

Notes: No effect within area of concern.

Wade 1992	
Species: *Utterbackia imbecillis*	
Test Endpoint: 9 day Survival	
C-R Curve Label: Am-Acute-38	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.52	1.00
0.52	1.00
0.52	1.00
2.54	1.00
2.54	1.00
2.54	1.00
4.7	1.00
4.7	1.00
4.7	1.00
9.04	1.00
9.04	0.933
9.04	1.00
17.59	0.533
17.59	0.467
17.59	0.533



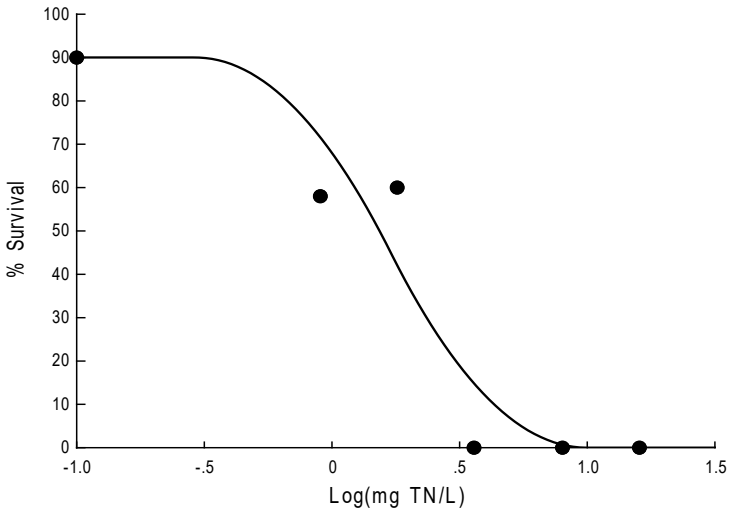
LC50:LC5 = 1.794

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.25	1.2494	2.84E-02	1.1913	1.3075
S	0.15	0.15161	2.51E-02	0.11474	0.22351
Y0	0.999	0.9999	8.68E-04	0.97244	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**17.759**	15.534	20.302	2.84E-02	1.2494
20	12.969	11.58	14.526	2.34E-02	1.1129
10	11.069	9.5994	12.765	2.83E-02	1.0441
5	**9.8965**	8.2987	11.802	3.38E-02	0.99548
0	7.5517	5.6218	10.144	4.99E-02	0.87805

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2017	
Species: *Utterbackia imbecilis* (glochidia)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-39	
Test: Single	
TAN, mg/L	**% Survival**
0.1	90
0.9	58
1.8	60
3.6	0
8	0
16	0



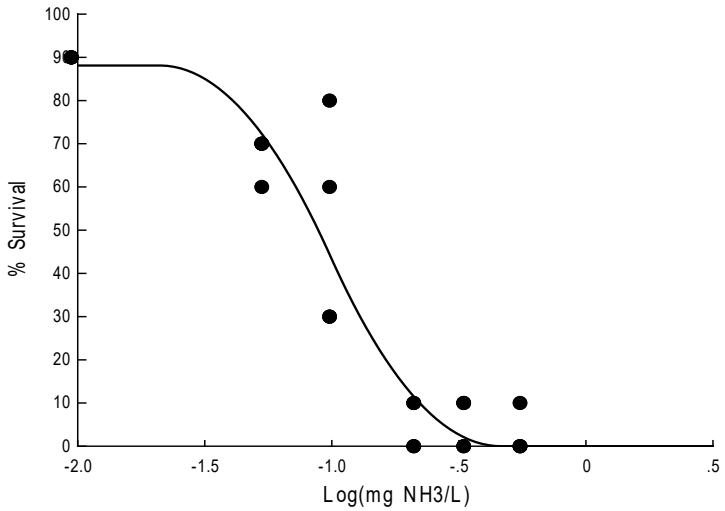
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.25	0.23034	0.088434	-0.015196	0.47587
S	1.5	1.306	0.55383	-0.2317	2.8437
Y0	90	90			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.6996**	0.96562	2.9914	0.088434	0.23034
20	0.889	0.31487	2.51	0.16236	-0.051097
10	0.6413	0.14971	2.7471	0.22756	-0.19294
5	**0.50905**	0.094623	2.7386	0.2632	-0.29324
0	0.29149	0.045132	1.8826	0.29179	-0.53538

LC50:LC5 = 3.339

Notes: No effect within area of concern.

Mummert et al. 2003	
Species: *Villosa iris* (2-5 d old juveniles)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-45	
Test: Single	
TAN, mg/L	**% Survival**
0.005	90
0.005	90
0.005	90
0.005	90
0.053	70
0.053	70
0.053	70
0.053	60
0.098	80
0.098	60
0.098	30
0.098	30
0.21	10
0.21	10
0.21	0
0.21	0
0.33	10
0.33	10
0.33	0
0.33	0
0.55	10
0.55	0
0.55	0
0.55	0



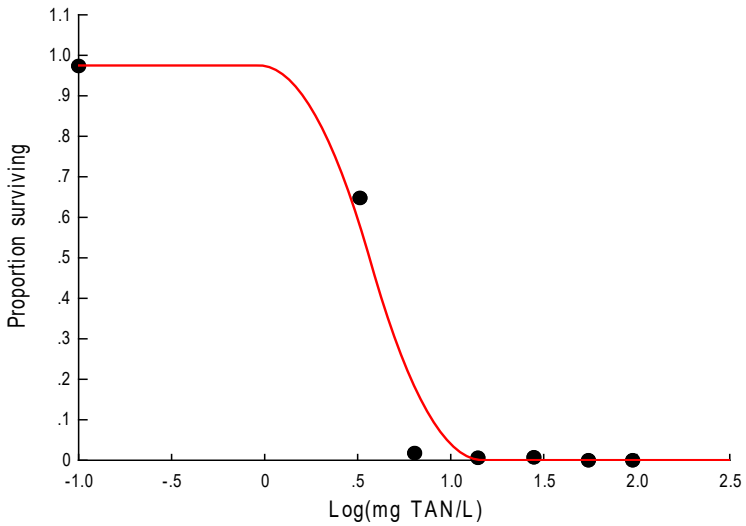
LC50:LC5 = 2.879

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-1	-1.0061	4.27E-02	-1.0948	-0.91735
S	1.5	1.4888	0.2661	0.93537	2.0421
Y0	90	88.091	5.4161	76.828	99.354

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**0.098613**	0.080392	0.12096	0.042662	-1.0061
20	0.055854	0.039399	0.079181	0.072883	-1.2529
10	0.04194	0.025352	0.069381	0.10512	-1.3774
5	**0.034248**	0.018233	0.064333	0.13165	-1.4654
0	0.021001	0.010613	0.041554	0.14252	-1.6778

Notes: No effect within area of concern.

Scheller et al 1997	
Species: *Villosa iris* (glochidia)	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-47	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.01	0.97
3.25	0.65
6.4	0.02
14	0.01
28	0.01
55	0.00
95	0.00



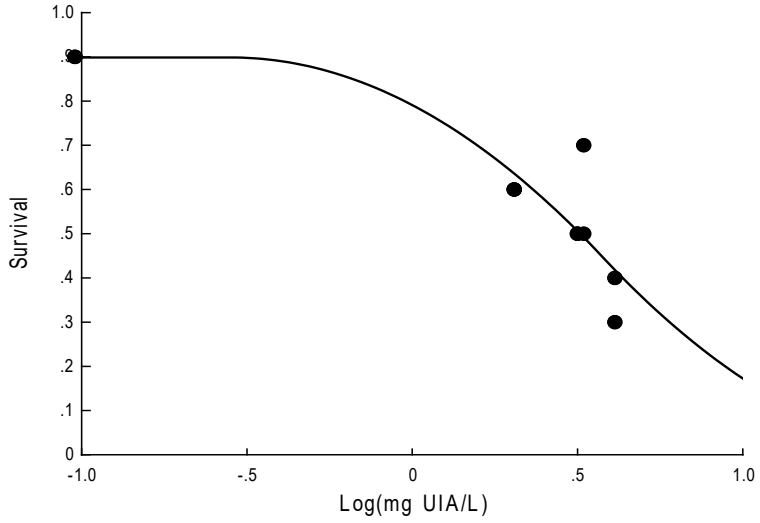
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.12112	0.57144	0.023246	0.52538	0.6175
S	0.61041	0.2455	0.017302	0.21577	0.28482
Y0	0.97368	0.97486	0.01466	0.92674	0.99504

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**3.7277**	3.3526	4.1448	0.023246	0.57144
20	2.2409	1.9111	2.6275	0.034715	0.35042
10	1.7339	1.4331	2.0978	0.041292	0.23902
5	**1.4463**	1.1676	1.7915	0.046118	0.16025
0	0.93344	0.71057	1.2262	0.057616	-0.02992

LC50:LC5 = 2.557

Notes: TRAP flagged for IP (No Unique Solution).

Evans 1979	
Species: *Orconectes nais* (2.78 cm)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-52	
Test: Single	
Unionized ammonia NH3, mg/L	**Proportion surviving**
0.04	0.9
0.04	0.9
2.035	0.6
2.035	0.6
3.16	0.5
3.16	0.5
3.3	0.7
3.3	0.5
4.1	0.3
4.1	0.4

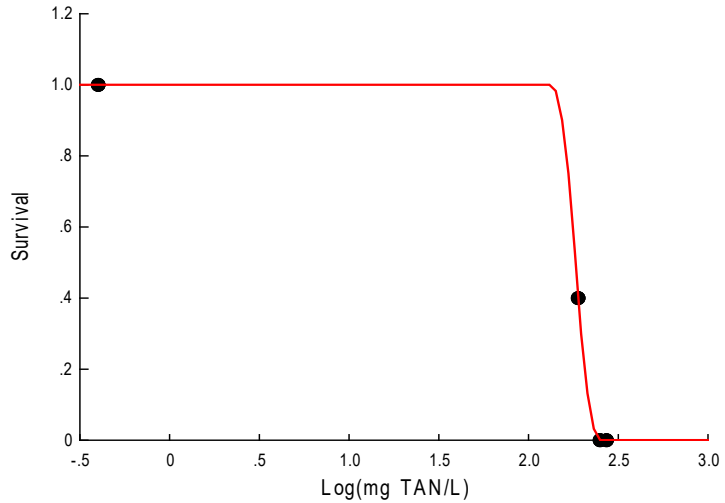


LC50:LC5 = 5.851

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.6	0.57308	0.1026	0.35902	0.78713
StDev	0.5	0.45808	0.34387	0.32007	0.8039
Y0	0.9	0.89842	0.067529	0.68107	0.98713
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**3.7418**	2.2857	6.1253	0.1026	0.57308
20	1.4477	0.34403	6.0917	0.28363	0.16067
10	0.89705	0.080005	10.058	0.44456	-0.047183
5	**0.6395**	0.02374	17.227	0.56446	-0.19416
0	0.2825	0.00040779	195.7	0.86727	-0.54898

Notes: No effect within area of concern.

Wicks and Randall 2002	
Species: *Oncorhynchus mykiss* (juvenile)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-54	
Test: Single	
TAN, mg/L	**Proportion surviving**
0.4	1.00
0.4	1.00
189	0.40
189	0.40
250	0.00
250	0.00
272	0.00
272	0.00

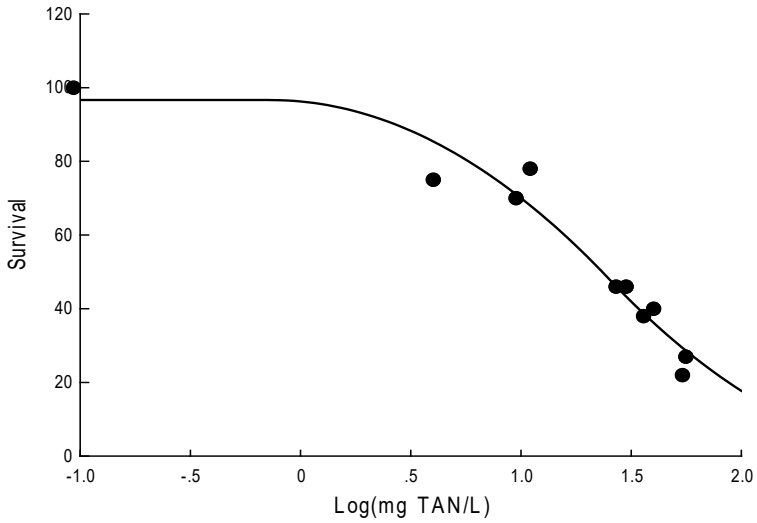


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.2623	2.2621			
StDev	0.062719	0.055447			
Y0	1	0.9999			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**182.86**				2.2621
20	163.01				2.2122
10	153.83				2.187
5	**147.66**				2.1693
0	133.75				2.1263

LC50:LC5 = 1.238

Notes: TRAP flagged for IP (No Unique Solution).

Wicks et al. 2002	
Species: *Oncorhynchus mykiss* (40 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-55	
Test: Swimming	
TAN, mg/L	**% Survival**
0.05	100
4	75
11	78
9.5	70
27	46
30	46
36	38
40	40
54	22
56	27



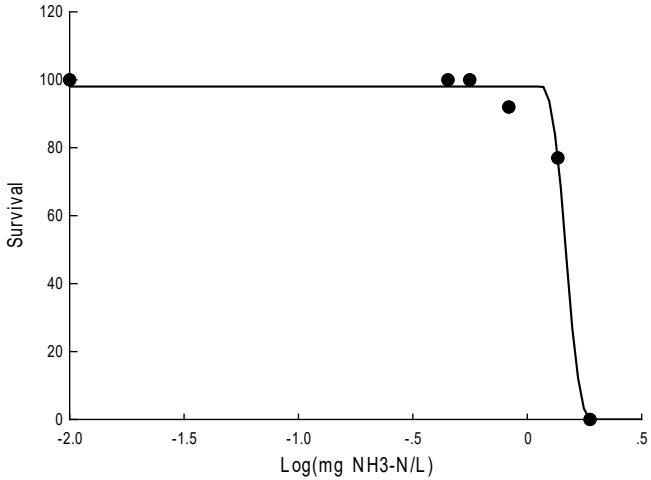
LC50:LC5 = 11.16

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.3955	0.076062	1.2157	1.5754
S	1	0.65278	0.11673	0.37674	0.92881
Y0	100	96.621	6.3199	81.677	111.57

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**24.86**	16.431	37.616	0.076062	1.3955
20	6.799	2.8895	16	0.15717	0.83247
10	3.538	1.111	11.263	0.2127	0.54869
5	**2.229**	0.54258	9.1539	0.25948	0.34803
0	0.73	0.067208	7.9391	0.4382	-0.1364

Notes: No effect within area of concern.

Swigert and Spacie 1983	
Species: *Campostoma anomalum* (2.1 g)	
Test Endpoint: 4 day Survival	
C-R Curve Label: Am-Acute-57	
Test: Single	
NH3-N, mg/L	**% Survival**
0.01	100
0.45	100
0.56	100
0.83	92
1.36	77
1.88	0



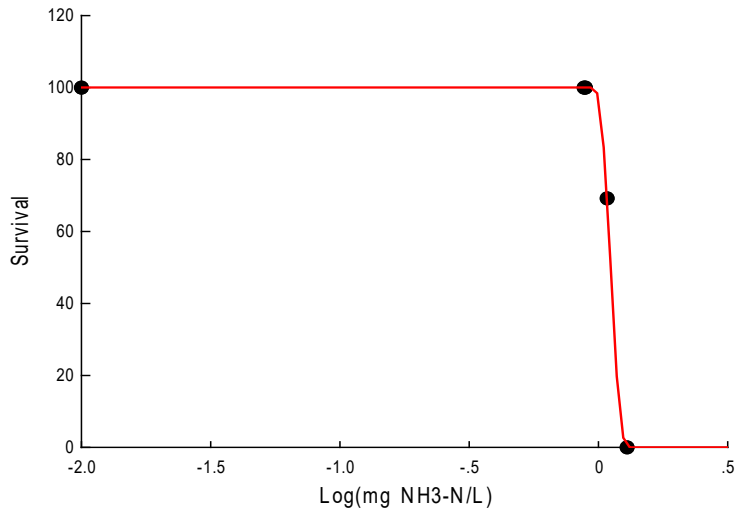
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.125	0.16964	3.0863	-9.6522	9.9915
S	6	9.5648	817.58	-2592.3	2611.5
Y0	100	98	2	91.635	104.36

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.4779**	2.2E-10	9806800000	3.0863	0.16964
20	1.3528	1.2837	1.4255	0.0071529	0.13122
10	1.2938	1.214	1.3787	0.0086776	0.11185
5	**1.2536**	1.1695	1.3437	0.0094742	0.098156
0	1.1617	1.0709	1.2602	0.011109	0.065095

LC50:LC5 = 1.179

Notes: Poor model fit. Large SE for X50, steepness (S).

Swigert and Spacie 1983	
Species: *Cyprinella spiloptera* (0.5 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-60	
Test: Single	
NH3-N, mg/L	**% Survival**
0.01	100
0.88	100
0.89	100
1.08	69.2
1.29	0

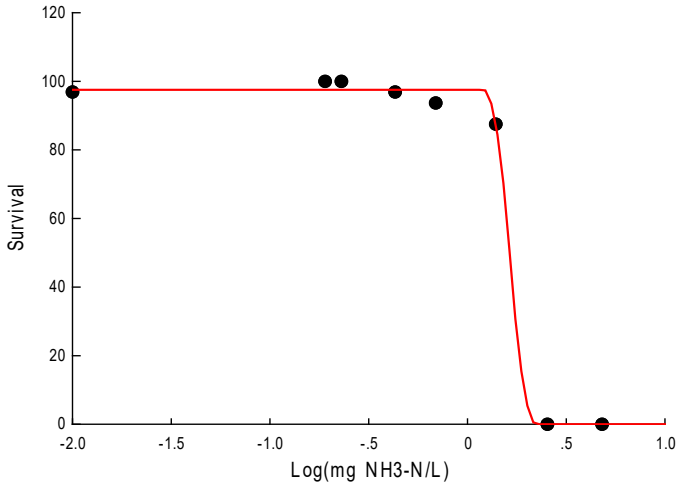


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.05	0.047086			
S	8	15.747			
Y0	100	100			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.1145**				0.047086
20	1.0562	1.0562	1.0562	5.8847E-14	0.023746
10	1.028	1.028	1.028	6.5628E-14	0.011982
5	**1.0085**	1.0085	1.0085	6.8491E-14	0.003664
0	0.9629	0.9629	0.9629	7.6208E-14	-0.01642

LC50:LC5 = 1.105

Notes: TRAP flagged for IP (No Unique Solution).

Hasan and MacIntosh 1986	
Species: *Cyprinus carpio*	
Test Endpoint: 168 and 96 hr Survival	
C-R Curve Label: Am-Acute-61	
Test: Trial 1	
NH3-N, mg/L	**% Survival**
0	96.9
0.19	100
0.23	100
0.43	96.9
0.69	93.7
1.39	87.5
2.54	0
4.8	0

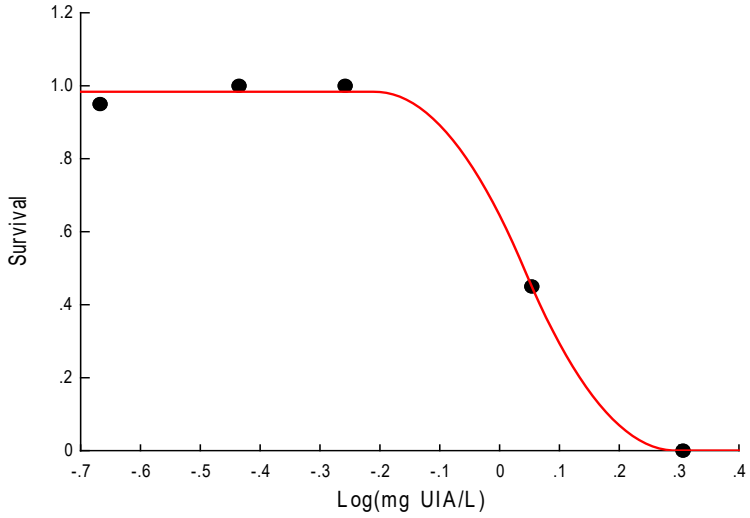


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.2	0.2151			
S	6	7.5897			
Y0	97.5	97.5			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.641**				0.2151
20	1.4678				0.16667
10	1.3876				0.14226
5	**1.3335**				0.12501
0	1.2115				8.33E-02

LC50:LC5 = 1.231

Notes: TRAP flagged for IP (No Unique Solution).

EA Engineering 1985	
Species: *Notemigonus crysoleucas*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-64	
Test: 254	
Unionized ammonia (NH3), mg/L	**Proportion surviving**
0.215	0.95
0.367	1.00
0.552	1.00
1.132	0.45
2.025	0.00



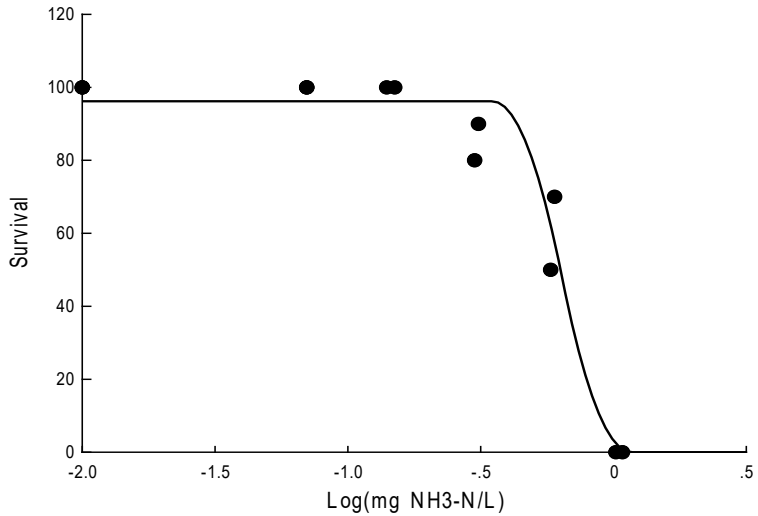
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0	4.30E-02			
StDev	0.29	0.10256			
Y0	0.98333	0.98333			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.104**				4.30E-02
20	0.89251				-4.94E-02
10	0.80182				-9.59E-02
5	**0.74331**				-0.12883
0	0.61905				-0.20828

LC50:LC5 = 1.485

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

Swigert and Spacie 1983	
Species: *Notemigonus crysoleucas* (8.7 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-65	
Test: Single	
Unionized ammonia nitrogen (NH3-N), mg/L	**Proportion surviving**
0.01	100
0.01	100
0.07	100
0.07	100
0.15	100
0.14	100
0.30	80
0.31	90
0.58	50
0.60	70
1.02	0
1.08	0



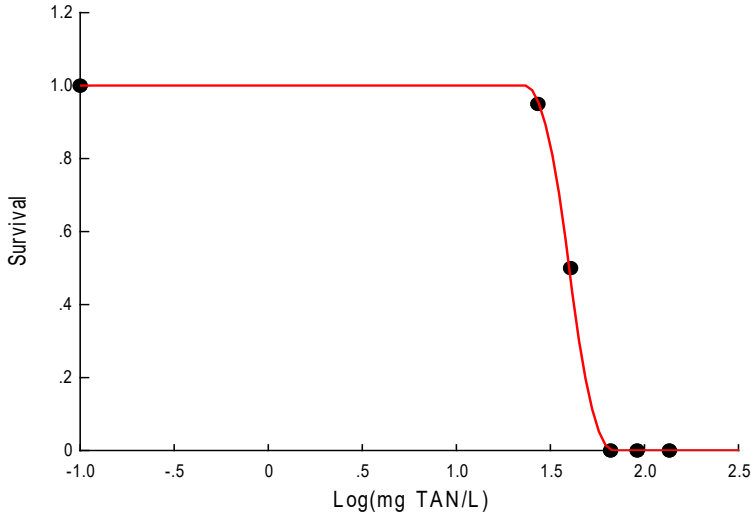
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.2	-0.19427	0.021893	-0.2438	-0.14475
S	2	3.8214	1.4672	0.50238	7.1404
Y0	100	96.162	3.1152	89.115	103.21

LC50:LC5 = 1.510

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**0.63933**	0.57043	0.71656	0.021893	-0.19427
20	0.51233	0.38705	0.67816	0.053835	-0.29045
10	0.45822	0.24963	0.84112	0.11661	-0.33893
5	**0.42344**	0.28585	0.62727	0.075441	-0.3732
0	0.34998	0.26422	0.46358	0.053968	-0.45596

Notes: Poor model fit.

EA Engineering 1985	
Species: *Pimephales promelas*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-66	
Test: 298	
TAN, mg/L	**Proportion surviving**
0.1	1.00
27.1	0.95
40.48	0.50
66.03	0.00
91.4	0.00
135.67	0.00



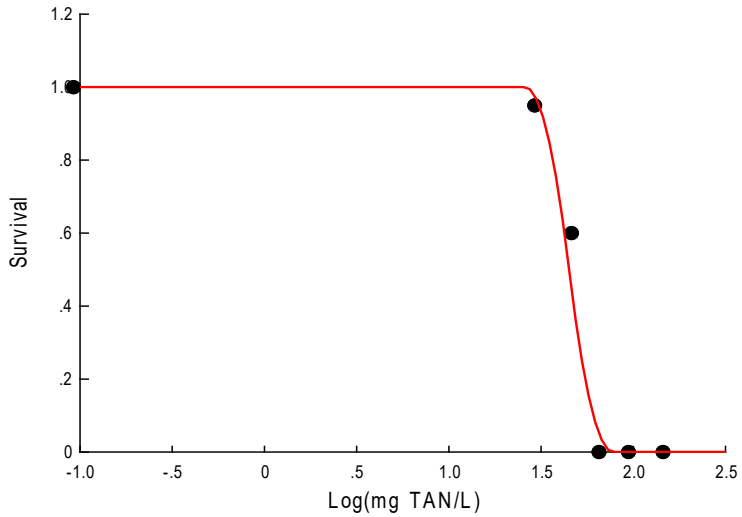
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.6	1.5997	0.018846	1.5609	1.6384
StDev	0.1	0.095159	0.012901	0.075293	0.12935
Y0	1	0.9999	0.0022356	0.83144	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**39.78**	36.382	43.496	0.018846	1.5997
20	32.659	29.135	36.608	0.023642	1.514
10	29.568	25.768	33.928	0.027798	1.4708
5	**27.56**	23.55	32.253	0.031032	1.4403
0	23.258	18.754	28.844	0.039159	1.3666

LC50:LC5 = 1.443

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

EA Engineering 1985	
Species: *Pimephales promelas*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-67	
Test: 299	
TAN, mg/L	**Proportion surviving**
0.09	1.00
29.2	0.95
46.2	0.60
65.16	0.00
94.1	0.00
144.9	0.00

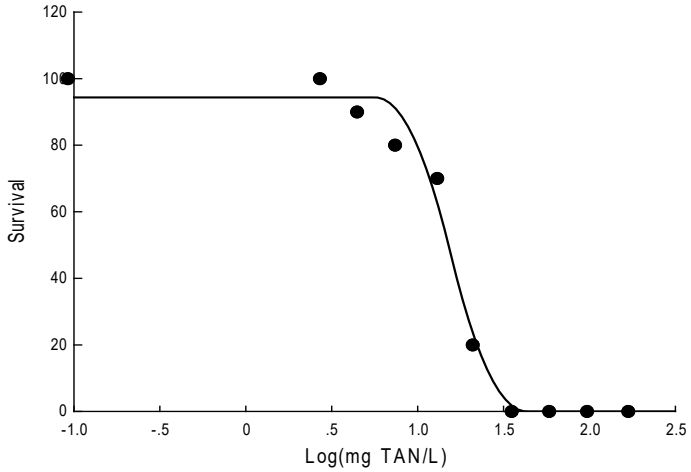


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.6517	0.019102	1.6124	1.691
StDev	0.15	0.097047	0.014506	0.075198	0.13688
Y0	1	0.9999	0.002235	0.83145	1
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**44.845**	40.967	49.091	0.019102	1.6517
20	36.673	32.689	41.142	0.023732	1.5643
10	33.137	28.782	38.151	0.02822	1.5203
5	**30.844**	26.146	36.387	0.03215	1.4892
0	25.942	20.519	32.799	0.041255	1.414

LC50:LC5 = 1.454

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

Buhl 2002	
Species: *Pimephales promelas* (4-6 d old)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-68	
Test:	
TAN, mg/L	**% Survival**
<0.10	100
2.7	100
4.44	90
7.38	80
13.00	70
20.9	20
35.2	0
58.2	0
96.7	0
168	0



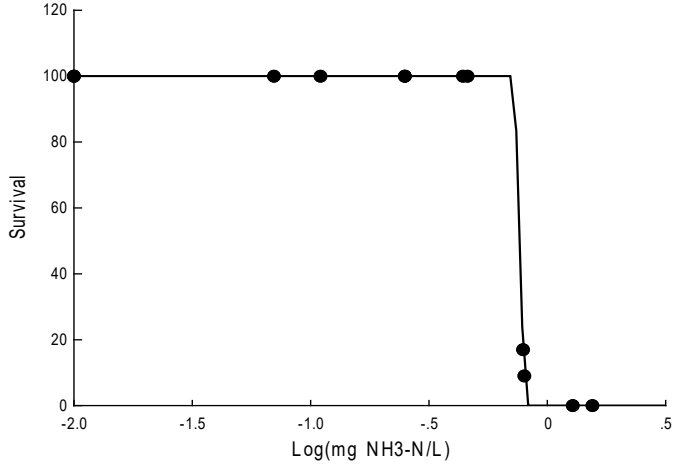
LC50:LC5 = 1.992

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.2	1.1935	0.028804	1.1254	1.2616
S	2	2.284	0.46024	1.1957	3.3723
Y0	100	94.327	3.4969	86.058	102.6

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**15.613**	13.347	18.264	0.028804	1.1935
20	10.779	8.2916	14.012	0.04818	1.0326
10	8.9426	6.2012	12.896	0.067237	0.95146
5	**7.8363**	5.0525	12.154	0.080606	0.89411
0	5.6972	3.5525	9.1366	0.086746	0.75566

Notes: Not core data. Poor model fit.

Swigert and Spacie 1983	
Species: *Catostomus commersonii*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-72	
Test: Single	
NH3-N, mg/L	**% Survival**
Control (0.01)	100
Control (0.01)	100
0.07	100
0.11	100
0.25	100
0.25	100
0.44	100
0.46	100
0.79	17
0.8	9
1.28	0
1.55	0



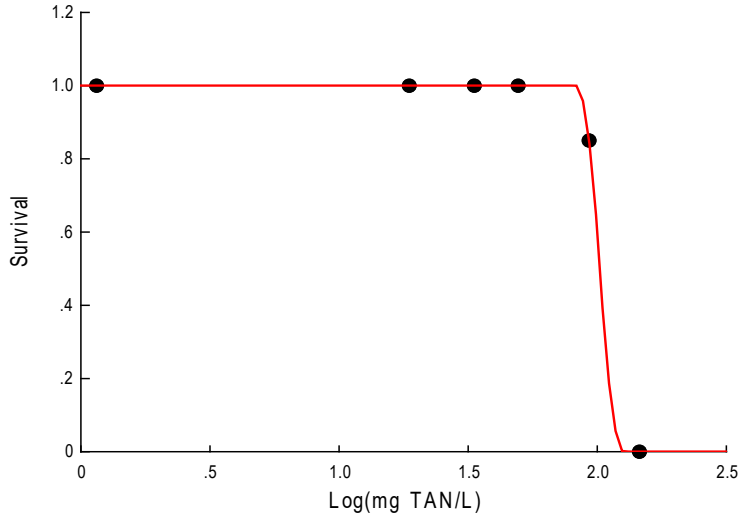
LC50:LC5 = 1.056

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.125	-0.1167	0	-0.11671	-0.11671
S	12	29.075	0	29.075	29.075
Y0	100	100	0	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**0.76434**	0.76434	0.76434	0	-0.11671
20	0.74241	0.74241	0.74241	0	-0.12935
10	0.7316	0.7316	0.7316	0	-0.13572
5	**0.72405**	0.72405	0.72405	0	-0.14023
0	0.70614	0.70614	0.70614	0	-0.15111

Notes: No TRAP flags for IP, but curve slope based on arbitrary breakpoint.

EA Engineering 1985	
Species: *Ictalurus punctatus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-73	
Test: 255	
TAN, mg/L	**Proportion surviving**
1.15	1.00
18.7	1.00
33.4	1.00
49.38	1.00
92.93	0.85
145.69	0.00

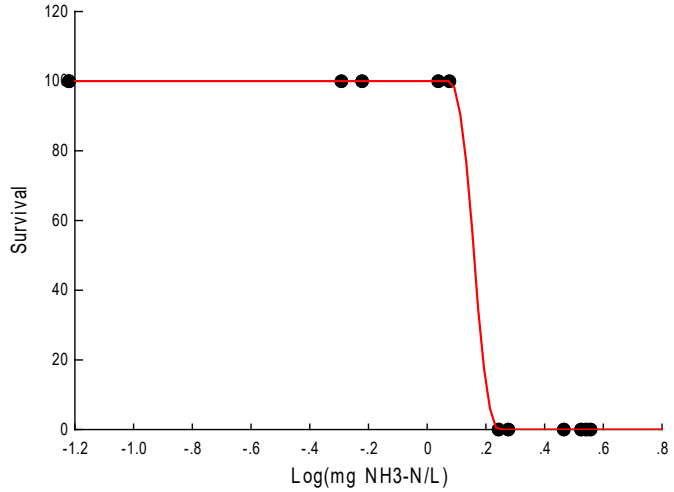


Log X50	2	2.0097			
StDev	0.05	3.75E-02			
Y0	1	0.9999			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**102.26**				2.0097
20	94.613				1.976
10	90.978				1.9589
5	**88.491**				1.9469
0	82.765				1.9178

LC50:LC5 = 1.156

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

Reinbold and Pescitelli1982d	
Species: *Ictalurus punctatus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-75	
Test: #2	
NH3-N, mg/L	**% Survival**
Control (0.05)	100
Control (0.05)	100
0.51	100
0.6	100
1.09	100
1.19	100
1.75	0
1.89	0
2.92	0
3.34	0
3.48	0
3.6	0

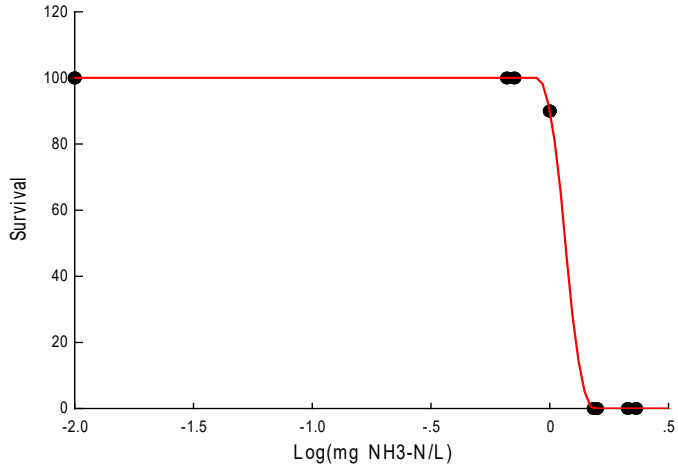


LC50:LC5 = 1.140

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.16	0.15985			
S	12	12.021			
Y0	100	100			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.4449**				0.15985
20	1.3467				0.12928
10	1.2998				0.11387
5	**1.2676**				0.10297
0	1.1931				0.076667

Notes: TRAP flagged for IP (No Unique Solution).

Swigert and Spacie 1983	
Species: *Ictalurus punctatus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-76	
Test: Single	
NH3-N, mg/L	**% Survival**
Control (0.01)	100
Control (0.01)	100
0.66	100
0.71	100
1	90
1	90
1.53	0
1.58	0
2.13	0
2.31	0



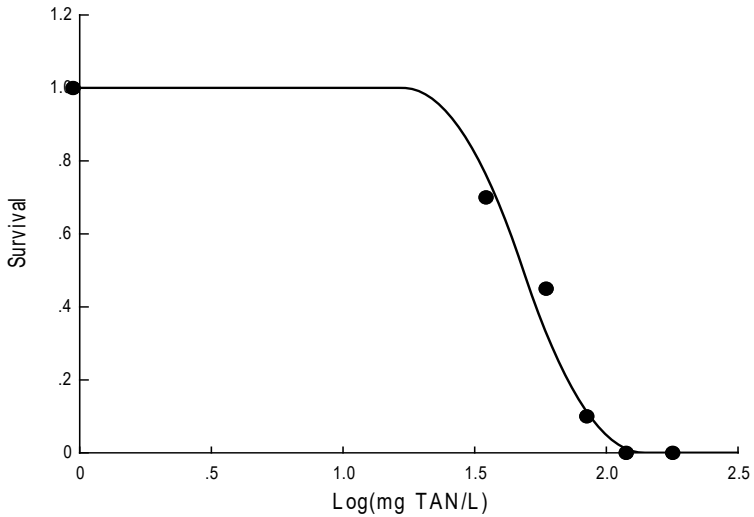
LC50:LC5 = 1.206

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.05	0.06575	7.27E-09	0.06575	0.06575
S	8	8.4075	9.3E-07	8.4075	8.4075
Y0	100	100	7.8E-12	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.1635**	1.1635	1.1635	7.2718E-09	0.06575
20	1.052	1.052	1.052	3.7449E-14	0.022033
10	1	1	1	3.479E-14	3.96E-10
5	**0.96476**	0.96476	0.96476	3.8135E-14	-0.01558
0	0.88472	0.88472	0.88472	4.6146E-14	-0.05319

Notes: TRAP flagged for IP (No Unique Solution).

EA Engineering 1985	
Species: *Lepomis macrochirus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-78	
Test: 186	
TAN, mg/L	**Proportion surviving**
0.46	1.00
34.9	0.70
59.02	0.45
84.25	0.10
118.88	0.00
178.6	0.00



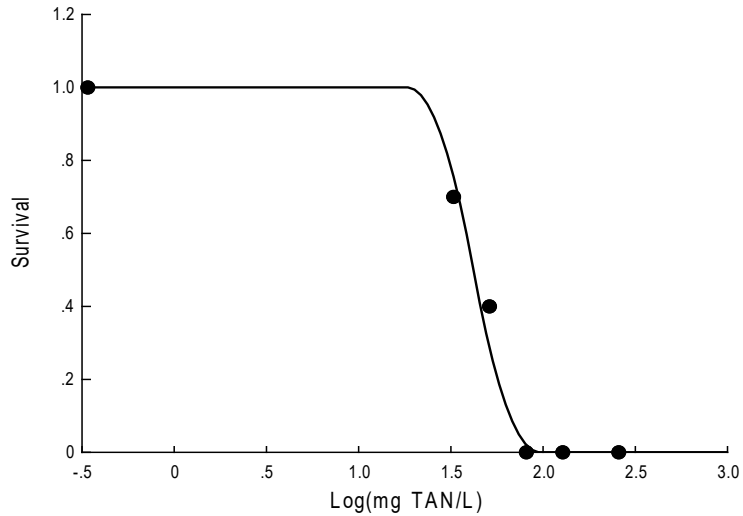
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.7	1.6848	0.038662	1.6049	1.7648
StDev	0.2	0.1867	0.031713	0.14042	0.27859
Y0	1	0.9999	0.0022359	0.83139	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**48.399**	40.264	58.178	0.038662	1.6848
20	32.867	24.505	44.081	0.059847	1.5168
10	27.042	18.671	39.166	0.072609	1.432
5	**23.558**	15.269	36.346	0.081799	1.3721
0	16.886	8.9782	31.758	0.10416	1.2275

LC50:LC5 = 2.054

Notes: Not core data. No effect within area of concern.

EA Engineering 1985	
Species: *Lepomis macrochirus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-79	
Test: 187	
TAN, mg/L	**Proportion surviving**
0.34	1.00
32.72	0.70
51.24	0.40
81.04	0.00
127.75	0.00
257	0.00



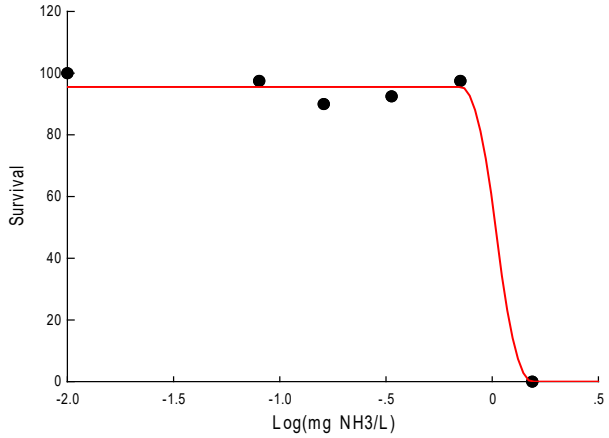
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.6	1.6228	0.03233	1.5554	1.6901
StDev	0.15	0.14634	0.027707	0.10709	0.23104
Y0	1	0.9999	0.002236	0.83139	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**41.954**	35.929	48.991	0.03233	1.6228
20	30.976	24.299	39.488	0.048746	1.491
10	26.584	18.885	37.422	0.065337	1.4246
5	**23.86**	16.481	34.543	0.067327	1.3777
0	18.379	10.453	32.316	0.08635	1.2643

LC50:LC5 = 1.758

Notes: Not core data. No effect within area of concern.

Smith et al. 1984	
Species: *Lepomis macrochirus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-81	
Test: Single	
NH3, mg/L	**% Survival**
Control (0.01)	100
0.08	97.5
0.161	90
0.336	92.5
0.708	97.5
1.543	0

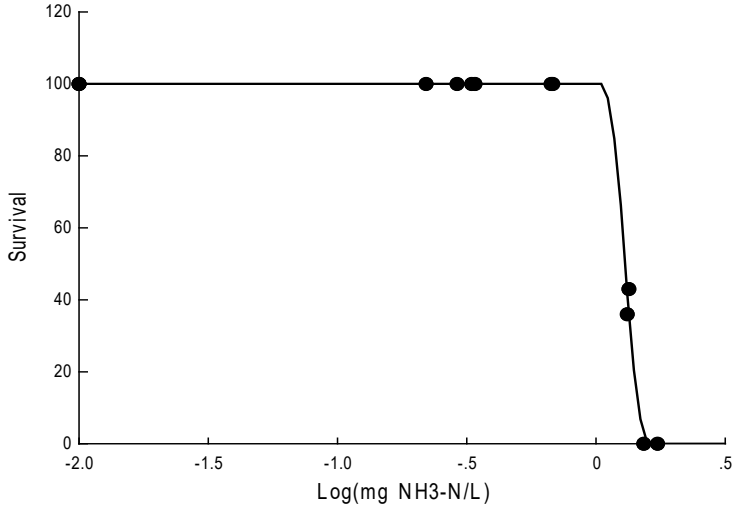


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.02	0.02			
S	6	6			
Y0	95.5	95.5			
p	Xp	95% LCI	95% UCL	Log Xp SE	Log Xp
50	**1.0471**				0.02
20	0.90937				-0.041257
10	0.84697				-0.072131
5	**0.80545**				-0.093962
0	0.7134				-0.14667

LC50:LC5 = 1.300

Notes: TRAP flagged for IP (No Unique Solution).

Swigert and Spacie 1983	
Species: *Lepomis macrochirus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-82	
Test: Jan 22, 1981 test	
NH3-N, mg/L	**% Survival**
Control (0.01)	100
Control (0.01)	100
0.22	100
0.29	100
0.33	100
0.34	100
0.67	100
0.68	100
1.32	36
1.34	43
1.53	0
1.73	0



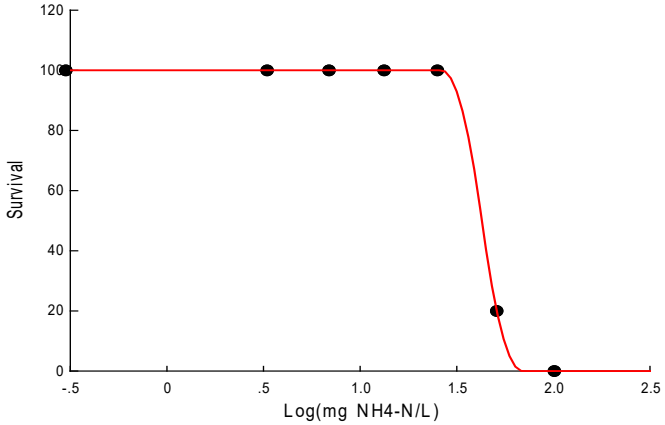
LC50:LC5 = 1.159

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.1	0.11272	0.003645	0.10447	0.12096
S	10	10.679	2.2361	5.6207	15.737
Y0	100	100	1.1446	97.411	102.59

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**1.2963**	1.272	1.3212	0.003645	0.11272
20	1.1976	1.0991	1.3049	0.016479	0.0783
10	1.1507	0.85415	1.5501	0.05721	0.060953
5	**1.1186**	0.89055	1.4051	0.043777	0.048688
0	1.0449	0.92165	1.1846	0.024097	0.019076

Notes: No TRAP flags for IP, but curve slope based on arbitrary breakpoint.

Schuytema and Nebeker 1999a	
Species: *Pseudacris regilla*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-88	
Test: ammonium nitrate	
NH4-N, mg/L	**% Survival**
0.3	100
3.3	100
6.9	100
13.3	100
25.1	100
50.9	20
101.2	0



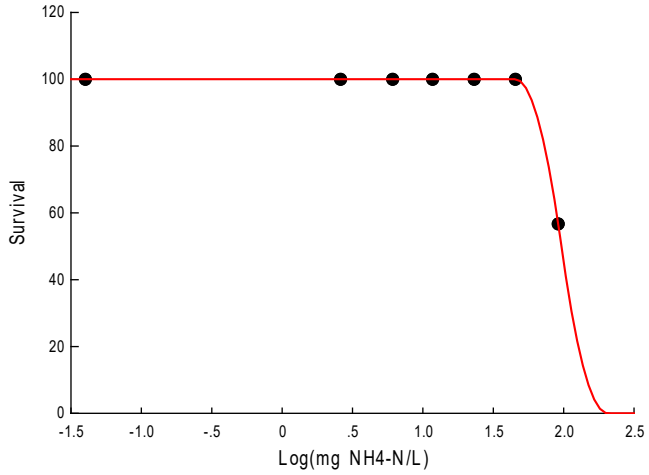
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.6	1.6301			
S	4.8	4.7993			
Y0	100	100			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**42.671**				1.6301
20	35.773				1.5536
10	32.731				1.515
5	**30.737**				1.4877
0	26.41				1.4218

LC50:LC5 = 1.388

Notes: TRAP flagged for IP (No Unique Solution).

Schuytema and Nebeker 1999a	
Species: *Pseudacris regilla*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-90	
Test: ammonium sulfate	
NH4-N, mg/L	**% Survival**
0.04	100
2.6	100
6.1	100
11.7	100
23.1	100
45.4	100
91.5	56.7



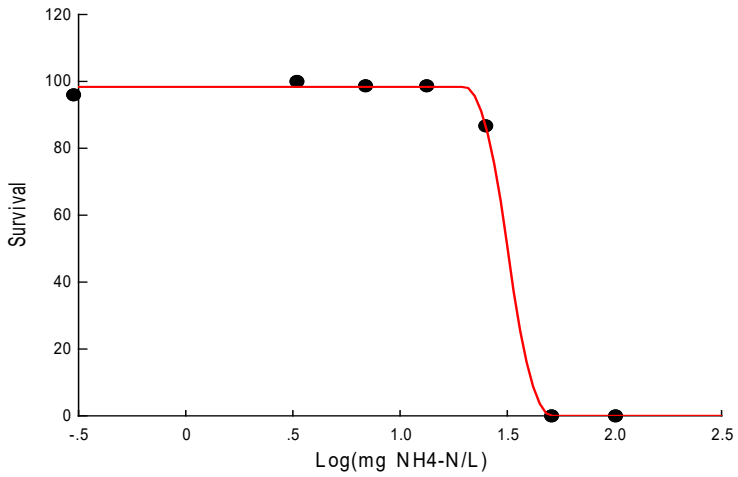
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2	1.9841	0	1.9841	1.9841
S	3	3.0575	0	3.0575	3.0575
Y0	100	100	0	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**96.41**	96.41	96.41	0	1.9841
20	73.099	73.099	73.099	0	1.8639
10	63.581	63.581	63.581	0	1.8033
5	**57.608**	57.608	57.608	0	1.7605
0	45.4	45.4	45.4	0	1.6571

LC50:LC5 = 1.674

Notes: TRAP flagged for IP (No Unique Solution).

Schuytema and Nebeker 1999a	
Species: *Xenopus laevis*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-91	
Test: ammonium nitrate	
NH4-N, mg/L	**% Survival**
0.3	96
3.3	100
6.9	99
13.3	99
25.1	87
50.9	0
101.2	0



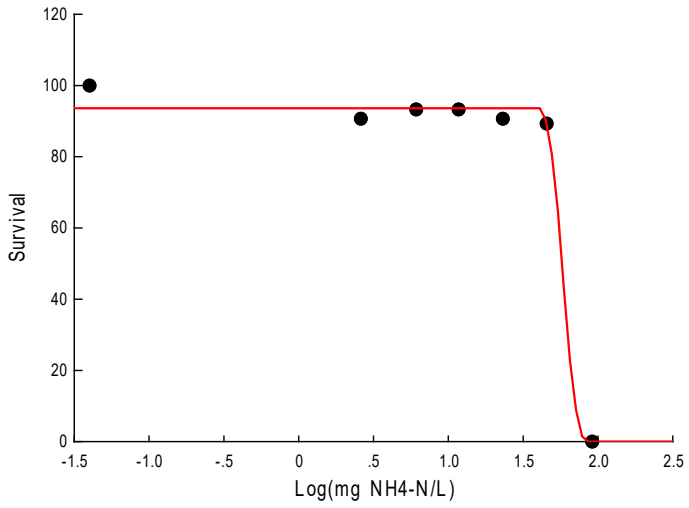
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.5038			
S	5	4.9303			
Y0	98.35	98.35			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**31.899**				1.5038
20	26.868				1.4292
10	24.641				1.3917
5	**23.179**				1.3651
0	19.996				1.301

LC50:LC5 = 1.376

Notes: TRAP flagged for IP (No Unique Solution).

Schuytema and Nebeker 1999a	
Species: *Xenopus laevis*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Am-Acute-92	
Test: ammonium sulfate	
NH4-N, mg/L	**% Survival**
0.04	100
2.6	91
6.1	93
11.7	93
23.1	91
45.4	89
91.5	0



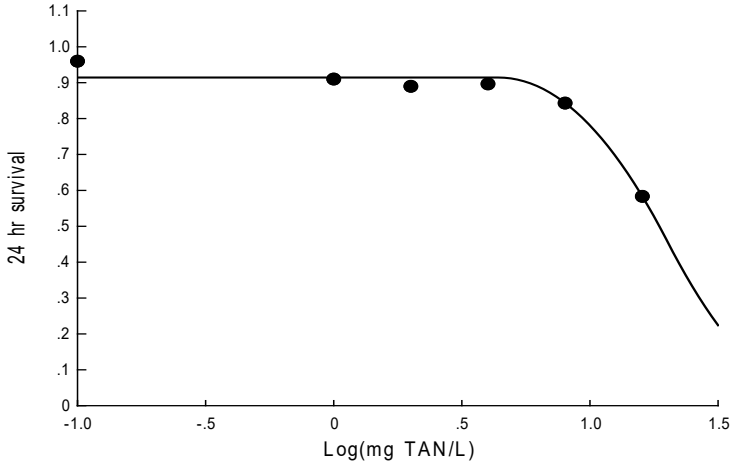
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.75	1.7656			
S	5.5	6.4217			
Y0	100	93.6			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**58.288**				1.7656
20	51.091				1.7083
10	47.807				1.6795
5	**45.614**				1.6591
0	40.724				1.6099

LC50:LC5 = 1.278

Notes: TRAP flagged for IP (No Unique Solution).

Wang et al. 2007b	
Species: *Alasmidonta heterodon*	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-93	
Test: glochidia	
TAN, mg/L	**Proportion surviving**
0.1	0.96
1	0.91
2	0.89
4	0.90
8	0.84
16	0.58



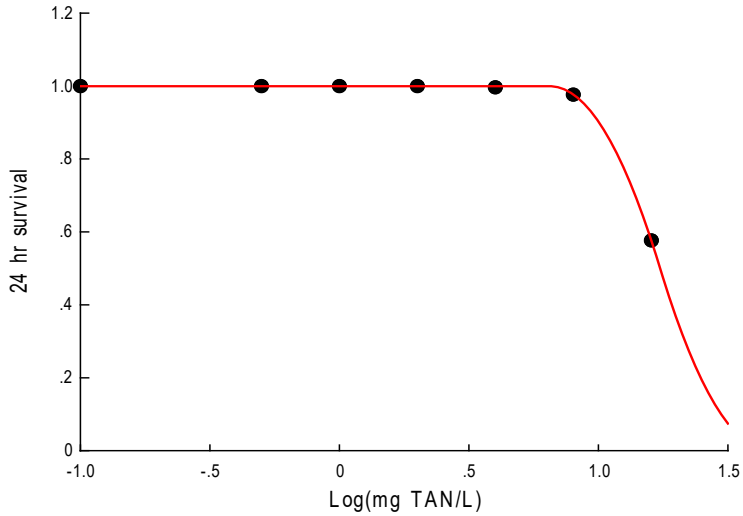
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.3	1.3024	0.034365	1.2337	1.3711
StDev	0.27	0.26884	0.041333	0.20701	0.38361
Y0	0.96	0.91417	0.008086	0.89687	0.9294

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**20.062**	17.126	23.501	0.034365	1.3024
20	11.49	10.264	12.863	0.023927	1.0603
10	8.6765	7.2734	10.35	0.03627	0.93834
5	**7.1135**	5.6037	9.0302	0.047597	0.85209
0	4.4039	2.8608	6.7794	0.077515	0.64384

LC50:LC5 = 2.820

Notes: No TRAP flags, but lack of partials greater than 50% to define tail end of curve.

Wang et al. 2007b	
Species: *Potamilus ohiensis*	
Test Endpoint: 24 hr Survival	
C-R Curve Label: Am-Acute-94	
Test: glochidia	
TAN, mg/L	**Proportion surviving**
0.1	1.00
0.5	1.00
1	1.00
2	1.00
4	1.00
8	0.98
16	0.58



	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.2311	1.2383	1.49E-02	1.2089	1.2677
StDev	0.15169	0.17388	1.27E-02	0.15222	0.2028
Y0	0.99556	0.99933	6.66E-04	0.99629	0.99998
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**3.2149**	2.9613	3.4902	0.018114	0.50716
20	1.7994	1.5815	2.0474	0.028359	0.25513
10	1.3431	1.1433	1.5778	0.035207	0.12811
5	**1.0922**	0.90698	1.3152	0.040435	0.038292
0	0.6629	0.51582	0.85193	0.053785	-0.17855

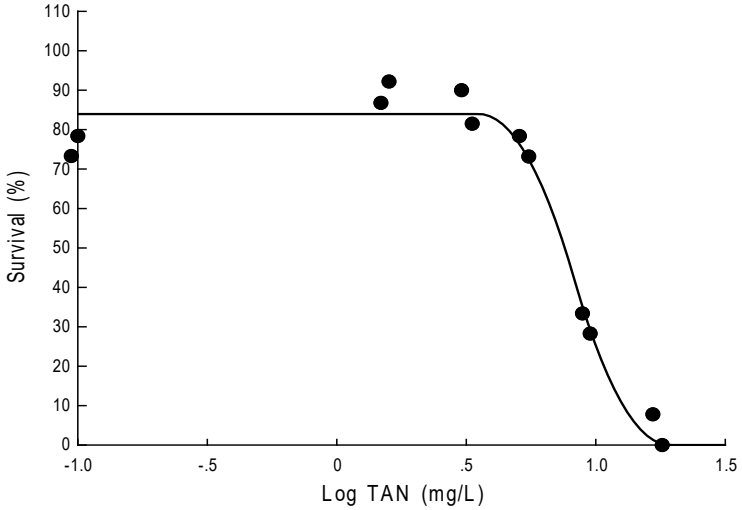
LC50:LC5 = 2.944

Notes: TRAP flagged for IP (No Unique Solution). Lack of partials greater than 50% to define tail end of curve.

Appendix A.3

Test Information, C-R Data and Resulting TRAP models for Chronic Ammonia Toxicity Tests Acceptable for TAF and MAF Calculation

Anderson et al. 1978	
Species: *Musculium transversum*	
Test Endpoint: 42-d Juvenile Survival	
C-R Curve Label: Am-Chronic-4	
Test: Chronic bioassays 2 and 3 combined	
TAN, mg/L	**% Survival**
0.08	73.3
0.1	78.4
1.48	86.8
1.59	92.2
3.03	90
3.33	81.5
5.07	78.4
5.51	73.2
8.88	33.4
9.51	28.3
16.6	7.8
18.04	0



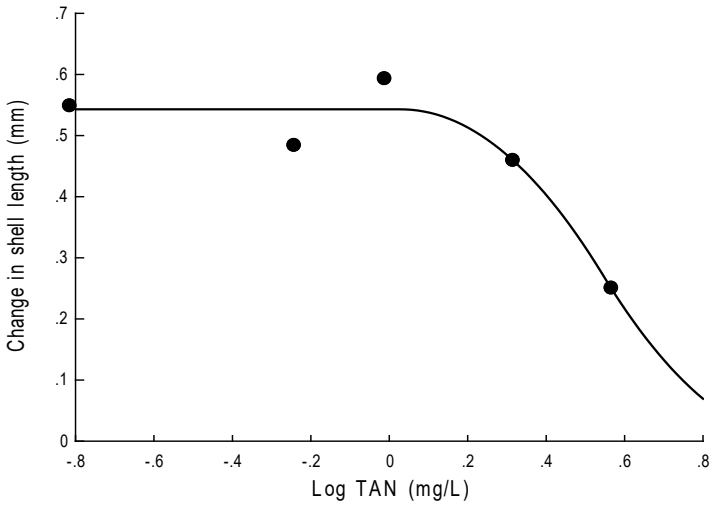
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.9	0.91709	0.019772	0.87236	0.96182
S	2.5	2.7149	0.48295	1.6224	3.8074
Y0	83.7	83.948	2.3969	78.526	89.371

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	8.2621	7.4536	9.1584	0.019772	0.91709
20	**6.0493**	5.0777	7.207	0.033617	0.78171
10	5.1698	4.1139	6.4967	0.04386	0.71348
5	**4.6262**	3.589	5.9633	0.048739	0.66523
0	3.5379	2.6158	4.7851	0.057972	0.54875

EC20:EC5 = 1.308

Notes: Acceptable model fit.

Besser 2011	
Species: *Fluminicola sp.*(juvenile)	
Test Endpoint: Change in shell length (0 – 28 days)	
C-R Curve Label: Am-Chronic-6	
Test: Single	
TAN, mg/L	**Change in shell length (mm)**
0.12	0.5497
0.57	0.4848
0.97	0.5939
2.06	0.4604
3.67	0.2513

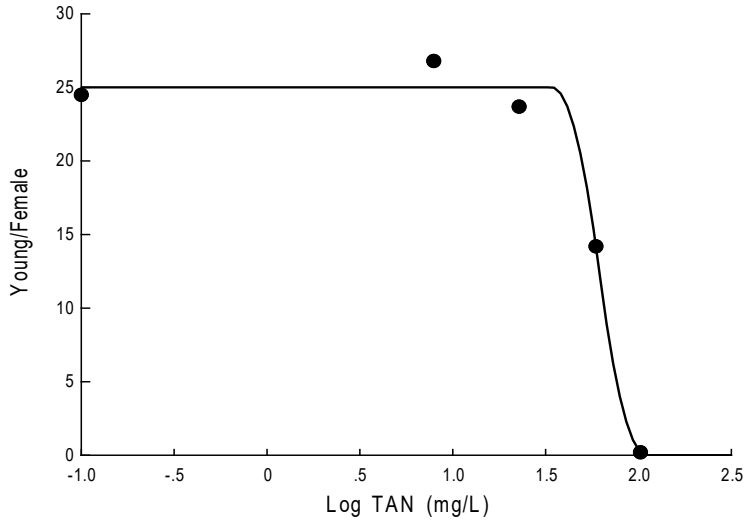


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.5496	0.54522	5.32E-02	0.31615	0.77429
StDev	1.7434	1.9407	0.87827	-1.8381	5.7196
Y0	0.5428	0.5428	3.17E-02	0.40648	0.67912
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	3.5093	2.0708	5.9469	5.32E-02	0.54522
20	**2.269**	0.9376	5.491	8.92E-02	0.35583
10	1.8213	0.5148	6.4436	0.12754	0.26038
5	**1.5592**	0.32367	7.5106	0.15869	0.19289
0	1.0714	7.28E-02	15.773	0.27145	2.99E-02

EC20:EC5 = 1.455

Notes: Acceptable model fit. Acceptable noise at low level effects.

Mount 1982	
Species: *Ceriodaphnia acanthina*	
Test Endpoint: 7-d LC Reproduction	
C-R Curve Label: Am-Chronic-7	
Test: Single	
TAN, mg/L	**Avg. young/female**
0.1	24.5
7.9	26.8
22.75	23.7
59	14.2
102.5	0.2



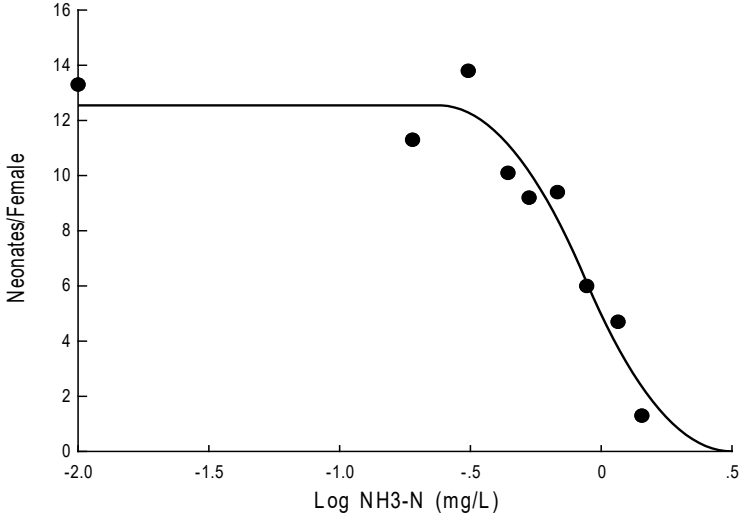
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.6135	1.7888	1.97E-02	1.7041	1.8734
S	1.6228	3.9354	2.1429	-5.2846	13.155
Y0	25.65	25	0.92916	21.002	28.998

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	61.484	50.591	74.722	1.97E-02	1.7888
20	**49.587**	5.7696	426.17	0.21713	1.6954
10	44.494	16.096	122.99	0.10263	1.6483
5	**41.211**	21.243	79.947	6.69E-02	1.615
0	34.25	20.598	56.95	5.13E-02	1.5347

EC20:EC5 = 1.203

Notes: Large SE for steepness. Acceptable model fit. Acceptable noise at low level effects.

Nimmo et al. 1989	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 7-d LC Reproduction	
C-R Curve Label: Am-Chronic-8	
Test: Single	
NH3-N (mg/L)	**Avg. # neonates/female**
Not detectable (0.01)	13.3
0.19	11.3
0.31	13.8
0.44	10.1
0.53	9.2
0.68	9.4
0.88	6.0
1.16	4.7
1.43	1.3



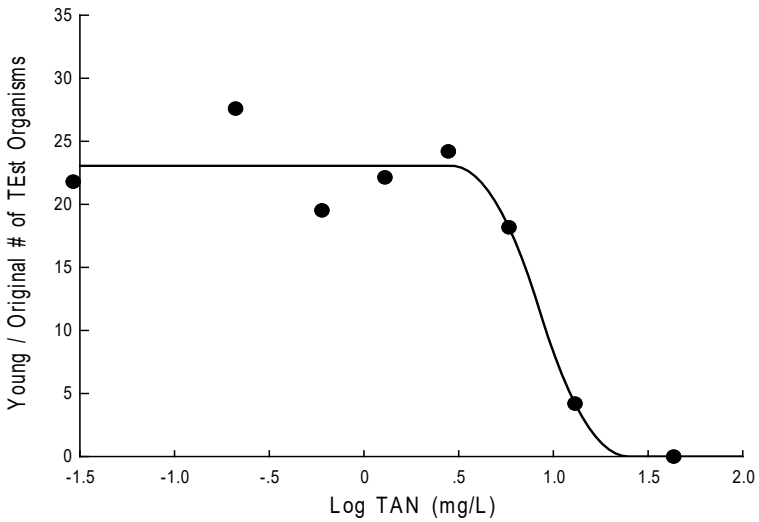
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.1	-0.0621	0.039824	-0.15955	0.035343
S	1.9	1.7858	0.41651	0.76665	2.805
Y0	12.8	12.544	0.80344	10.578	14.51

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.86676	0.69255	1.0848	0.039824	-0.0621
20	**0.53961**	0.36358	0.80087	0.07008	-0.26792
10	0.42497	0.24782	0.72873	0.095718	-0.37165
5	**0.35893**	0.18299	0.70401	0.11957	-0.44499
0	0.23874	0.066831	0.85285	0.22598	-0.62207

EC20:EC5 = 1.503

Notes: Acceptable model fit. Acceptable noise at low level effects.

Willingham 1987	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 7-d LC Reproduction	
C-R Curve Label: Am-Chronic-9	
Test: Single	
TAN, mg/L	**Young/original test animal (Brood 3)**
0.02	21.8
0.21	27.6
0.60	19.52
1.29	22.14
2.79	24.2
5.83	18.18
13.0	4.2
43.2	0

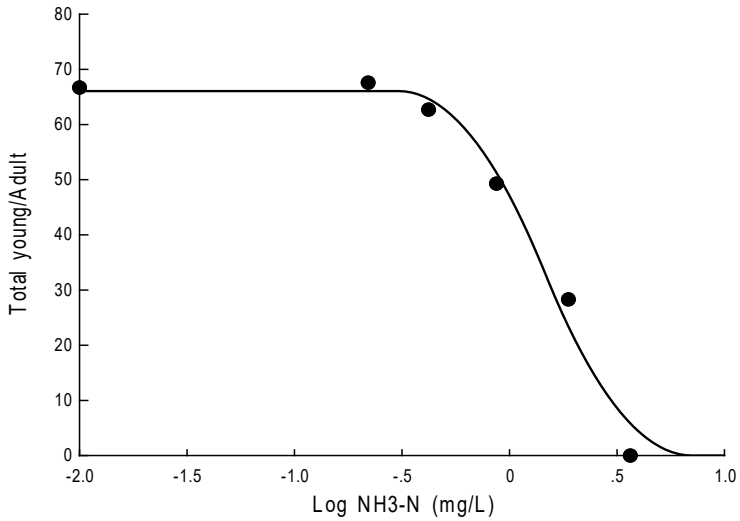


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	0.92895	0.064925	0.76206	1.0958
S	2	2.1425	0.77699	0.14523	4.1399
Y0	23.052	23.052	1.2145	19.93	26.174
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	8.4909	5.7818	12.469	0.064925	0.92895
20	**5.7202**	3.3223	9.8486	0.091795	0.75741
10	4.6876	2.3059	9.5291	0.11986	0.67095
5	**4.0721**	1.6429	10.093	0.15335	0.60981
0	2.8988			2.6871	0.46222

EC20:EC5 = 1.405

Notes: Acceptable model fit. Acceptable noise at low level effects.

Gersich et al. 1985	
Species: *Daphnia magna*	
Test Endpoint: 21-d LC Reproduction	
C-R Curve Label: Am-Chronic-10	
Test: Single	
NH3-N (mg/L)	**Total young/adult**
0.01	66.7
0.22	67.6
0.42	62.7
0.87	49.3
1.88	28.3
3.65	0

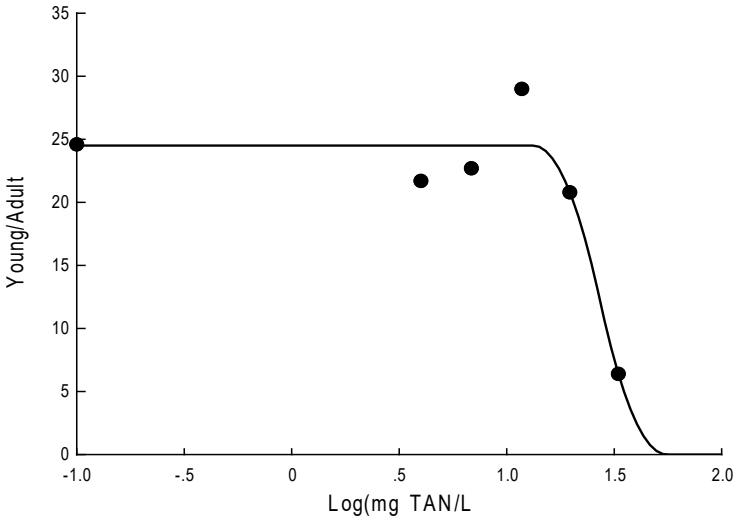


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.12	0.16559	0.049825	0.007022	0.32415
S	1.5	1.4637	0.30171	0.50356	2.4239
Y0	67.15	66.052	3.1285	56.095	76.008
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.4642	1.0163	2.1094	0.049825	0.16559
20	**0.82127**	0.44661	1.5102	0.083131	-0.08551
10	0.61367	0.2701	1.3943	0.11199	-0.21207
5	**0.4994**	0.1777	1.4035	0.14101	-0.30155
0	0.30367	0.062573	1.4737	0.21556	-0.5176

EC20:EC5 = 1.645

Notes: Acceptable model fit.

Reinbold and Pescitelli 1982a	
Species: *Daphnia magna*	
Test Endpoint: 21-d LC Reproduction	
C-R Curve Label: Am-Chronic-11	
Test: Single	
TAN, mg/L	**Mean # young produced/adult**
Control (0.1)	24.6
3.99	21.7
6.85	22.7
11.75	29
19.66	20.8
33.07	6.4



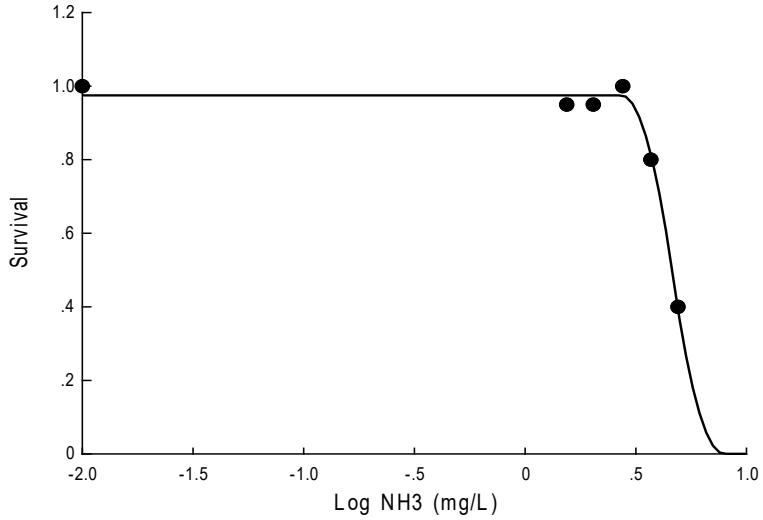
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.4334	1.4334	4.81E-02	1.2804	1.5864
S	2.7439	3.2216	1.3792	-1.1675	7.6108
Y0	24.5	24.5	1.6161	19.357	29.643

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	27.126	1.91E+01	38.585	4.81E-02	1.4334
20	**20.86**	12.271	35.459	7.24E-02	1.3193
10	18.273	9.2616	36.052	9.27E-02	1.2618
5	**16.64**	7.381	37.513	1.11E-01	1.2212
0	13.274	1.883	93.571	2.67E-01	1.123

EC20:EC5 = 1.254

Notes: Acceptable model fit. Acceptable noise at low level effects.

Thurston et al. 1984b	
Species: *Pteronarcella badia*	
Test Endpoint: 30-d Juvenile Survival	
C-R Curve Label: Am-Chronic-13	
Test: 293	
Mean NH3, mg/L	**Proportion Surviving**
0.01	1.0
1.54	1.0
2.03	1.0
2.76	1.0
3.7	0.8
4.9	0.4



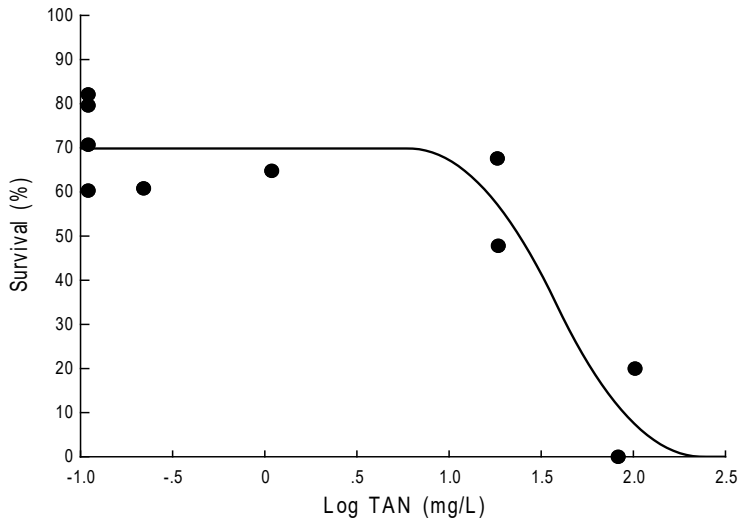
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.7	0.66659	0.024428	0.61451	0.71867
StDev	0.1	0.09446	0.035541	0.066001	0.16577
Y0	0.975	0.97461	0.017985	0.90987	0.99705

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	4.6407	4.1163	5.232	0.024428	0.66659
20	**3.8154**	3.22	4.521	0.032739	0.58155
10	3.4569	2.6783	4.4617	0.045824	0.53868
5	**3.2239**	2.2989	4.521	0.056517	0.50838
0	2.724	1.4051	5.2808	0.085269	0.43521

EC20:EC5 = 1.183

Notes: Acceptable model fit.

Koch et al. 1980	
Species: *Oncorhynchus clarkii* henshawi (fertilized eggs)	
Test Endpoint: 103-d ELS Survival	
C-R Curve Label: Am-Chronic-15	
Test: Single	
TAN, mg/L	**% Survival**
0.11	60.3
0.11	82.1
0.22	60.8
0.11	79.6
0.11	No data
0.11	70.7
1.09	64.8
1.09	Excluded
18.5	47.8
18.29	67.6
102.16	20
82.67	0



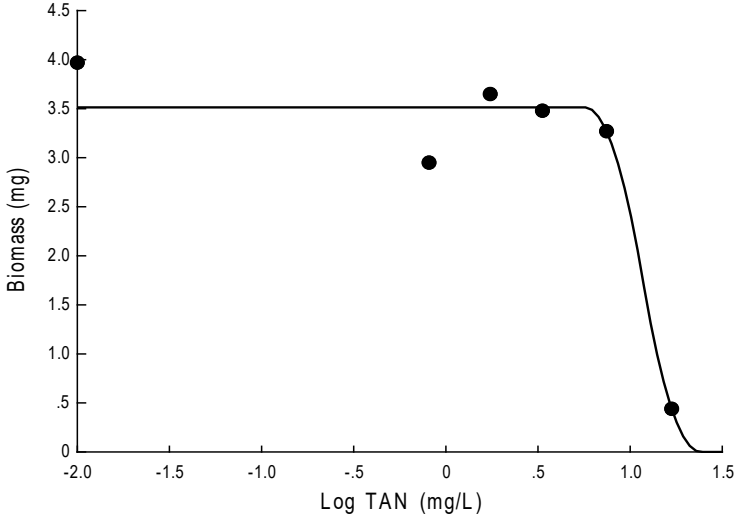
EC20:EC5 = 1.784

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.5782	0.12521	1.2821	1.8743
S	1.3	1.2579	0.44137	0.21424	2.3016
Y0	70	69.817	4.7023	58.698	80.936

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	37.86	19.147	74.86	0.12521	1.5782
20	**19.319**	7.9019	47.234	0.1642	1.286
10	13.764	4.4551	42.521	0.20717	1.1387
5	**10.829**	2.5134	46.659	0.26826	1.0346
0	6.0703	0.12263	300.48	0.71665	0.78321

Notes: Acceptable model fit. Acceptable noise at low level effects.

Brinkman et al. 2009	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 90-d ELS Biomass	
C-R Curve Label: Am-Chronic-16	
Test: Single	
TAN, mg/L	**Final Biomass (g)**
<0.02	3.97
0.81	2.95
1.74	3.65
3.34	3.48
7.44	3.27
16.8	0.44

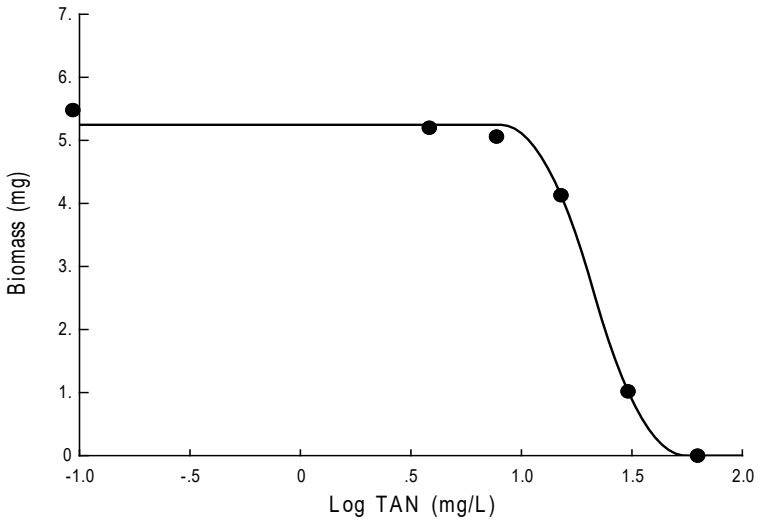


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	1.0687	0.066497	0.85704	1.2803
S	3	3.1884	1.2138	-0.67441	7.0513
Y0	3.52	3.5125	0.21324	2.8339	4.1911
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	11.713	7.1951	19.067	0.066497	1.0687
20	**8.9823**	4.6437	17.374	0.090031	0.95339
10	7.8576	3.6162	17.074	0.10591	0.89529
5	**7.1484**	2.9902	17.089	0.11894	0.85421
0	5.6889	1.2172	26.588	0.21042	0.75503

EC20:EC5 = 1.257

Notes: Acceptable model fit. Acceptable noise at low level effects.

Harrahy et al. 2004	
Species: *Esox lucius* (fertilized eggs)	
Test Endpoint: 52-d ELS Biomass	
C-R Curve Label: Am-Chronic-17	
Test: Single	
TAN, mg/L	**Mean Biomass(mg)**
0.05	5.48
3.83	5.2
7.71	5.06
15.1	4.13
30.38	1.02
62.67	0



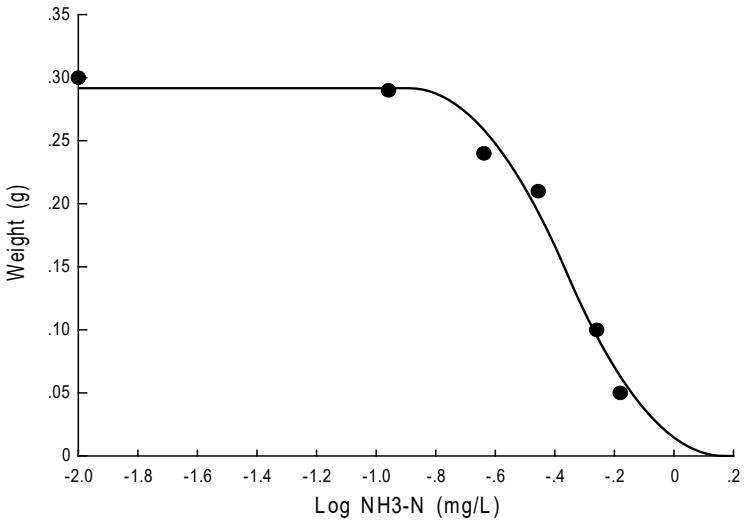
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.3	1.3247	0.016683	1.2716	1.3778
S	2.3	2.3847	0.24967	1.5901	3.1793
Y0	5.48	5.2467	0.10081	4.9258	5.5675

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	21.122	18.691	23.868	0.016683	1.3247
20	**14.812**	12.411	17.677	0.024132	1.1706
10	12.386	9.8355	15.597	0.031462	1.0929
5	**10.914**	8.1548	14.607	0.039775	1.038
0	8.0424	0.68577	94.317	0.33597	0.90538

EC20:EC5 = 1.357

Notes: Acceptable model fit.

Mallet and Sims 1994	
Species: *Cyprinus carpio*	
Test Endpoint: 28-d ELS Weight	
C-R Curve Label: Am-Chronic-18	
Test: Single	
Un-ionized ammonia NH3-N (mg/L)	**Weight (g)**
0.01	0.30
0.11	0.29
0.23	0.24
0.35	0.21
0.55	0.1
0.66	0.05



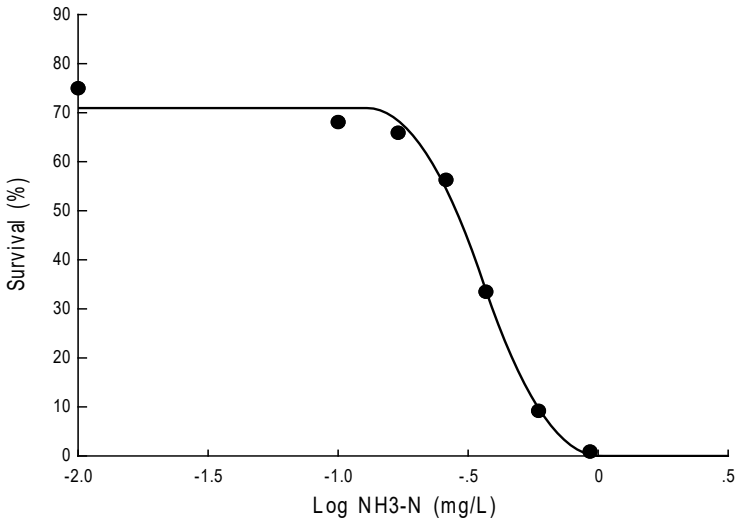
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.37886	-0.36113	0.027151	-0.44754	-0.27473
S	1.6758	1.8925	0.30589	0.91904	2.866
Y0	0.295	0.2916	0.012014	0.25337	0.32984

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.43538	0.35683	0.53122	0.027151	-0.36113
20	**0.27839**	0.19724	0.39294	0.047029	-0.55534
10	0.22222	0.14014	0.35236	0.062911	-0.65322
5	**0.18948**	0.10727	0.3347	0.077642	-0.72244
0	0.12896	0.042073	0.39531	0.15286	-0.88953

EC20:EC5 = 1.469

Notes: Acceptable model fit.

Mayes et al. 1986	
Species: *Pimephales promelas* (embryo-larvae)	
Test Endpoint: 28-d ELS Survival	
C-R Curve Label: Am-Chronic-19	
Test: Single	
NH3-N (mg/L)	**% Survival**
Control (0.01)	75
0.1	68.1
0.17	65.9
0.26	56.3
0.37	33.5
0.59	9.2
0.93	0.9

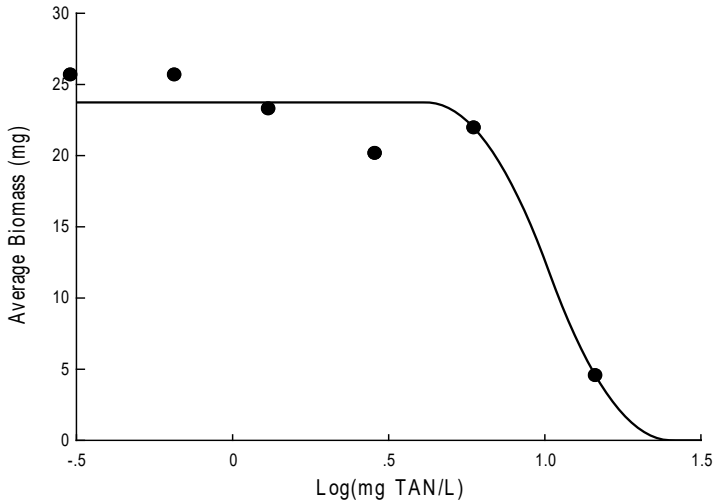


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.5	-0.44216	0.016496	-0.48796	-0.39636
S	2	2.234	0.2626	1.5049	2.9631
Y0	75	70.934	1.9575	65.499	76.368
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.36127	0.32512	0.40145	0.016496	-0.44216
20	**0.24735**	0.20628	0.2966	0.028403	-0.60669
10	0.20436	0.16035	0.26044	0.037931	-0.68961
5	**0.17855**	0.13573	0.23488	0.04289	-0.74824
0	0.12888	0.093959	0.17679	0.049439	-0.8898

EC20:EC5 = 1.385

Notes: Acceptable model fit.

Adelman et al. 2009	
Species: *Pimephales promelas* (embryo-larvae)	
Test Endpoint: 32-d ELS Biomass	
C-R Curve Label: Am-Chronic-20	
Test: Single	
TAN, mg/L	**Biomass(mg)**
0.13	25.704
0.65	25.704
1.3	23.325
2.85	20.194
5.91	21.984
14.49	4.592

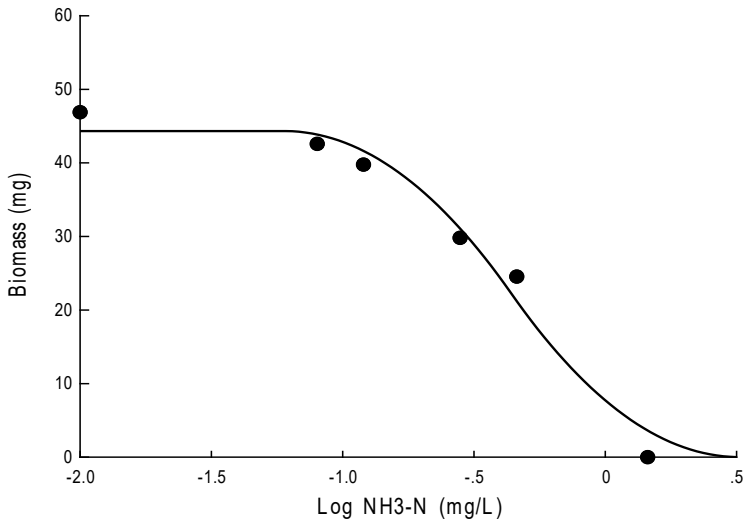


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	1.013	0.065131	0.80573	1.2203
S	2.5	2.5524	0.91461	-0.35825	5.4631
Y0	25.704	23.732	1.3058	19.576	27.887
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	10.304	6.3934	16.607	0.065131	1.013
20	**7.3962**	3.6679	14.914	0.095711	0.86901
10	6.258	2.6705	14.665	0.11622	0.79644
5	**5.5606**	2.1068	14.676	0.13244	0.74512
0	4.1805	0.11568	151.07	0.48955	0.62123

EC20:EC5 = 1.330

Notes: Large SE for steepness (S). Acceptable model fit. Acceptable noise at low level effects.

Swigert and Spacie 1983	
Species: *Pimephales promelas*	
Test Endpoint: 30-d ELS Biomass	
C-R Curve Label: Am-Chronic-21	
Test: Single	
Mean NH3-N (mg/L)	**Biomass(mg)**
Control (0.01)	46.895
0.08	42.585
0.12	39.77
0.28	29.82
0.46	24.552
1.45	0



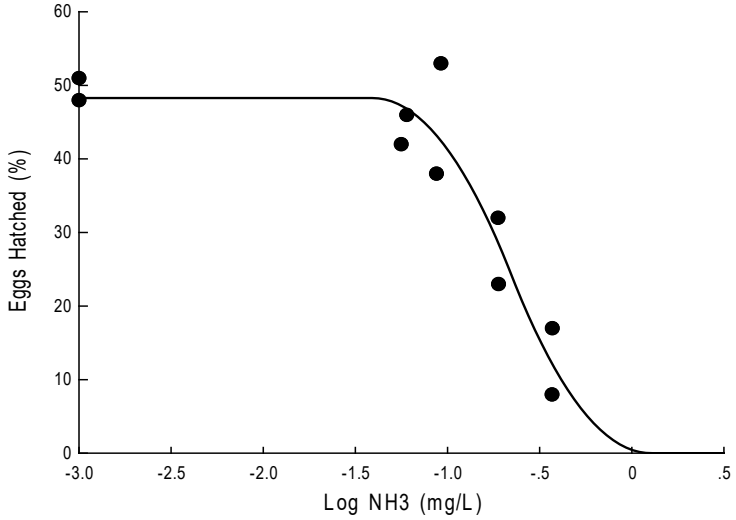
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.4	-0.35593	0.063673	-0.55857	-0.1533
S	1.15	1.1525	0.28868	0.23381	2.0712
Y0	46.895	44.322	2.7949	35.428	53.217

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.44062	0.27633	0.70259	0.063673	-0.35593
20	**0.21143**	0.089742	0.49811	0.11694	-0.67484
10	0.14603	0.040764	0.52311	0.17413	-0.83557
5	**0.1124**	0.02008	0.6292	0.23504	-0.94922
0	0.059759	0.0055898	0.63886	0.32334	-1.2236

EC20:EC5 = 1.881

Notes: Acceptable model fit.

Thurston et al. 1986	
Species: *Pimephales promelas*	
Test Endpoint: LC Reproduction	
C-R Curve Label: Am-Chronic-22	
Test: Single	
NH3 (mg/L)	**% eggs hatched**
0	48
0.001	51
0.056	42
0.060	46
0.087	38
0.092	53
0.188	32
0.189	23
0.369	8
0.370	17



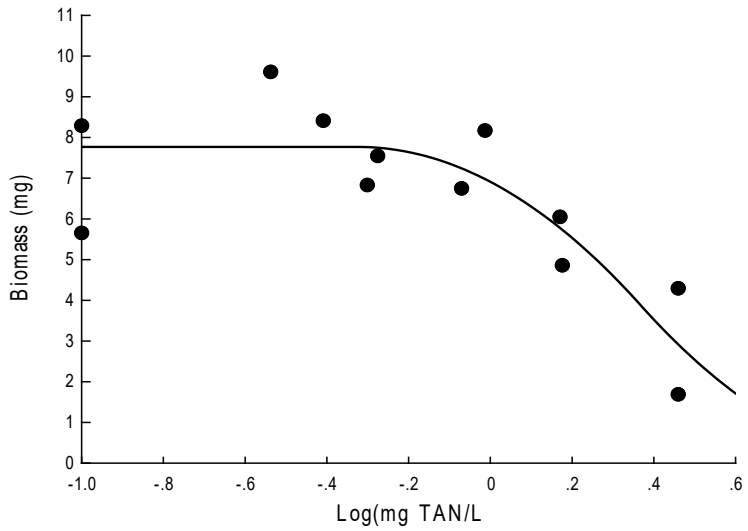
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.6	-0.65142	0.068628	-0.8137	-0.48914
S	2	1.3263	0.39632	0.38917	2.2635
Y0	52	48.262	3.7719	39.343	57.181

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.22314	0.15357	0.32423	0.068628	-0.65142
20	**0.11789**	0.060843	0.22841	0.12148	-0.92854
10	0.085467	0.03467	0.21069	0.16571	-1.0682
5	**0.068083**	0.022176	0.20902	0.20602	-1.167
0	0.03932	0.005894	0.26231	0.34855	-1.4054

EC20:EC5 = 1.732

Notes: Acceptable model fit.

Reinbold and Pescitelli 1982a	
Species: *Catostomus commersonii*	
Test Endpoint: 30-d Biomass	
C-R Curve Label: Am-Chronic-23	
Test: Single	
TAN, mg/L	**Biomass (mg)**
Control (0.1)	5.655
Control (0.1)	8.2925
0.39	8.415
0.29	9.6125
0.53	7.5488
0.50	6.8338
0.97	8.1732
0.85	6.7496
1.5	4.86
1.48	6.05
2.88	4.2945
2.88	1.6906



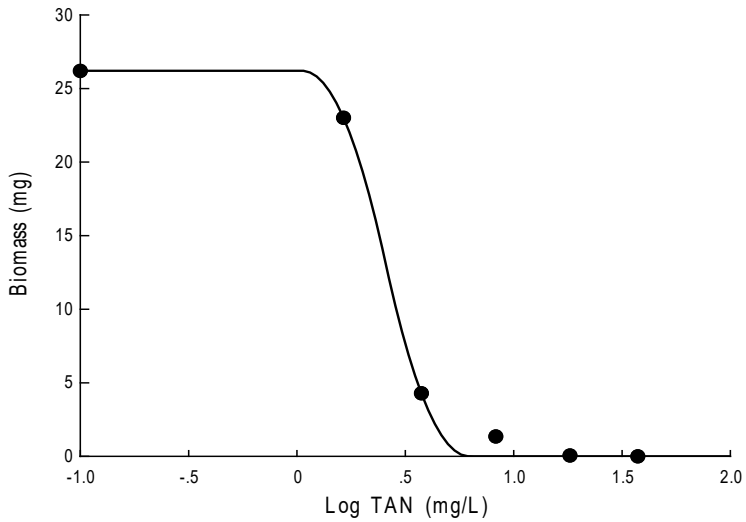
EC20:EC5 = 1.656

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.36	0.3672	0.080105	0.18599	0.54841
S	2	1.444	0.6006	0.085326	2.8026
Y0	7.7581	7.7683	0.55466	6.5136	9.023

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.3292	1.5346	3.5352	0.080105	0.3672
20	**1.2962**	0.67956	2.4723	0.12397	0.11266
10	0.96467	0.3944	2.3595	0.17171	-0.01562
5	**0.78283**	0.25625	2.3915	0.2144	-0.10633
0	0.47279	0.059615	3.7496	0.39755	-0.32533

Notes: Acceptable model fit. Acceptable noise at low level effects.

Smith et al. 1984	
Species: *Lepomis macrochirus*	
Test Endpoint: 30-d ELS Biomass	
C-R Curve Label: Am-Chronic-27	
Test: Single	
TAN, mg/L	**Biomass (mg)**
0.1	26.2
1.64	23.01
3.75	4.29
8.27	1.35
18.18	0.0625
37.38	0



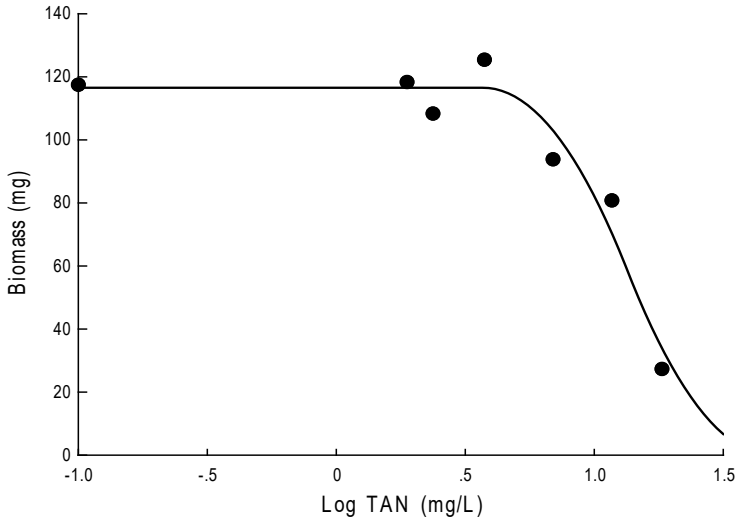
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.40961	0.40958	1.88E-02	0.34972	0.46945
S	1.039	2.6011	0.25408	1.7925	3.4097
Y0	26.2	26.2	0.78026	23.717	28.683

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.5679	2.24E+00	2.9475	1.88E-02	0.40958
20	**1.8547**	1.524	2.2572	2.68E-02	0.26828
10	1.5742	1.2417	1.9957	3.24E-02	0.19706
5	**1.4019**	1.0655	1.8444	3.74E-02	0.1467
0	1.0596	3.93E-02	28.563	4.50E-01	2.51E-02

EC20:EC5 = 1.323

Notes: Acceptable model fit.

Broderius et al. 1985	
Species: *Micropterus dolomieu*	
Test Endpoint: 32-d ELS Biomass	
C-R Curve Label: Am-Chronic-30	
Test: pH 7.83	
TAN, mg/L	**Biomass (mg)**
0.05	118
1.88	118
2.37	108
3.75	125
6.92	94
11.7	81
18.3	27



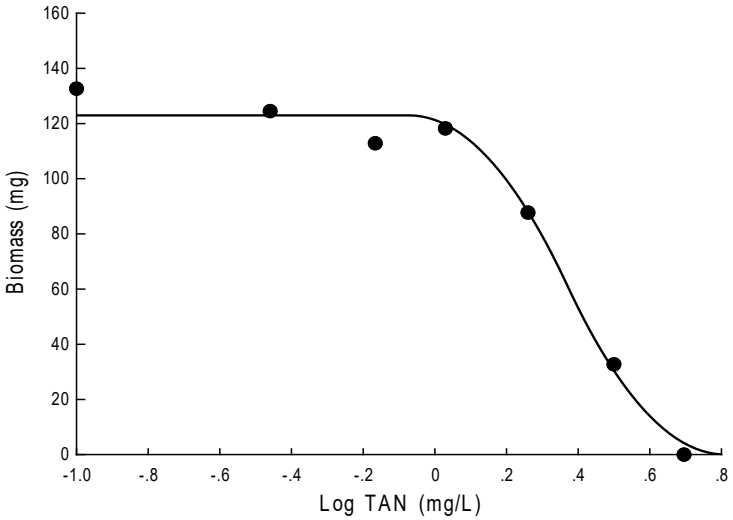
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.1	1.1297	4.09E-02	1.0162	1.2432
S	1.7	1.7867	0.49131	0.4226	3.1508
Y0	117.93	116.51	4.9015	102.9	130.12

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	13.481	10.38	17.508	4.09E-02	1.1297
20	**8.3946**	5.4119	13.021	6.87E-02	0.924
10	6.6118	3.5582	12.286	9.69E-02	0.82032
5	**5.5848**	2.5468	12.247	0.12283	0.74701
0	3.7155	0.90484	15.257	0.22095	0.57002

EC20:EC5 = 1.503

Notes: Acceptable model fit. Acceptable noise at low level effects.

Broderius et al. 1985	
Species: *Micropterus dolomieu*	
Test Endpoint: 32-d ELS Biomass	
C-R Curve Label: Am-Chronic-31	
Test: pH 8.68	
TAN, mg/L	**Biomass (mg)**
0.05	133
0.347	124
0.682	113
1.07	118
1.82	88
3.16	33
4.96	0



	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.4	0.36892	2.75E-02	0.29265	0.44519
S	2.5	2.2667	0.38425	1.1998	3.3335
Y0	132.63	122.94	4.1069	111.53	134.34

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.3384	1.9618	2.7874	2.75E-02	0.36892
20	**1.6098**	1.2216	2.1214	4.32E-02	0.20677
10	1.3337	0.91474	1.9445	5.90E-02	0.12505
5	**1.1675**	0.72729	1.8742	7.40E-02	6.73E-02
0	0.84674	0.48918	1.4656	8.58E-02	-7.23E-02

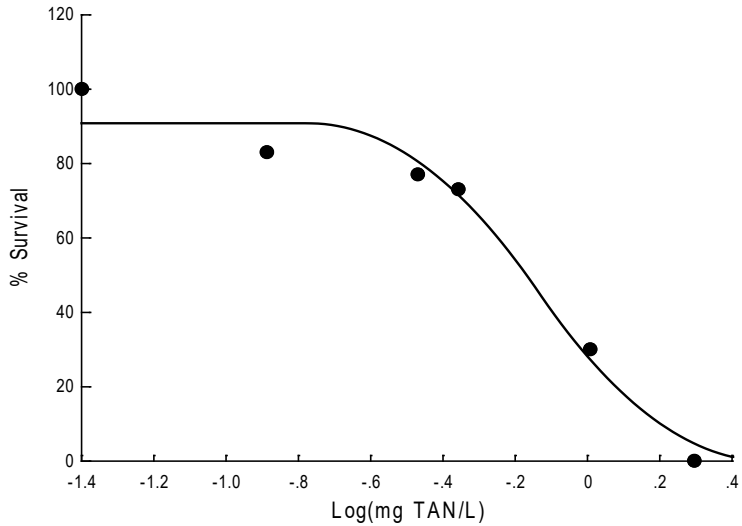
EC20:EC5 = 1.379

Notes: Acceptable model fit. Acceptable noise at low level effects.

Appendix A.4

Test Information, C-R Data and Resulting TRAP models for Chronic Ammonia Toxicity Tests Considered Unacceptable for TAF and MAF Calculation

Wang et al. 2007a	
Species: *Lampsilis fasciola* (2 month old juveniles)	
Test Endpoint: 28-d Juvenile Survival	
C-R Curve Label: Am-Chronic-1	
Test: Single	
TAN, mg/L	**% Survival**
0.04	100
0.13	83
0.34	77
0.44	73
1.02	30
1.98	0



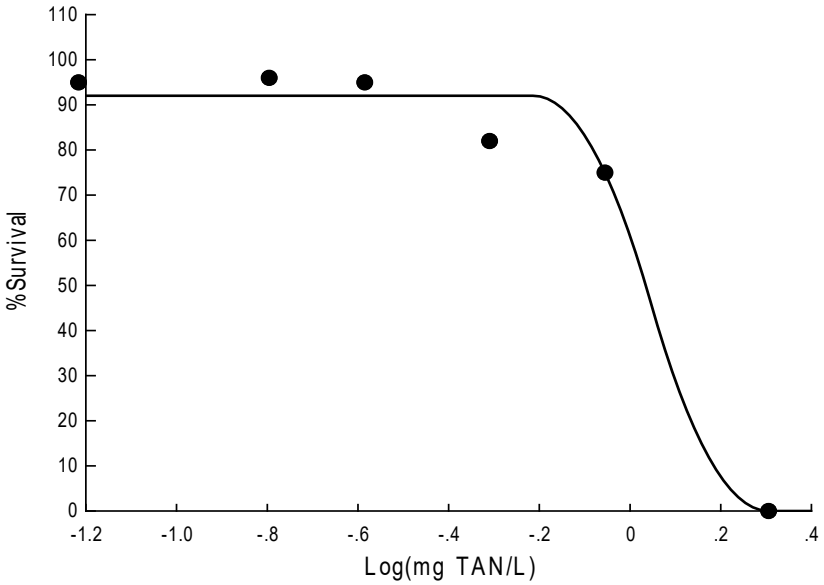
	Initial	Final	SE	95%LCL	95%UCL
LogX50	-0.15214	-0.13544	0.057599	-0.31875	0.047864
S	0.86383	1.5709	0.34755	0.46482	2.6769
Y0	100	90.838	5.5688	73.116	108.56

p	Xp	95%LCL	95%UCL	logXp SE	log Xp
50	0.73208	0.48001	1.1165	0.057599	-0.13544
20	**0.42715**	0.23211	0.78608	0.083233	-0.36942
10	0.32558	0.14709	0.72067	0.10843	-0.48734
5	**0.26871**	0.10041	0.71904	0.13432	-0.57072
0	0.16903	0.046296	0.61715	0.17673	-0.77203

EC20:EC5 = 1.590

Notes: Poor model fit.

Wang et al. 2007a	
Species: *Lampsilis siliquoidea* (2 month old juveniles)	
Test Endpoint: 28-d Juvenile Survival	
C-R Curve Label: Am-Chronic-2	
Test: with substrate test	
TAN, mg/L	**% Survival**
0.06	95
0.16	96
0.26	95
0.49	82
0.88	75
2.02	0



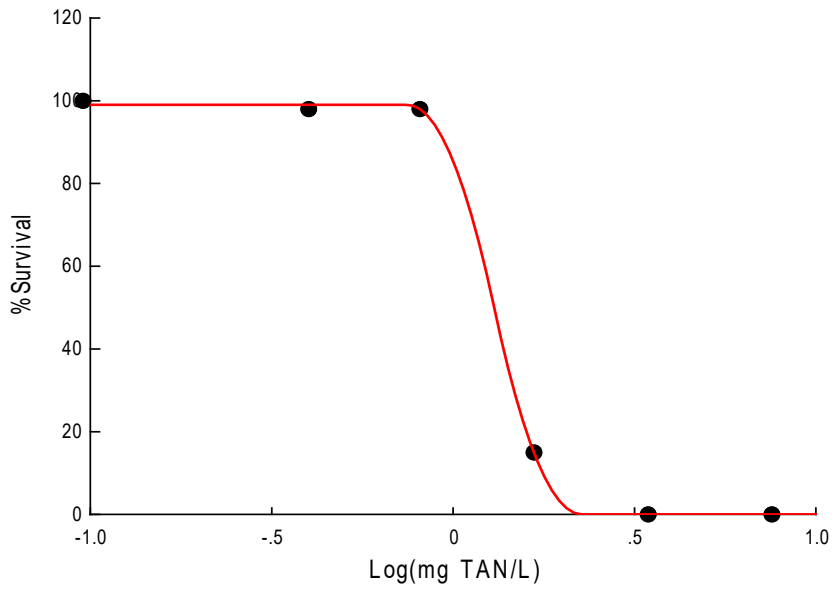
	Initial	Final	SE	95%LCL	95%UCL
LogX50	0.05828	0.046167	8.5591	-27.193	27.285
S	3.288	3.8559	324.56	-1029	1036.7
Y0	91.43	92	3.3417	81.365	102.63

p	Xp	95%LCL	95%UCL	logXp SE	log Xp
50	1.1122			8.5591	0.0462
20	0.8930	0.7010	1.1376	0.0330	-0.0492
10	0.7995	0.6017	1.0622	0.0388	-0.0972
5	0.7393	0.5410	1.0103	0.0426	-0.1312
0	0.6121	0.4226	0.8865	0.0506	-0.2132

EC20:EC5 = 1.208

Notes: Large SE for steepness (S) and X50. Poor model fit.

Wang et al. 2007a	
Species: *Villosa iris* (2 month old juveniles)	
Test Endpoint: 28-d Juvenile Survival	
C-R Curve Label: Am-Chronic-3	
Test: Single	
TAN, mg/L	**% Survival**
0.08	100
0.4	98
0.81	98
1.67	15
3.45	0
7.56	0



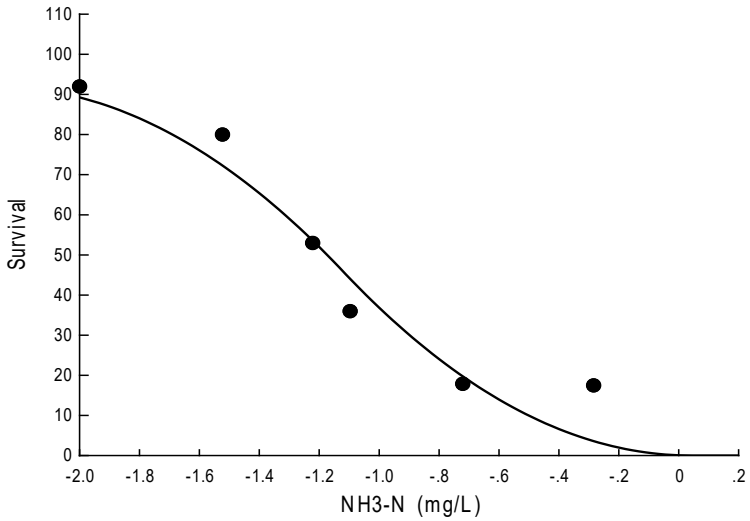
	Initial	Final	SE	95%LCL	95%UCL
LogX50	0.125	0.11467	6.45E-03	9.41E-02	1.35E-01
S	4.5	4.1606	2.28E-01	3.4364	4.8848
Y0	98.667	99	0.57735	97.163	100.84

p	Xp	95%LCL	95%UCL	logXp SE	log Xp
50	1.3022	1.2421	1.3652	0.0065	0.1147
20	1.0625	0.9814	1.1503	0.0108	0.0263
10	0.9590	0.8709	1.0560	0.0132	-0.0182
5	0.8919	0.8002	0.9942	0.0148	-0.0497
0	0.7487	0.6474	0.8659	0.0198	-0.1257

EC20:EC5 = 1.191

Notes: TRAP flagged for IP (No Unique Solution).

Sparks and Sandusky 1981	
Species: *Musculium transversum*	
Test Endpoint: 42-d Juvenile Survival	
C-R Curve Label: Am-Chronic-5	
Test: Single	
NH3-N (mg/L)	**% Survival**
0.01	92
0.03	80
0.06	53
0.08	36
0.19	17.9
0.52	17.5

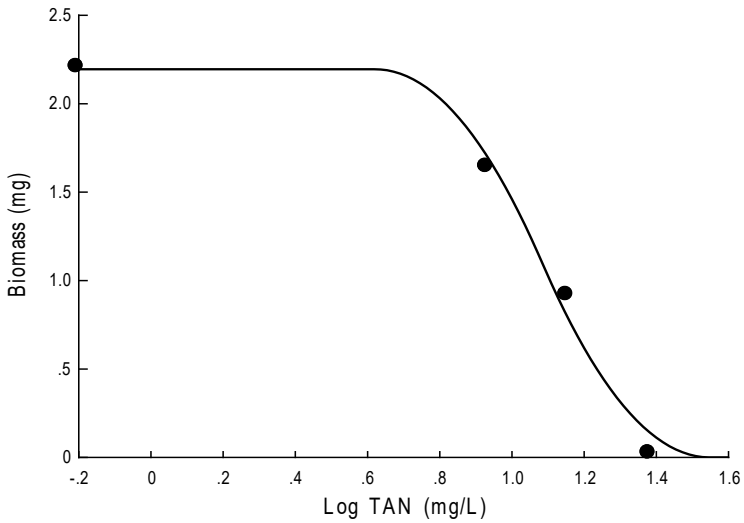


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-1	-1.1218	0.068782	-1.3128	-0.93084
S	1	0.86019	0.19851	0.30904	1.4113
Y0	92	92			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.075543	0.048666	0.11726	0.068782	-1.1218
20	**0.028243**	0.012899	0.06184	0.12259	-1.5491
10	0.017201	0.005259	0.056267	0.18538	-1.7644
5	**0.012114**	0.002566	0.057193	0.24278	-1.9167
0	0.005196	0.000726	0.037184	0.30784	-2.2843

EC20:EC5 = 2.331

Notes: Poor model fit due to no pre-threshold value.

Borgmann 1994	
Species: *Hyalella azteca*	
Test Endpoint: 28-d Biomass	
C-R Curve Label: Am-Chronic-12	
Test: Single	
TAN, mg/L	**Avg. Biomass (mg)**
0.616	2.21884
8.4	1.6543
14	0.93
23.66	0.034

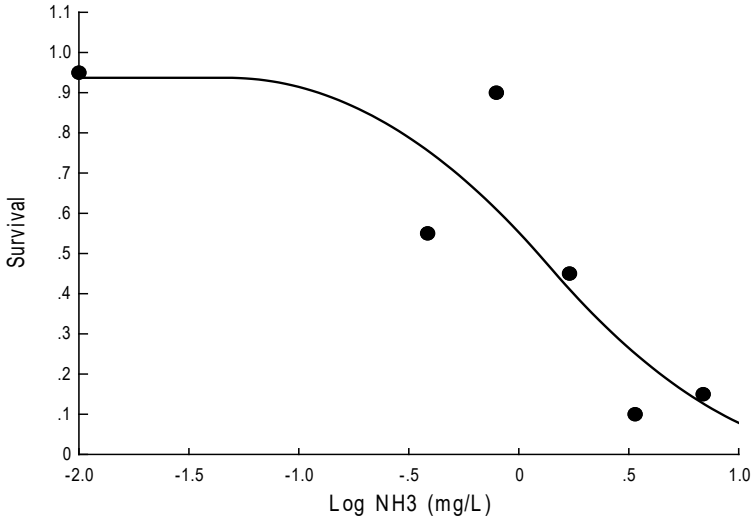


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.1	1.0845			
S	2.2	2.1593			
Y0	2.22	2.1944			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	12.148	3.6157	40.817	0.041423	1.0845
20	**8.2092**	1.0397	64.819	0.070627	0.9143
10	6.7377	0.38723	117.23	0.097632	0.82851
5	**5.8594**	0.14879	230.74	0.12555	0.76785
0	4.1822	0.032161	543.84	0.16638	0.6214

EC20:EC5 = 1.401

Notes: No effect within area of concern.

Thurston et al. 1984b	
Species: *Pteronarcella badia*	
Test Endpoint: 24-d Survival	
C-R Curve Label: Am-Chronic-14	
Test: 501	
Unionized ammonia (NH3) (mg/L)	**Proportion Surviving**
0.01	0.95
0.385	0.55
0.791	0.90
1.7	0.45
3.38	0.10
6.89	0.15

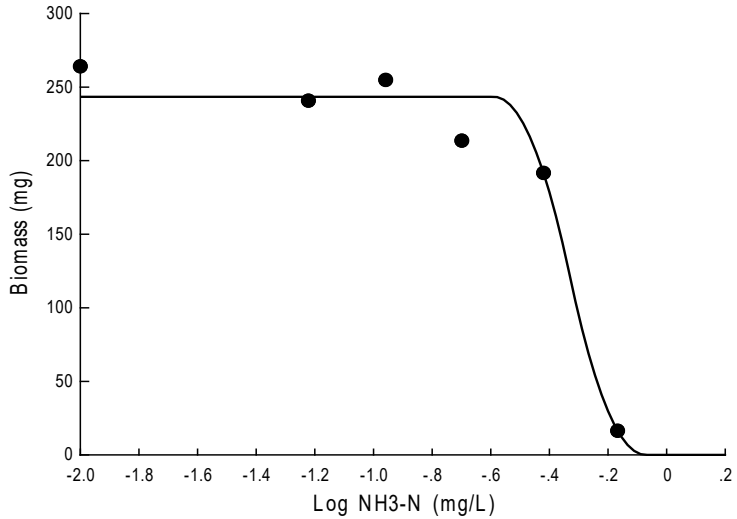


0	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.1	0.13766	0.11117	-0.08981	0.36514
StDev	0.4	0.59554	0.14071	0.41612	1.0451
Y0	0.95	0.93685	0.054061	0.73428	0.99682
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.373	0.81319	2.3181	0.11117	0.13766
20	**0.39948**	0.15171	1.0519	0.19504	-0.3985
10	0.21442	0.055545	0.82776	0.25386	-0.66873
5	**0.1381**	0.025132	0.75886	0.2987	-0.85981
0	0.04774	0.002253	1.0116	0.41563	-1.3211

EC20:EC5 = 2.893

Notes: Poor model fit and no effect within area of concern.

Swigert and Spacie 1983	
Species: *Ictalurus punctatus*	
Test Endpoint: 30-d Biomass	
C-R Curve Label: Am-Chronic-24	
Test: Single	
Mean NH3-N (mg/L)	**Biomass(mg)**
Control (0.01)	264.11
0.06	240.8
0.11	254.91
0.2	213.6
0.38	191.7
0.68	16.49



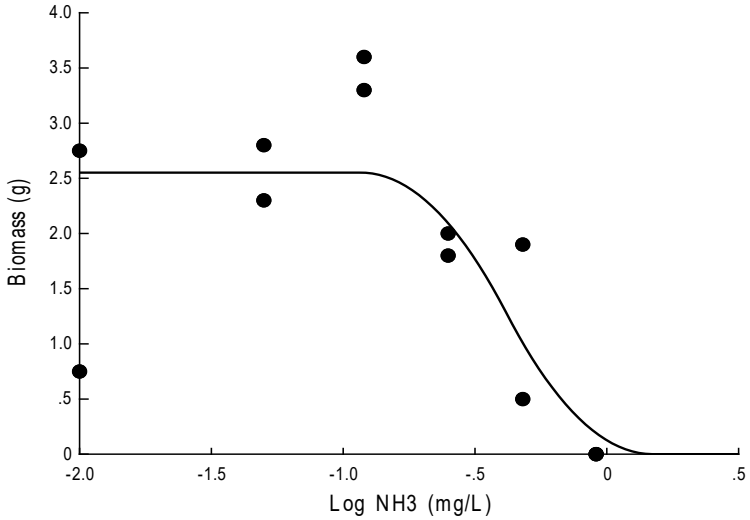
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.4	-0.33039	0.033735	-0.43775	-0.22303
S	3	3.8789	1.1326	0.27439	7.4835
Y0	253.3	243.35	11.016	208.3	278.41

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.46732	0.36497	0.59838	0.033735	-0.33039
20	**0.37572**	0.28175	0.50102	0.039276	-0.42514
10	0.33659	0.22356	0.50678	0.055843	-0.4729
5	**0.31141**	0.11389	0.8515	0.13727	-0.50666
0	0.25811	0.12768	0.52181	0.096059	-0.58819

EC20:EC5 = 1.207

Notes: Poor model fit.

McCormick et al. 1984	
Species: *Lepomis cyanellus*	
Test Endpoint: 30-d Biomass	
C-R Curve Label: Am-Chronic-25	
Test: Single	
NH3 (mg/L)	**Biomass(g)**
0.01	2.75
0.01	0.75
0.05	2.8
0.05	2.3
0.12	3.6
0.12	3.3
0.25	2
0.25	1.8
0.48	1.9
0.48	0.5
0.91	0
0.91	0



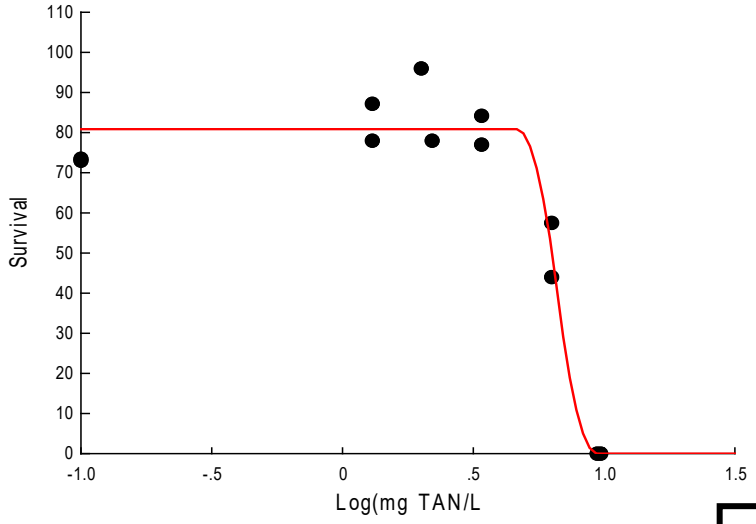
EC20:EC5 = 1.496

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.4	-0.37993	0.12544	-0.66369	-0.096171
S	2	1.807	1.2492	-1.0189	4.6329
Y0	2.58	2.5508	0.34506	1.7702	3.3314

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.41693	0.21692	0.80136	0.12544	-0.37993
20	**0.26102**	0.0858	0.79404	0.21359	-0.58333
10	0.20614	0.043865	0.96869	0.29708	-0.68585
5	**0.17445**	0.023988	1.2686	0.3809	-0.75833
0	0.11659	0.0076075	1.7868	0.52402	-0.93334

Notes: Large SE for steepness (S). Unacceptable noise at low level effects.

Reinbold and Pescitelli 1982a	
Species: *Lepomis cyanellus*	
Test Endpoint: 30-d Larval Survival	
C-R Curve Label: Am-Chronic-26	
Test: Single	
TAN, mg/L	**% Survival**
Control (0.1)	73
Control (0.1)	73.5
1.3	78
1.3	87.2
2	96
2.2	78
3.4	77
3.4	84.2
6.3	57.5
6.3	44
9.7	0
9.4	0



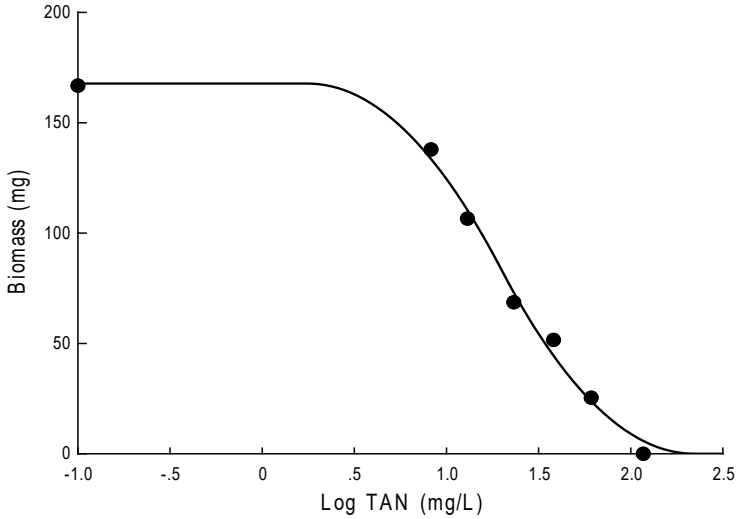
EC20:EC5 = 1.118

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.8	0.8203	1.7533	-3.146	4.7866
S	5	6.5367	546.87	-1230.6	1243.6
Y0	82.1	80.863	2.6846	74.79	86.935

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	6.6115	7.15E-04	61176	1.7533	0.8203
20	**5.8086**	4.9091	6.8729	3.23E-02	0.76407
10	5.4417	4.6496	6.3686	3.02E-02	0.73573
5	**5.1963**	4.4625	6.0507	2.92E-02	0.71569
0	4.6485	3.9988	5.4038	2.89E-02	0.66732

Notes: **Notes**: TRAP flagged for IP (No Unique Solution).

Broderius et al. 1985	
Species: *Micropterus dolomieu*	
Test Endpoint: 32-d ELS Biomass	
C-R Curve Label: Am-Chronic-28	
Test: pH 6.6	
TAN, mg/L	**Biomass (mg)**
0.05	167
8.24	138
13	107
23.2	69
38.1	52
61	25
117	0



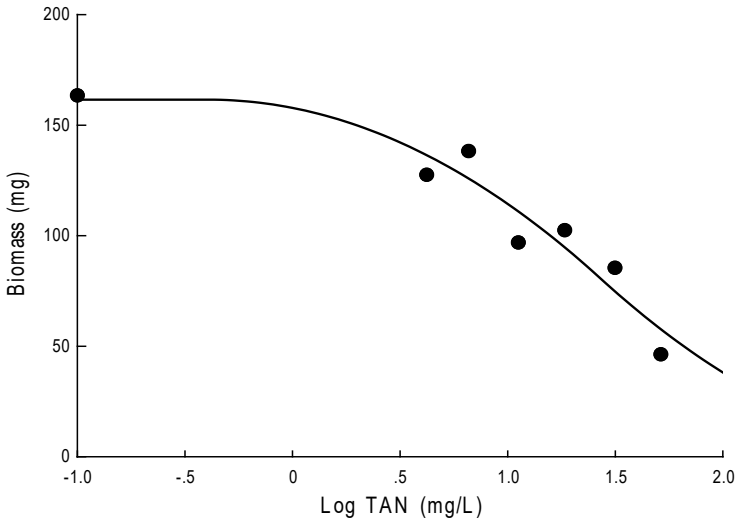
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.3	1.2958	3.26E-02	1.2053	1.3863
S	1	0.95465	8.17E-02	0.72771	1.1816
Y0	166.83	167.71	5.8153	151.56	183.85

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	19.761	16.044	24.339	3.26E-02	1.2958
20	**8.1432**	5.6472	11.742	5.73E-02	0.91079
10	5.209	3.1384	8.6456	7.93E-02	0.71675
5	**3.7979**	1.9973	7.2218	0.10053	0.57954
0	1.7713	0.79684	3.9374	0.12495	0.24829

EC20:EC5 = 2.144

Notes: No effect within area of concern.

Broderius et al. 1985	
Species: *Micropterus dolomieu*	
Test Endpoint: 32-d ELS Biomass	
C-R Curve Label: Am-Chronic-29	
Test: pH 7.25	
TAN, mg/L	**Biomass (mg)**
0.05	163.4934
4.2	127.596
6.58	138.2976
11.2	96.9612
18.4	102.48
31.5	85.5
51.5	46.371



	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.4299	0.12276	1.089	1.7707
S	0.75	0.549	0.14909	0.13507	0.96293
Y0	163.49	161.51	13.368	124.4	198.63

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	26.906	12.275	58.977	0.12276	1.4299
20	**5.7593**	1.2975	25.565	0.23313	0.76037
10	2.6482	0.32296	21.715	0.32913	0.42296
5	**1.5289**	0.10976	21.296	0.41202	0.18437
0	0.40584	4.86E-03	33.912	0.69225	-0.39164

EC20:EC5 = 3.767

Notes: No effect within area of concern.

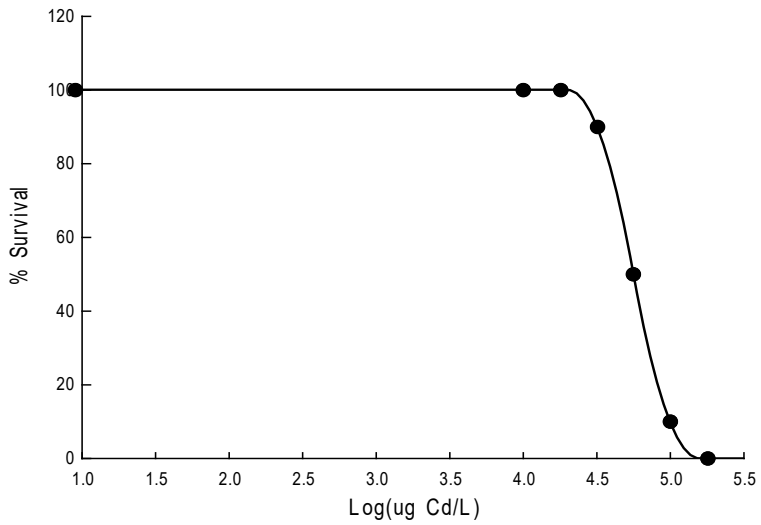
Appendix B

Test Information, C-R Data and Resulting TRAP models for Acute and Chronic Cadmium Toxicity Tests Considered Acceptable or Unacceptable for TAF and MAF Calculation

Appendix B.1

Test Information, C-R Data and Resulting TRAP models for Acute Cadmium Toxicity Tests Acceptable for TAF and MAF Calculation

Rathore and Khangarot 2002	
Species: *Tubifex tubifex*	
Test Endpoint: 96 hr survival	
C-R Curve Label: Cd-Acute-2	
Test: 15°C	
Cd, µg/L	**%Survival**
5	100
10000	100
18000	100
32000	90
56000	50
100000	10
180000	0



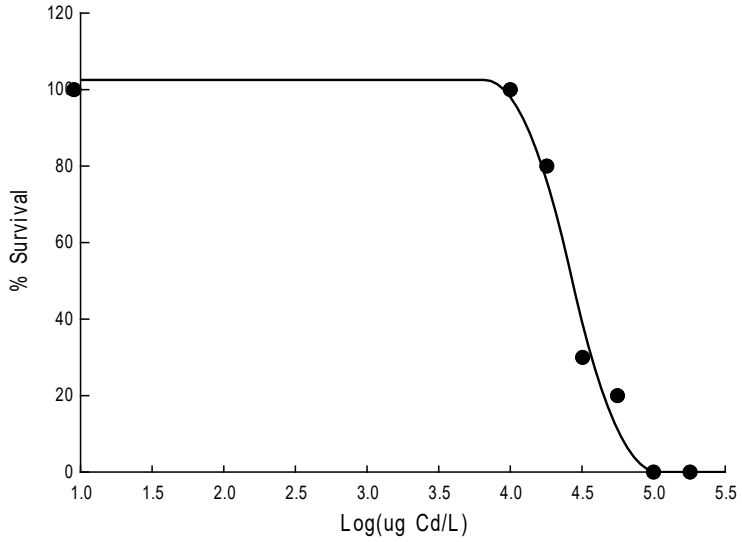
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.75	4.7493	1.07E-03	4.7463	4.7523
S	2.2	2.2324	1.72E-02	2.1846	2.2802
Y0	100	100.05	0.14604	99.649	100.46

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50.0	56141.0	55758.0	56526.0	0.0	4.7
20.0	38427.0	37986.0	38873.0	0.0	4.6
10.0	31744.0	31220.0	32276.0	0.0	4.5
5.0	27732.0	27139.0	28338.0	0.0	4.4
0.0	20014.0	19399.0	20648.0	0.0	4.3

LC50:LC5 = 2.024

Notes: Acceptable model fit.

Rathore and Khangarot 2002	
Species: *Tubifex tubifex*	
Test Hardness: 237 mg/L	
Test Endpoint: 96 hr survival	
C-R Curve Label: Cd-Acute-5	
Test: 30°C	
Cd, µg/L	**%Survival**
5	100
10000	100
18000	80
32000	30
56000	20
100000	0
180000	0



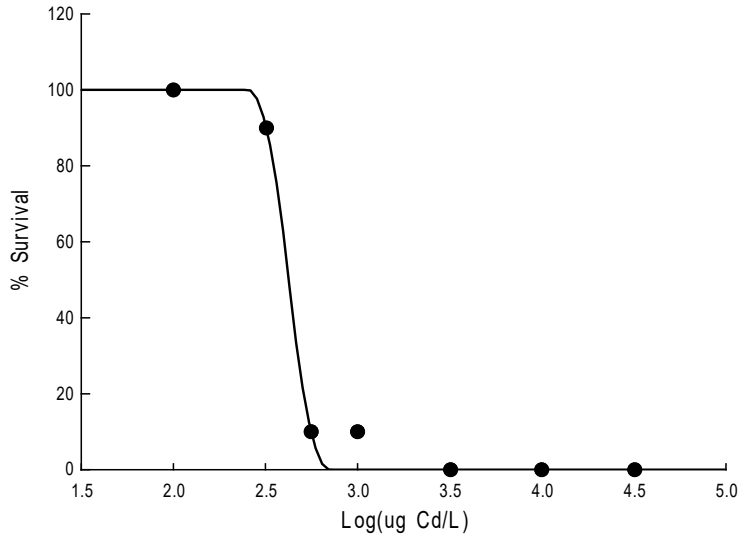
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.425	4.4257	4.18E-02	4.3095	4.5419
S	1.65	1.6544	3.21E-01	0.76438	2.5444
Y0	100	102.5	6.0941	85.581	119.42

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50.0	26650.0	20396.0	34822.0	0.0	4.4
20.0	15978.0	10093.0	25296.0	0.1	4.2
10.0	12347.0	6893.5	22115.0	0.1	4.1
5.0	10289.0	5407.9	19577.0	0.1	4.0
0.0	6625.8	3139.2	13985.0	0.1	3.8

LC50:LC5 = 2.590

Notes: Acceptable model fit.

Rathore and Khangarot 2003	
Species: *Tubifex tubifex*	
Test End Point: 96 hr survival	
C-R Curve Label: Cd-Acute-6	
Test: Hardness = 45 mg/L	
Cd, µg/L	**%Survival**
100	100
320	90
560	10
1000	10
3200	0
10000	0
32000	0



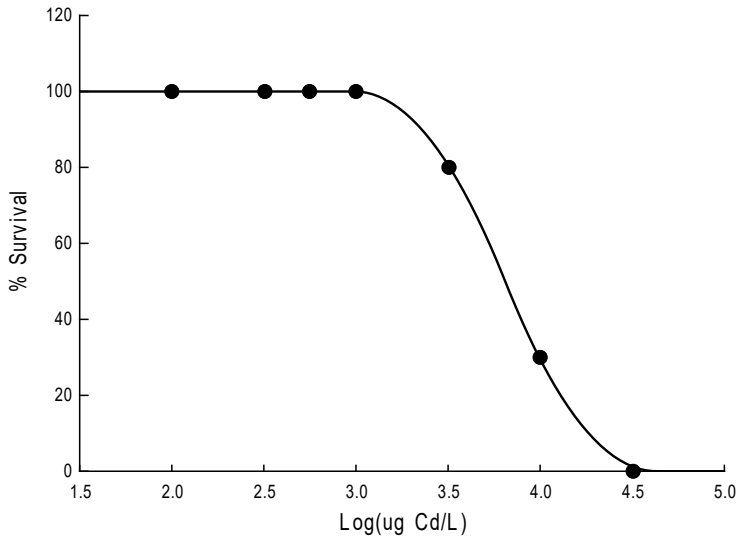
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.65	2.6267	2.13E-02	2.5676	2.6858
S	3.5	4.549	7.47E-01	2.4737	6.6242
Y0	100	100	5	86.118	113.88

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50.0	423.3	369.5	485.0	0.0	2.6
20.0	351.5	293.4	421.0	0.0	2.5
10.0	320.0	259.0	395.3	0.0	2.5
5.0	299.5	234.8	381.9	0.0	2.5
0.0	255.2	177.7	366.5	0.1	2.4

LC50:LC5 = 1.414

Notes: Acceptable model. No TRAP flags or errors. There is also a no effect concentration that defines the plateau prior to the breakpoint of the decline in response, which passes through the first effect (10%) concentration.

Rathore and Khangarot 2003	
Species: *Tubifex tubifex*	
Test End Point: 96 hr survival	
C-R Curve Label: Cd-Acute-8	
Test: Hardness = 305 mg/L	
Cd, µg/L	**%Survival**
100	100
320	100
560	100
1000	100
3200	80
10000	30
32000	0



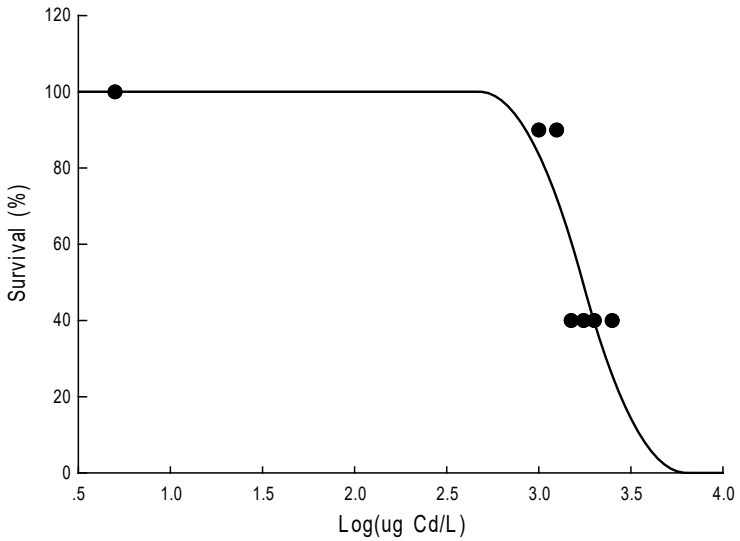
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.8	3.8104	5.61E-03	3.7948	3.826
S	1.2	1.2201	2.51E-02	1.1505	1.2898
Y0	100	99.975	0.32254	99.079	100.87

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50.0	6462.5	6235.0	6698.4	0.0	3.8
20.0	3229.7	3049.3	3420.9	0.0	3.5
10.0	2276.9	2109.5	2457.6	0.0	3.4
5.0	1778.2	1630.1	1939.9	0.0	3.3
0.0	979.1	888.4	1079.0	0.0	3.0

LC50:LC5= 3.634

Notes: Acceptable model fit.

Coeurdassier et al. 2004	
Species: *Lymnaea stagnalis*	
Test End Point: 96 hr Survival	
C-R Curve Label: Cd-Acute-9	
Test: Juvenile-S2	
Cd, µg/L	**%Survival**
5	100
1000	90
1250	90
1500	40
1750	40
2000	40
2500	40



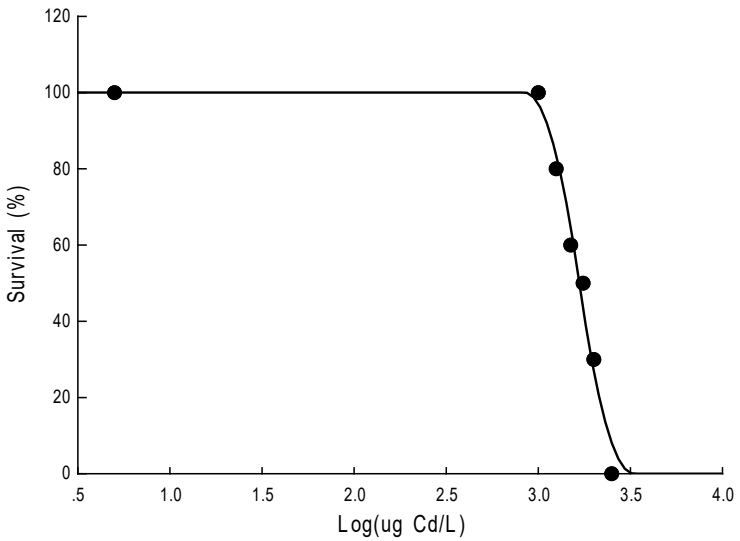
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.1844	3.2393	0.041883	3.1316	3.347
S	3.5591	1.7845	0.67098	0.059722	3.5093
Y0	100	100			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1735	1354	2223.1	0.041883	3.2393
20	1079.8	659.99	1766.6	0.08317	3.0333
10	850.21	405.32	1783.4	0.12516	2.9295
5	718	273.26	1886.6	0.16321	2.8561
0	477.44	69.134	3297.2	0.32647	2.6789

LC50:LC5= 2.416

Notes: Acceptable model. No TRAP flags or errors. There is also a no effect concentration that defines the plateau prior to the breakpoint of the decline in response, which passes near the first effect concentrations.

Coeurdassier et al. 2004	
Species: *Lymnaea stagnalis*	
Test End Point: 96 hr Survival	
C-R Curve Label: Cd-Acute-10	
Test: Adult	
Cd, µg/L	**%Survival**
5	100
1000	100
1250	80
1500	60
1750	50
2000	30
2500	0



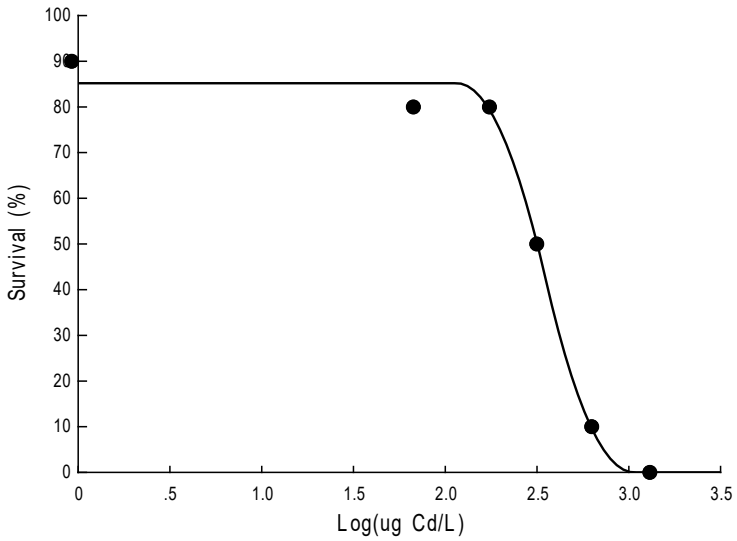
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3	3.2227	0.016394	3.1771	3.2682
S	3.5	3.3971	0.57652	1.7965	4.9978
Y0	100	99.994	5.5517	84.58	115.41

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1669.8	1503.6	1854.3	0.016394	3.2227
20	1301.6	1073.1	1578.7	0.030196	3.1145
10	1148	878.29	1500.5	0.041888	3.0599
5	1050.5	746.97	1477.3	0.053335	3.0214
0	847.8	502.76	1429.6	0.081734	2.9283

LC50:LC5= 1.590

Notes: Acceptable model fit.

Pais 2012	
Species: *Lymnaea stagnalis*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-12	
Test: 25 mm length	
Cd, µg/L	**%Survival**
0.5	90
67	80
174	80
315	50
628	10
1301	0



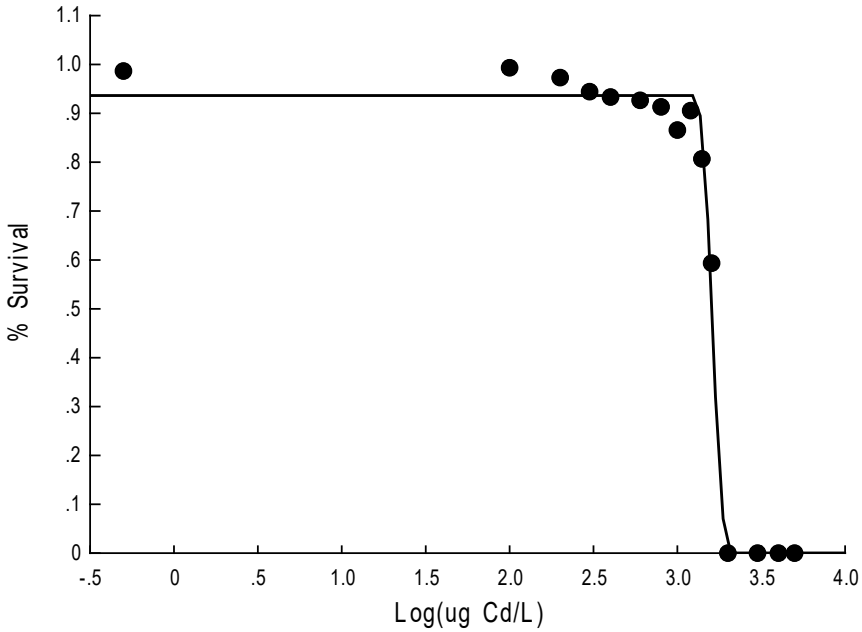
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.5	2.5451	0.024484	2.4671	2.623
S	2	2.0763	0.30884	1.0934	3.0591
Y0	90	85.166	2.8024	76.247	94.084

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	350.81	293.19	419.75	0.024484	2.5451
20	233.37	176.52	308.52	0.038096	2.368
10	190.03	127.53	283.17	0.054431	2.2788
5	164.34	96.2	280.74	0.073077	2.2157
0	115.73	49.165	272.4	0.11682	2.0634

LC50:LC5= 2.135

Notes: No TRAP errors or flags. Acceptable noise at low level effects.

Woodard 2005	
Species: *Physa acuta* (adult)	
Test End Point: 96 hr Survival	
C-R Curve Label: Cd-Acute-14	
Test: Single	
Cd, µg/L	**%Survival**
0.5	98.67
100	99.33
200	97.32
300	94.44
400	93.33
600	92.67
800	91.33
1000	86.58
1200	90.54
1400	80.67
1600	59.33
2000	0
3000	0
4000	0
5000	0



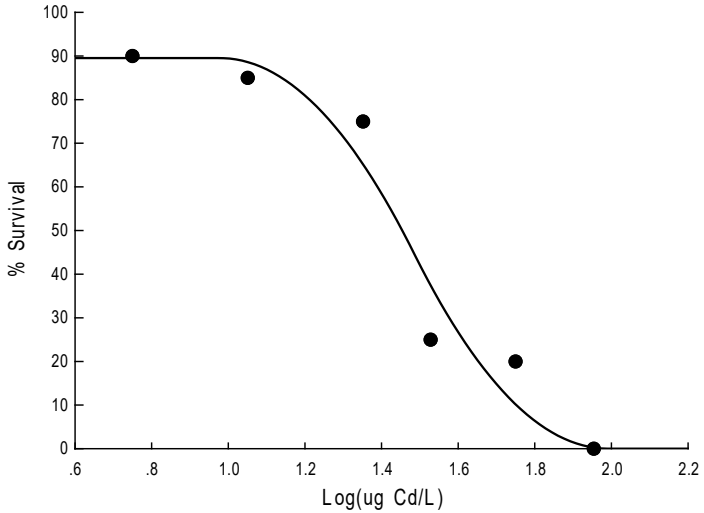
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.1964	3.2092	3.57E-03	3.20E+00	3.2162
StDev	5.55E-02	4.23E-02	2.61E-03	3.78E-02	4.82E-02
Y0	0.93801	0.93617	6.65E-03	0.92179	0.94861

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1618.700	1592.700	1645.200	0.004	3.209
20	1482.700	1450.600	1515.500	0.005	3.171
10	1418.500	1382.400	1455.700	0.006	3.152
5	1374.900	1335.400	1415.400	0.006	3.138
0	1274.900	1227.900	1323.600	0.008	3.106

LC50:LC5= 1.177

Notes: Acceptable model.

Shaw et al. 2006	
Species: *Ceriodaphnia dubia* (< 24 h old)	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Cd-Acute-17	
Test: Single	
Cd, µg/L	**%Survival**
6	90
11	85
22	75
34	25
56	20
90	0



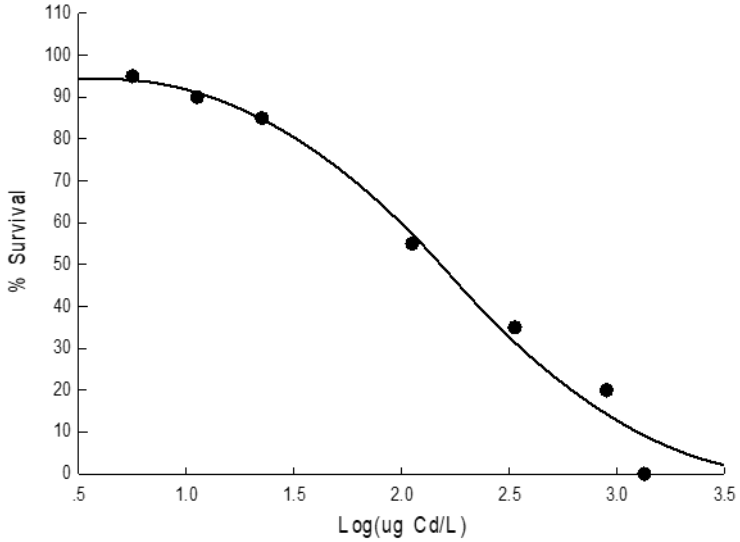
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.4848	0.060731	1.2916	1.6781
S	2	1.9744	0.77123	-0.48003	4.4288
Y0	90	89.505	8.8753	61.26	117.75

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	30.537	19.569	47.655	0.060731	1.4848
20	19.892	8.6052	45.983	0.11435	1.2987
10	16.027	5.2605	48.829	0.15203	1.2049
5	13.757	4.0303	46.955	0.16754	1.1385
0	9.5136	2.4694	36.653	0.18406	0.97835

LC50:LC5 = 2.220

Notes: No TRAP flags or errors. Acceptable model fit.

Shaw et al. 2006	
Species: *Daphnia magna* (<24 h old)	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Cd-Acute-19	
Test: Single	
Cd, µg/L	**%Survival**
5.6205	95
11.241	90
22.482	85
112.41	55
337.23	35
899.28	20
1348.92	0



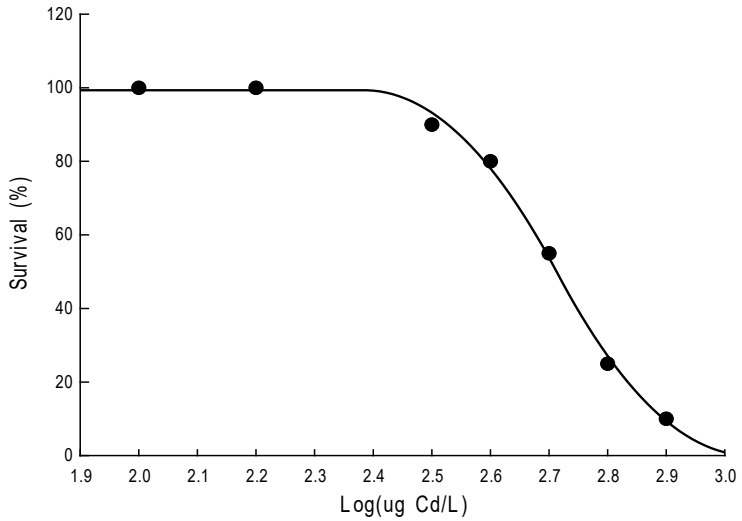
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.2	2.2325	0.10946	1.9286	2.5364
S	0.65	0.62348	0.11077	0.31594	0.93103
Y0	95	94.318	5.9716	77.738	110.9

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	170.81	84.837	343.89	0.10946	2.2325
20	43.954	12.166	158.8	0.20092	1.643
10	22.177	3.8257	128.55	0.27488	1.3459
5	13.671	1.4185	131.76	0.35441	1.1358
0	4.2522	0.096408	187.55	0.5923	0.62861

LC50:LC5 = 12.49

Notes: Acceptable model fit despite no true control.

Perez and Beiras 2010	
Species: *Daphnia magna* (<24 h old)	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Cd-Acute-22	
Test: Single	
Cd, µg/L	**%Survival**
100	100
158	100
316	90
398	80
501	55
631	25
794	10



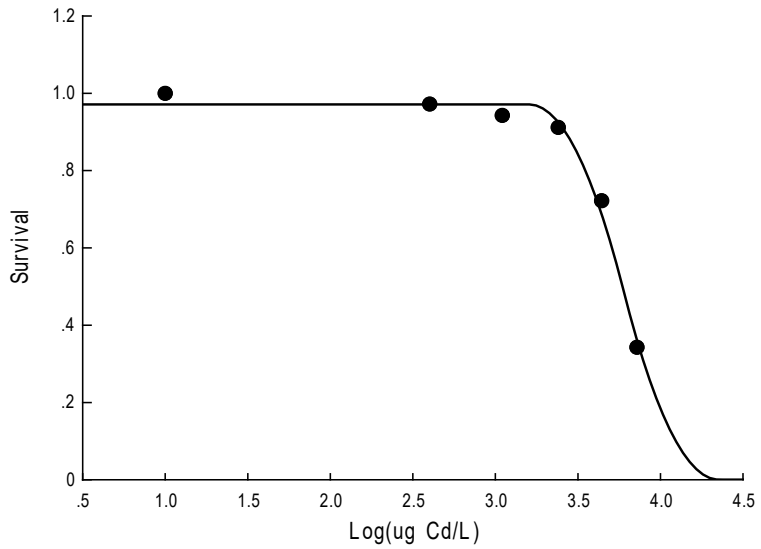
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.7	2.714	0.0063449	2.6964	2.7316
S	3	3.0385	0.1747	2.5534	3.5235
Y0	100	99.306	1.56	94.974	103.64

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	517.6	497.02	539.03	0.0063449	2.714
20	391.77	365.9	419.47	0.010687	2.593
10	340.46	309.83	374.11	0.014745	2.5321
5	308.29	273.39	347.64	0.018791	2.489
0	242.6	200.94	292.88	0.029467	2.3849

LC50:LC5 = 1.679

Notes: Acceptable model fit.

Mirenda 1986	
Species: *Orconectes virilis* (adult)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-30	
Test: Single	
Cd, µg/L	**%Survival**
10	100
400	97.22
1100	94.29
2400	91.18
4400	72.22
7200	34.29



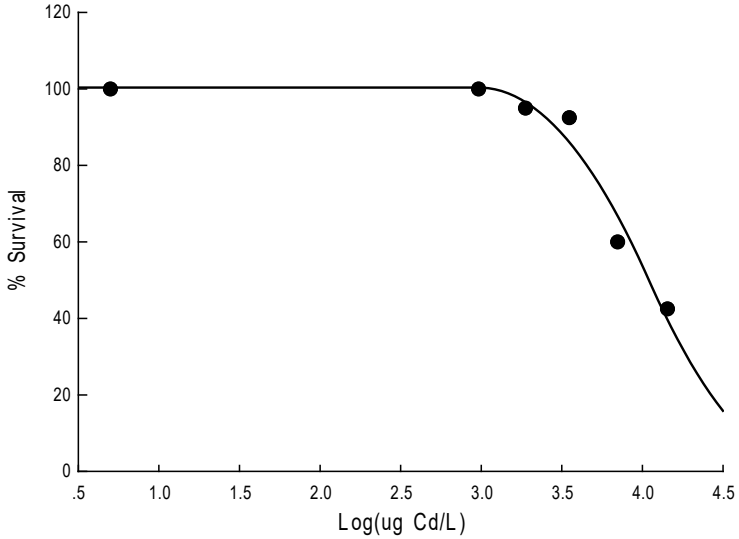
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.75	3.7786	0.041905	3.6932	3.8641
StDev	0.25	0.23494	0.051081	0.1655	0.40425
Y0	0.97169	0.97113	0.016126	0.91933	0.99377

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	6006.8	4934.3	7312.4	0.041905	3.7786
20	3690.8	2910.9	4679.7	0.048149	3.5671
10	2887.5	2051.9	4063.4	0.064925	3.4605
5	2427.4	1554.5	3790.3	0.079352	3.3851
0	1596.4	684.94	3721	0.11901	3.2032

LC50:LC5 = 2.475

Notes: Acceptable model fit.

Brinkman and Vieira 2007; Brinkman and Johnston 2008	
Species: *Rhithrogena hageni* (nymph)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-35	
Test: Single	
Cd, µg/L (dissolved)	**%Survival**
5	100
963	100
1880	95
3520	92.5
7020	60
14300	42.5



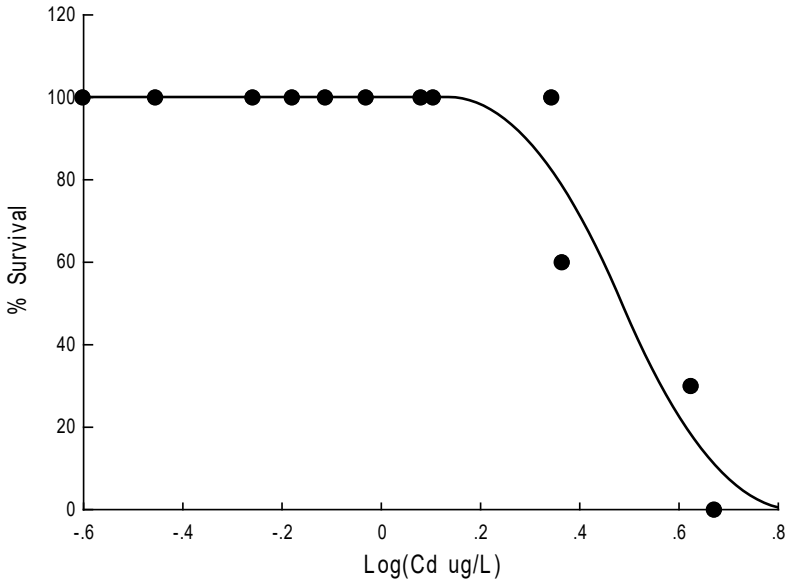
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.05	4.0384	5.53E-02	3.8624	4.2143
S	0.95	0.94933	0.1901	0.34436	1.5543
Y0	100	100.32	3.9035	87.9	112.75

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	10924	7285.3	16379	5.53E-02	4.0384
20	4479.3	2338.2	8580.9	8.87E-02	3.6512
10	2858.1	1144.9	7134.8	0.12484	3.4561
5	2080.2	662	6536.7	0.15625	3.3181
0	966.05	137.43	6790.8	0.26612	2.985

LC50:LC5 = 5.251

Notes: Acceptable model fit.

Phipps and Holcombe 1985	
Species: *Oncorhynchus mykiss* (8.8 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-47	
Test: Single	
Cd, (µg/L)	**%Survival**
0.25	100
0.35	100
0.55	100
0.66	100
0.77	100
0.93	100
1.2	100
1.27	100
2.2	100
2.31	60
4.2	30
4.68	0



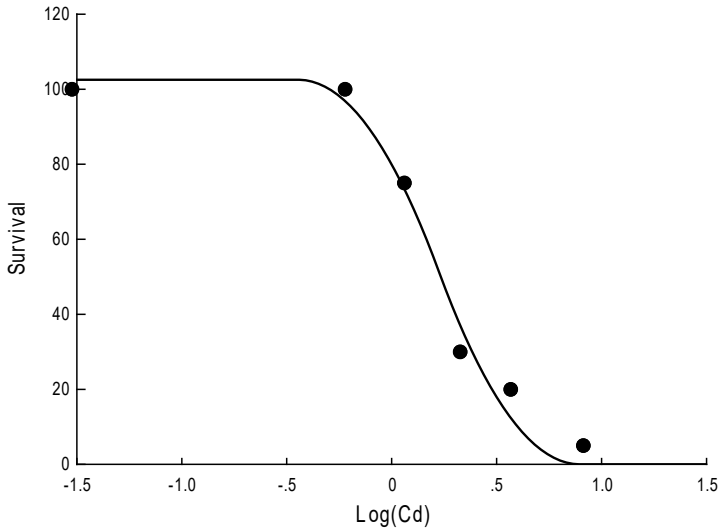
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.485	0.48496	0.03197	0.41264	0.55728
S	2.85	2.8514	0.61501	1.4601	4.2426
Y0	100	100.08	3.5668	92.015	108.15

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	3.0546	2.586	3.6081	0.03197	0.48496
20	2.2702	1.8168	2.8366	0.042768	0.35606
10	1.9548	1.4683	2.6023	0.054935	0.29109
5	1.7585	1.2118	2.5519	0.071488	0.24515
0	1.3622	0.43612	4.2549	0.21866	0.13425

LC50:LC5 = 1.737

Notes: Acceptable model fit despite noise in falling limb.

Stubblefield 1990	
Species: *Oncorhynchus mykiss* (18.3 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-48	
Test: Single	
Cd, (µg/L)	**%Survival**
0.03	100
0.6	100
1.15	75
2.12	30
3.69	20
8.19	5



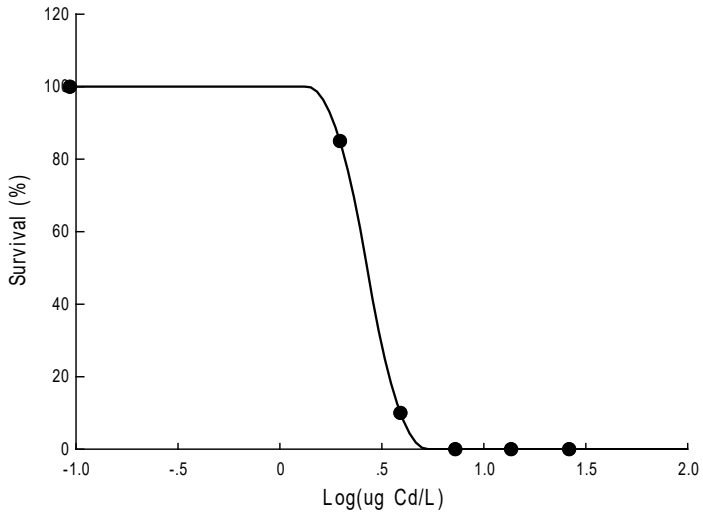
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.225	0.22594	0.048977	0.070072	0.38181
S	1.5	1.4901	0.30513	0.51905	2.4612
Y0	100	102.51	6.5946	81.522	123.5

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.6824	1.1751	2.4088	0.048977	0.22594
20	0.95342	0.51386	1.769	0.084351	-0.02072
10	0.71609	0.31236	1.6417	0.11322	-0.14503
5	0.58488	0.20684	1.6539	0.14185	-0.23293
0	0.3588	0.057941	2.2218	0.24882	-0.44515

LC50:LC5 = 2.876

Notes: Acceptable model fit.

Davies et al. 1993	
Species: *Oncorhynchus mykiss* (36 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-49	
Test: Acute 1 – 50 mg/L hardness	
Cd, (µg/L)	**%Survival**
0.07	100
1.97	85
3.90	10
7.24	0
13.6	0
26.2	0



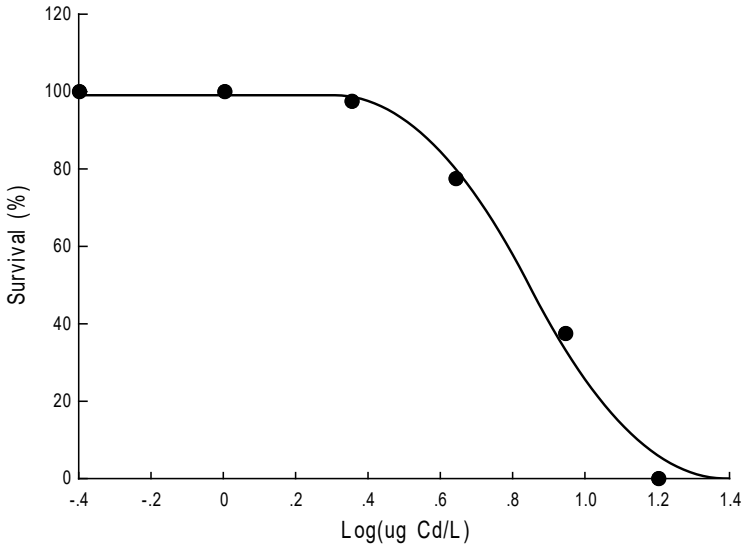
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.4	0.42794	0	0.42794	0.42794
S	3	3.3886	0	3.3886	3.3886
Y0	100	100	0	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.6788	2.6788	2.6788	0	0.42794
20	2.0868	2.0868	2.0868	0	0.31947
10	1.8399	1.8399	1.8399	0	0.26481
5	1.6833	1.6833	1.6833	0	0.22615
0	1.3578	1.3578	1.3578	0	0.13283

LC50:LC5 = 1.591

Notes: Acceptable model fit.

Davies et al. 1993	
Species: *Oncorhynchus mykiss* (36 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-53	
Test: Acute 2 – 200 mg/L hardness	
Cd, (µg/L)	**%Survival**
0.40	100
1.01	100
2.27	97.5
4.40	77.5
8.85	37.5
16.0	0



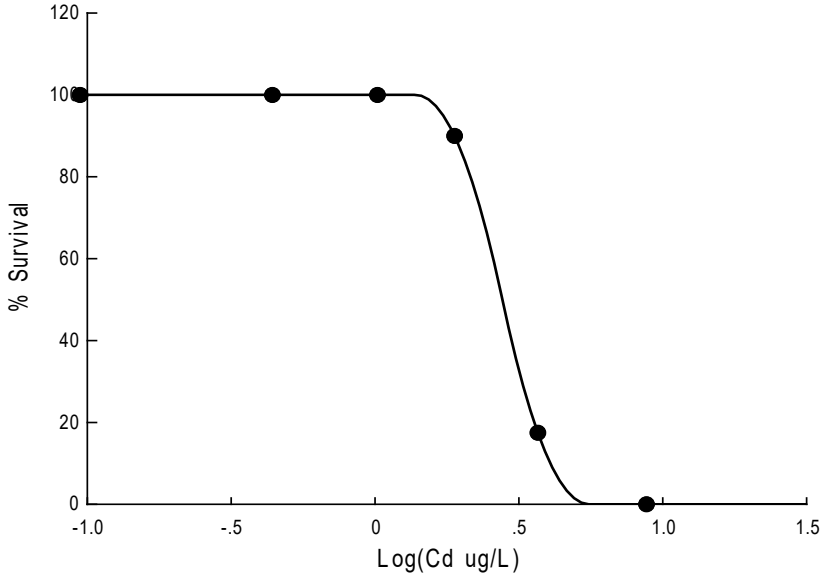
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.80976	0.84828	0.02619	0.76493	0.93163
S	2	1.8471	0.25073	1.0491	2.645
Y0	99.2	99.034	2.7908	90.153	107.92

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	7.0515	5.8202	8.5434	0.02619	0.84828
20	4.4596	3.2414	6.1355	0.043539	0.64929
10	3.54	2.2963	5.4572	0.059064	0.549
5	3.0067	1.7442	5.1831	0.074314	0.47809
0	2.0271	1.0107	4.0658	0.09498	0.30688

LC50:LC5 = 2.345

Notes: Acceptable model fit.

Davies and Brinkman 1994b	
Species: *Oncorhynchus mykiss* (fry, 1 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-55	
Test: Acute 1 – unaged soft (29 mg/L hardness)	
Cd, (µg/L)	**%Survival**
0.05	100
0.44	100
1.02	100
1.89	90
3.68	17.5
8.78	0



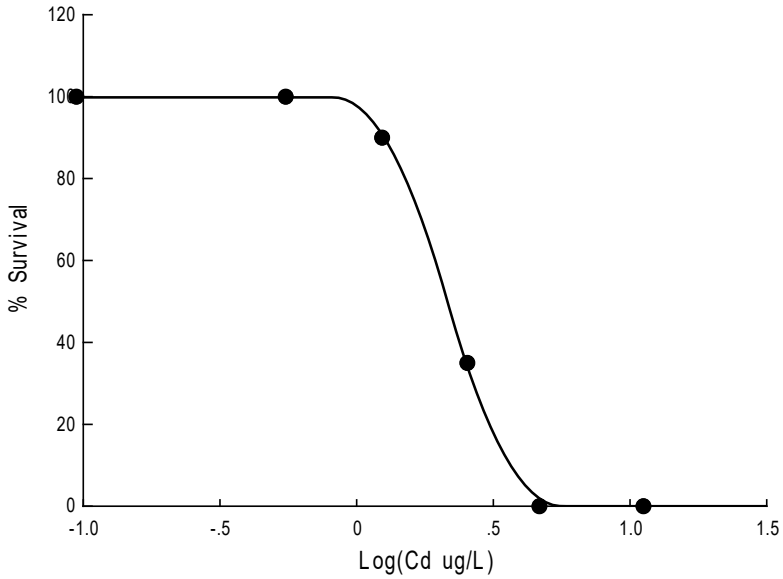
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.44	0.44289	0	0.44289	0.44289
S	3.3	3.3214	0	3.3214	3.3214
Y0	100	100	0	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.7726	2.7726	2.7726	0	0.44289
20	2.149	2.15E+00	2.149	0	0.33223
10	1.8900	1.8900	1.8900	0.0000	0.2765
5	1.7259	1.7259	1.7259	0.0000	0.2370
0	1.39E+00	1.39E+00	1.39E+00	0	0.14182

Notes: Acceptable model fit.

LC50:LC5 = 1.606

Davies and Brinkman 1994b	
Species: *Oncorhynchus mykiss* (fry, 1 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-58	
Test: Acute 2 - unaged soft (28 mg/L hardness)	
Cd, (µg/L)	**%Survival**
0.07	100
0.55	100
1.24	90
2.54	35
4.66	0
11.2	0



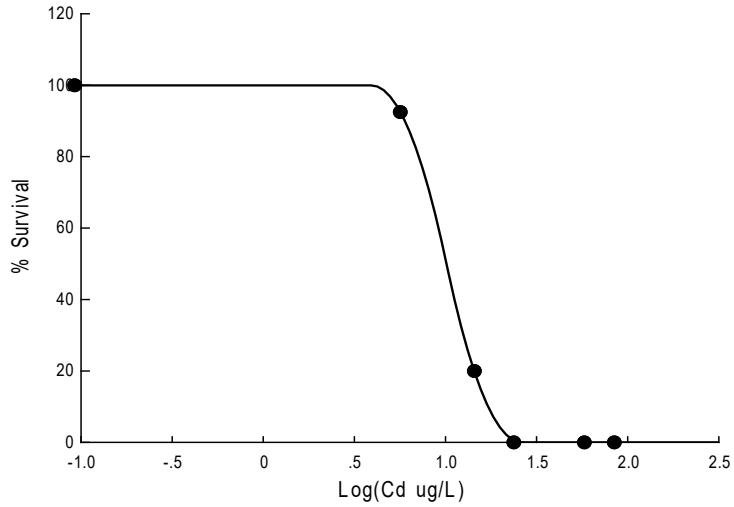
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.33	0.3329	6.55E-03	0.31206	0.35374
S	2.4	2.3978	1.06E-01	2.0612	2.7343
Y0	100	99.787	0.90252	96.915	102.66

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.1523	2.0515	2.2581	6.55E-03	0.3329
20	1.5122	1.39E+00	1.641	1.12E-02	0.17962
10	1.2658	1.1372	1.4089	0.0146	0.1024
5	1.1162	0.9876	1.2615	0.0167	0.0477
0	8.24E-01	7.12E-01	9.53E-01	1.99E-02	-8.41E-02

LC50:LC5 = 1.928

Notes: Acceptable model fit.

Davies and Brinkman 1994b	
Species: *Oncorhynchus mykiss* (fry, 2.5 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-60	
Test: Acute 2 - unaged hard (281 mg/L hardness)	
Cd, (µg/L)	**%Survival**
0.05	100
5.65	92.5
14.4	20
23.7	0
57.8	0
84.4	0



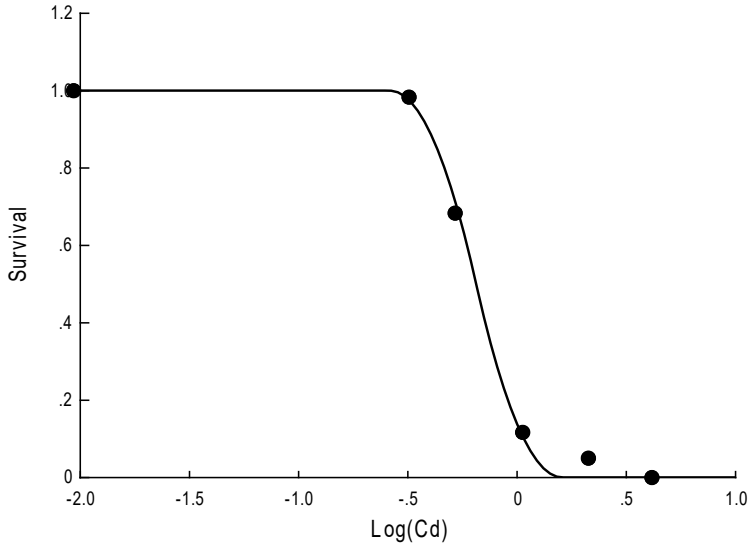
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1	1.006	2.46E-03	0.99816	1.0138
S	2.5	2.4258	2.96E-02	2.3316	2.5201
Y0	100	99.95	0.33445	98.886	101.01

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	10.139	9.9578	10.323	2.46E-03	1.006
20	7.1528	6.9565	7.3546	3.80E-03	0.85447
10	5.9994	5.8019	6.2038	4.57E-03	0.77811
5	5.298	5.1054	5.498	5.05E-03	0.72412
0	3.9243	3.7483	4.1084	6.26E-03	0.59376

LC50:LC5 = 1.914

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-61	
Test: Bank 1- hardness 30.4 mg/L; 263 mg fish	
Cd, (µg/L)	**Proportion Surviving**
0.0065	100
0.32	98
0.52	68
1.06	12
2.12	5
4.14	0



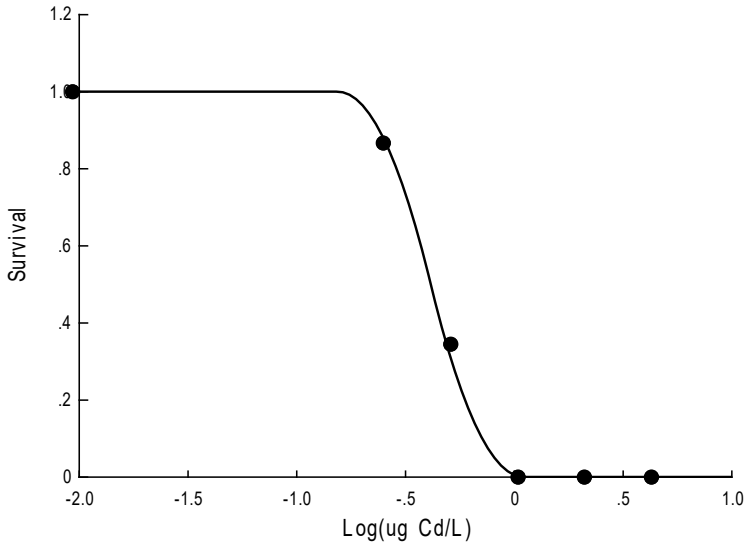
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.08599	-0.18706	0.019976	-0.22696	-0.14717
S	0.12	0.16109	0.01512	0.13614	0.19732
Y0	0.99167	0.9999	0.0012906	0.9402	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.65004	0.59299	0.71258	0.019976	-0.18706
20	0.46549	0.42265	0.51268	0.020812	-0.33209
10	0.39338	0.35104	0.44084	0.024273	-0.40518
5	0.34925	0.30647	0.39799	0.027548	-0.45687
0	0.26203	0.21833	0.31448	0.037103	-0.58165

LC50:LC5 = 1.861

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-62	
Test: Bank 3- 31.6 m/L hardness; 659 mg fish	
Cd, (µg/L)	**Proportion Surviving**
0.0065	100
0.25	87
0.51	34
1.04	0
2.1	0
4.27	0



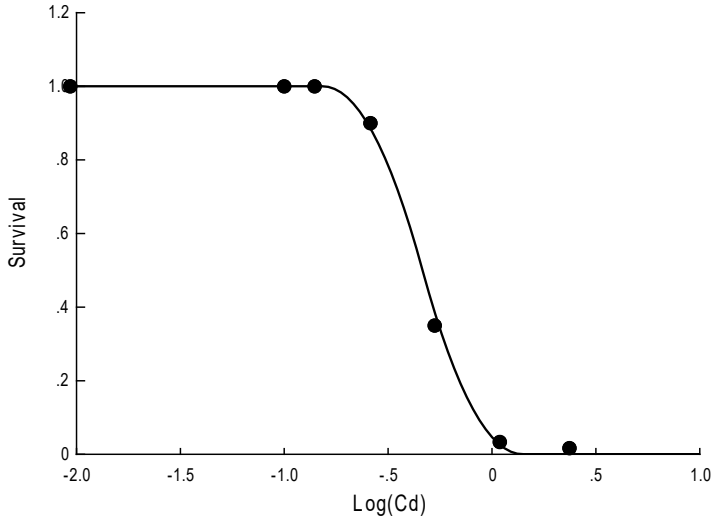
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.38779	-0.38367	0.021916	-0.42746	-0.33988
S	0.19335	0.17456	0.015269	0.14909	0.21063
Y0	1	0.9999	0.0012909	0.94017	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.41336	0.37371	0.45721	0.021916	-0.38367
20	0.28785	0.25113	0.32994	0.029436	-0.54083
10	0.23986	0.2039	0.28217	0.034697	-0.62004
5	0.21084	0.17562	0.25312	0.038677	-0.67605
0	0.15443	0.12193	0.1956	0.04847	-0.81126

LC50:LC5 = 1.961

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-63	
Test: Bank 2- 32 mg/L hardness; 1,150 mg fish	
Cd, (µg/L)	**Proportion Surviving**
0.0065	100
0.14	100
0.26	90
0.53	35
1.09	3
2.36	2



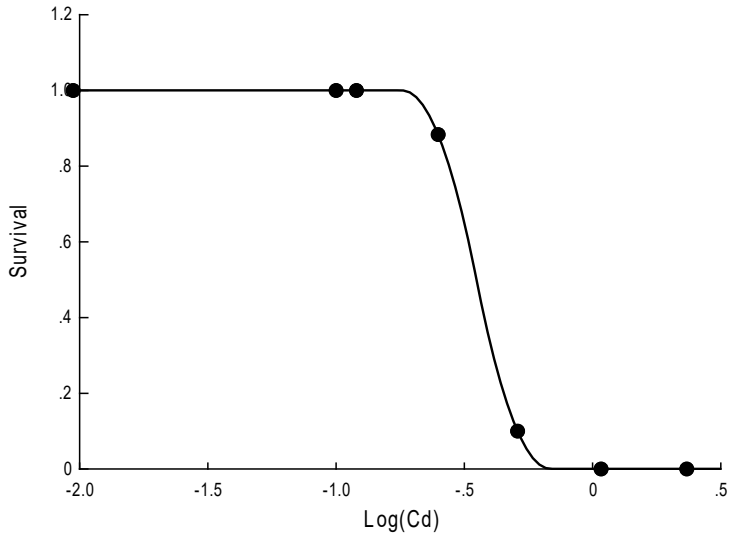
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.33	-0.33402	0.023102	-0.38007	-0.28797
S	0.2	0.19626	0.01889	0.16522	0.24178
Y0	1	0.9999	0.000877	0.97182	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.46342	0.4168	0.51526	0.023102	-0.33402
20	0.30852	0.26617	0.35761	0.031872	-0.51072
10	0.25132	0.20912	0.30203	0.039209	-0.59977
5	0.2174	0.1767	0.26748	0.043721	-0.66274
0	0.15319	0.11601	0.20229	0.056444	-0.81477

LC50:LC5 = 2.132

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-64	
Test: Bank 3 – 31.9 mg/L hardness; 1,130 mg fish	
Cd, (µg/L)	**%Survival**
0.0065	100
0.12	100
0.25	88
0.51	10
1.08	0
2.33	0



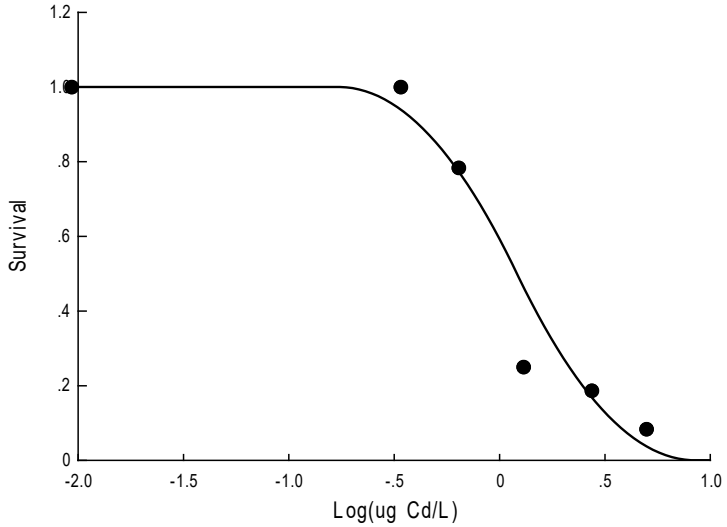
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.45	-0.45243	0.017653	-0.48799	-0.41687
S	0.12	0.11813	0.013466	0.096648	0.15197
Y0	1	0.9999	0.00087701	0.97182	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.35283	0.32509	0.38294	0.017653	-0.45243
20	0.2762	0.24945	0.30581	0.021669	-0.55878
10	0.24413	0.21592	0.27602	0.025686	-0.61238
5	0.22373	0.19432	0.25758	0.029005	-0.65028
0	0.18122	0.14913	0.22022	0.037975	-0.74178

LC50:LC5 = 1.577

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-65	
Test: Bank 3- 30.9 mg/L hardness; 299 mg fish	
Cd, (µg/L)	**%Survival**
0.0065	100
0.34	100
0.64	78
1.3	25
2.74	19
4.98	8



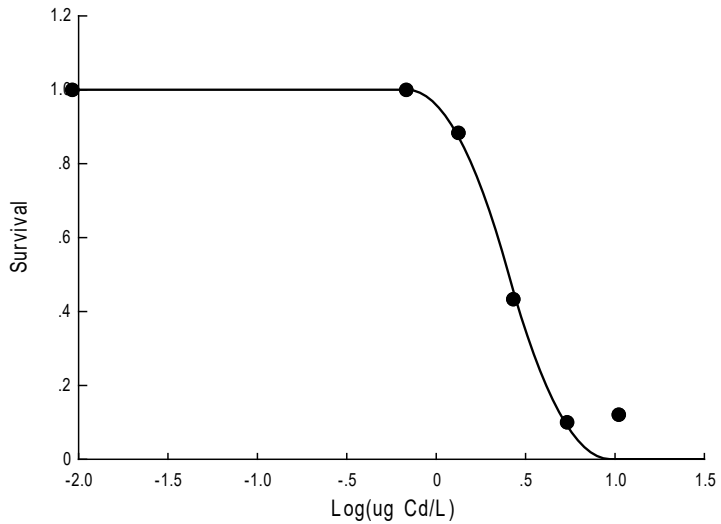
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	9.00E-02	8.29E-02	3.05E-02	2.25E-02	0.14326
S	0.2	0.3451	2.72E-02	0.29903	0.40809
Y0	1	0.9999	1.29E-03	0.94018	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.2103	1.0533	1.3908	3.05E-02	8.29E-02
20	0.59186	0.49058	0.71404	4.09E-02	-0.22778
10	0.41269	0.32721	0.52051	5.02E-02	-0.38437
5	0.31982	0.24434	0.41862	5.78E-02	-0.49509
0	0.17282	0.1198	0.24932	7.68E-02	-0.7624

LC50:LC5 = 3.784

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-66	
Test: Bank 2- 88.6 mg/L hardness; 289 mg fish	
Cd, (µg/L)	**%Survival**
0.0065	100
0.68	100
1.33	88
2.7	43
5.39	10
10.5	12



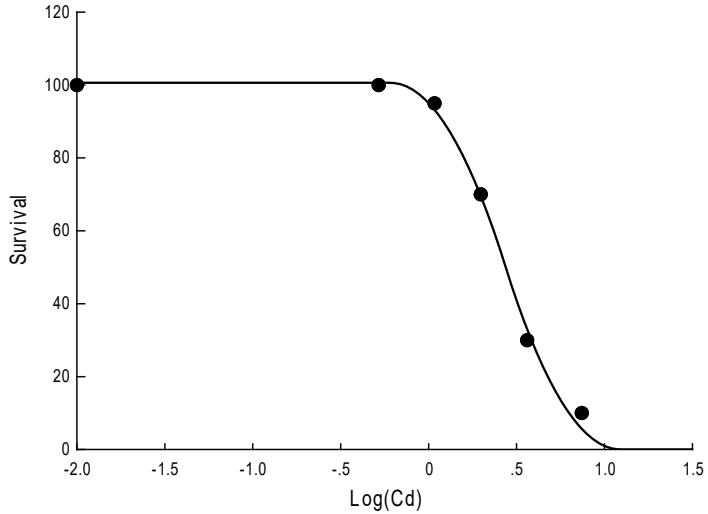
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.40588	0.40619	0.025753	0.35495	0.45743
S	0.2	0.23177	0.026398	0.18966	0.2981
Y0	1	0.9999	0.00091281	0.96952	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.548	2.2644	2.867	0.025753	0.40619
20	1.5759	1.3263	1.8725	0.037155	0.19753
10	1.237	0.99184	1.5427	0.046804	0.092366
5	1.0423	0.80341	1.3523	0.054291	0.018003
0	0.6894	0.47589	0.99872	0.073206	-0.16153

LC50:LC5 = 2.445

Notes: Acceptable model fit.

Stubblefield 1990	
Species: *Salmo trutta* (22.4 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-76	
Test: Single	
Cd, (µg/L)	**%Survival**
0.01	100
0.52	100
1.08	95
1.98	70
3.63	30
7.43	10



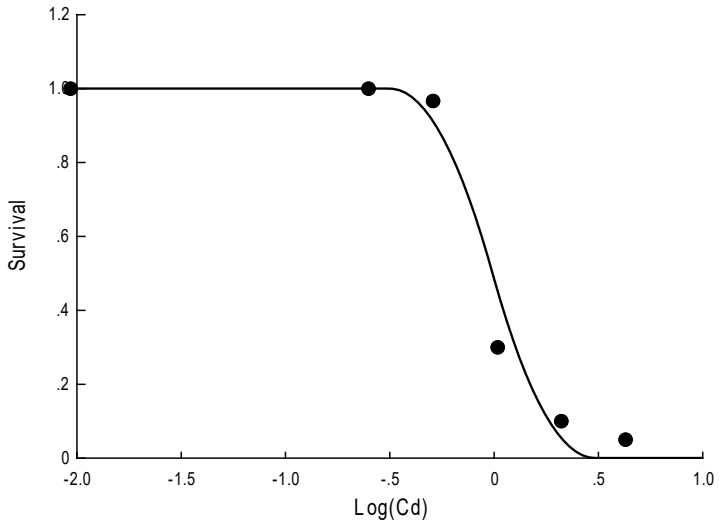
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.4365	0.43652	0.020497	0.37129	0.50175
S	1.53	1.531	0.13852	1.0902	1.9719
Y0	100	100.6	2.264	93.393	107.8

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.7323	2.3512	3.1751	0.020497	0.43652
20	1.572	1.2328	2.0046	0.033169	0.19646
10	1.1898	0.85002	1.6654	0.045888	0.075468
5	0.97704	0.63571	1.5017	0.058653	-0.010086
0	0.60725	0.34778	1.0603	0.076064	-0.21663

LC50:LC5 = 2.797

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Salvelinus confluentus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-79	
Test: Bank 3-32.1 mg/L hardness; 200 mg fish	
Cd, (µg/L)	**Proportion surviving**
0.0065	100
0.25	100
0.51	97
1.04	30
2.1	10
4.27	5



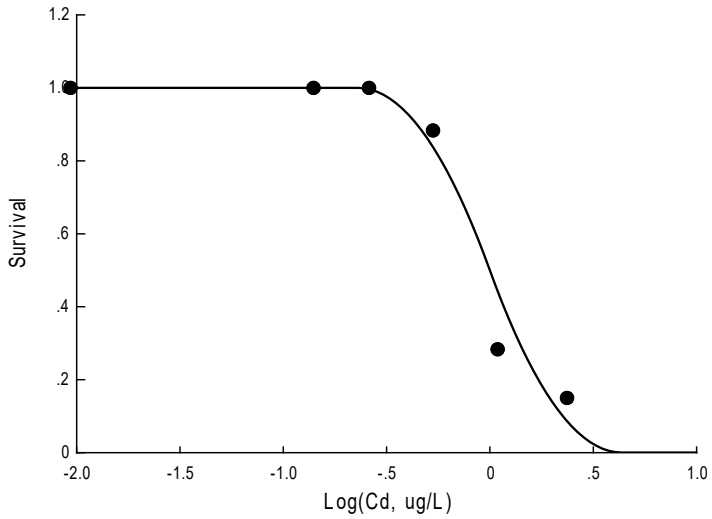
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.008	-0.0075579	0.022623	-0.052589	0.037473
S	0.15	0.20081	0.020007	0.16812	0.2494
Y0	0.98889	0.9999	0.0009128	0.96952	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.98275	0.88595	1.0901	0.022623	-0.0075579
20	0.64811	0.56219	0.74718	0.030726	-0.18835
10	0.52545	0.44035	0.627	0.037687	-0.27947
5	0.453	0.36835	0.55712	0.043595	-0.3439
0	0.31663	0.23905	0.4194	0.056854	-0.49945

LC50:LC5 = 2.169

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Salvelinus confluentus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-80	
Test: Bank 2- 33.1 mg/L hardness; 221 mg fish	
Cd, (µg/L)	**Proportion surviving**
0.0065	100
0.14	100
0.26	100
0.53	88
1.09	28
2.36	15



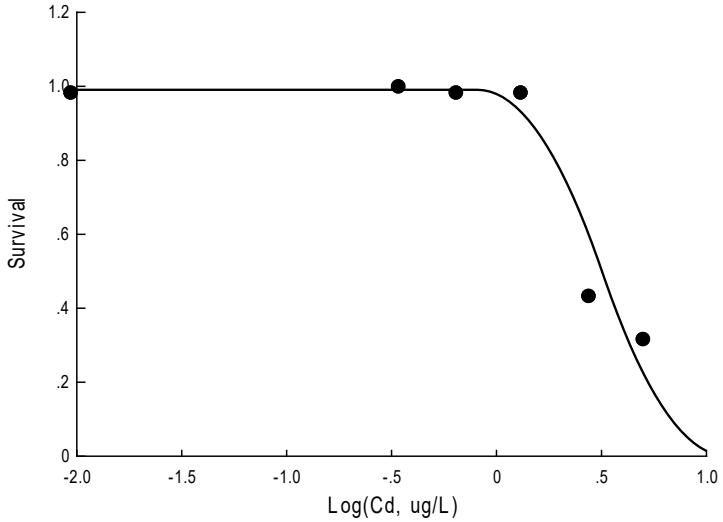
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.025	-0.0002606	0.026789	-0.053445	0.052924
S	0.26	0.26076	0.020684	0.22576	0.30872
Y0	1	0.9999	0.00087564	0.9719	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.9994	0.88421	1.1296	0.026789	-0.0002606
20	0.58207	0.50913	0.66545	0.029104	-0.23502
10	0.44326	0.37831	0.51935	0.034169	-0.35335
5	0.36559	0.30511	0.43805	0.038703	-0.43701
0	0.22962	0.17933	0.294	0.051572	-0.639

LC50:LC5 = 2.734

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Salvelinus confluentus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-82	
Test: Bank 3 – 30.6 mg/L hardness; 84.2 mg fish	
Cd, (µg/L)	**Proportion surviving**
0.0065	98
0.34	100
0.64	98
1.3	98
2.74	43
4.98	32



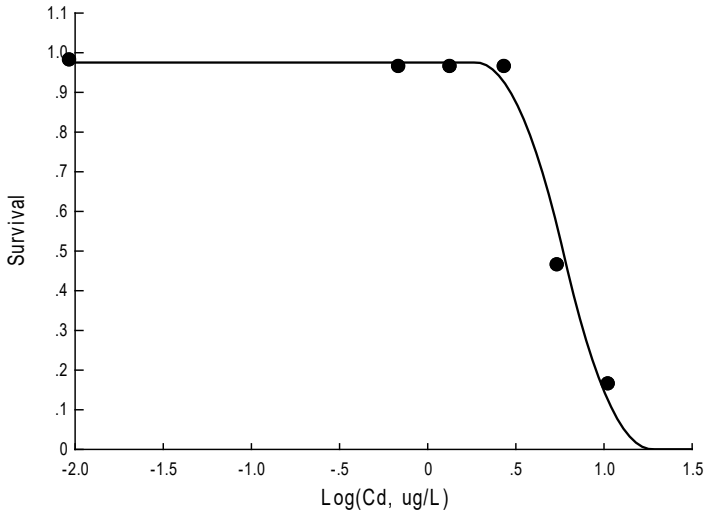
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.505	0.50514	0.029004	0.4473	0.56299
S	0.243	0.24291	0.031194	0.19431	0.32412
Y0	0.99	0.99078	0.0069255	0.9646	0.9991

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	3.1999	2.8009	3.6558	0.029004	0.50514
20	1.934	1.6403	2.2803	0.035278	0.28645
10	1.5005	1.2088	1.8625	0.045316	0.17623
5	1.254	0.96507	1.6294	0.05379	0.098298
0	0.8131	0.54417	1.2149	0.076875	-0.089858

LC50:LC5 = 2.552

Notes: Acceptable model fit.

Stratus Consulting 1999	
Species: *Salvelinus confluentus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-83	
Test: Bank 2- 90.3 mg/L hardness; 72.7 mg fish	
Cd, (µg/L)	**Proportion surviving**
0.0065	98
0.68	97
1.33	97
2.7	97
5.39	47
10.5	17



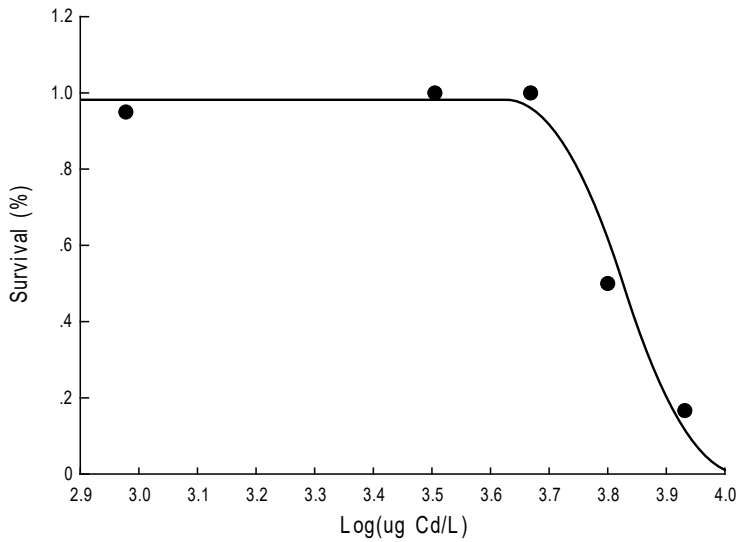
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.775	0.77394	0.025227	0.72357	0.82432
S	0.205	0.20455	0.024364	0.16602	0.26655
Y0	1	0.97634	0.010961	0.94359	0.9928

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	5.9422	5.2914	6.6729	0.025227	0.77394
20	3.8885	3.3281	4.5433	0.033369	0.58979
10	3.1403	2.5777	3.8257	0.041563	0.49697
5	2.6999	2.1387	3.4083	0.048204	0.43134
0	1.8746	1.3366	2.6289	0.065892	0.2729

LC50:LC5 = 2.201

Notes: Acceptable model fit.

Carrier 1987; Carrier and Beitinger 1988a	
Species: *Cyprinella lutrensis* (adult)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-85	
Test: Single	
Cd, (µg/L)	**%Survival**
10	Not reported
950	95
3200	100
4660	100
6310	50
8540	17



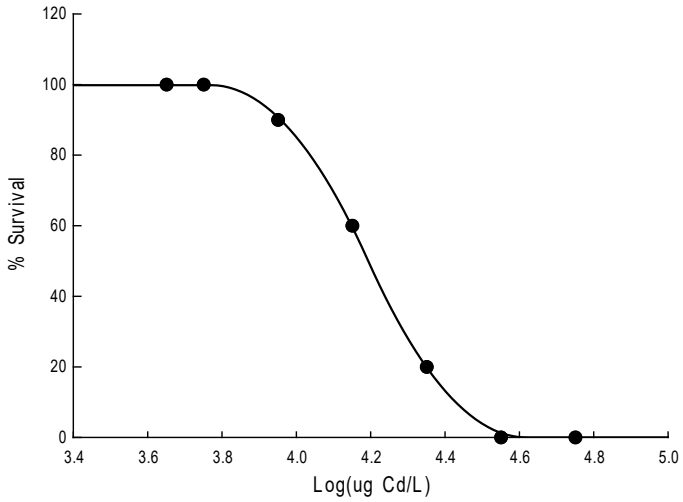
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.8	3.828	0.018929	3.7884	3.8677
StDev	0.08	0.08217	0.017175	0.058531	0.1377
Y0	0.983	0.98177	0.020725	0.88276	0.99983

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	6730.5	6143.4	7373.8	0.018929	3.828
20	5676.4	5019.2	6419.8	0.02436	3.7541
10	5209.5	4435.4	6118.7	0.029951	3.7168
5	4902.7	4025.5	5970.9	0.034529	3.6904
0	4234.3	3036.4	5905	0.046788	3.6268

LC50:LC5 = 1.373

Notes: Acceptable model fit.

Vergauwen 2012; Vergauwen et al. 2013	
Species: *Danio rerio* (adult)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-86	
Test: 18C	
Cd, (µg/L)	**%Survival**
4475	100
5634	100
8929	90
14152	60
22429	20
35547	0
56338	0

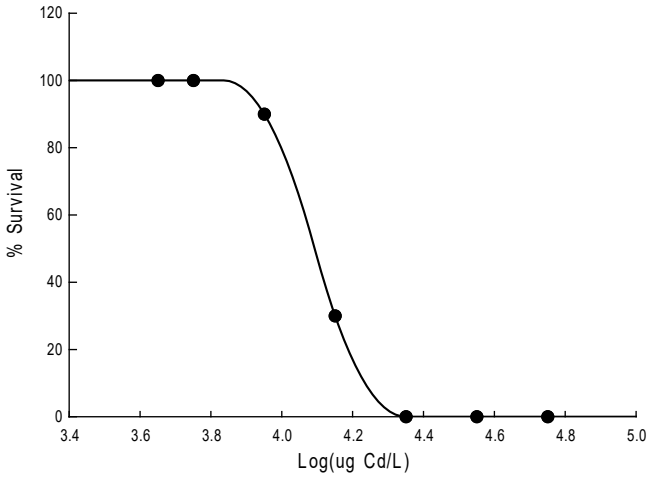


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.19	4.194	0.0032331	4.185	4.203
S	2.36	2.3559	0.052654	2.2097	2.5021
Y0	100	99.819	0.53491	98.333	101.3
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	15631	15311	15957	0.003233	4.194
20	10914	10553	11286	0.005255	4.038
10	9106.2	8695.2	9536.7	0.007224	3.9593
5	8012	7587.5	8460.2	0.008514	3.9037
0	5881.8	5543	6241.3	0.009279	3.7695

LC50:LC5 = 1.951

Notes: Acceptable model fit.

Vergauwen 2012; Vergauwen et al. 2013	
Species: *Danio rerio* (adult)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-87	
Test: 26C	
Cd, (µg/L)	**%Survival**
4475	100
5634	100
8929	90
14152	60
22429	20
35547	0
56338	0



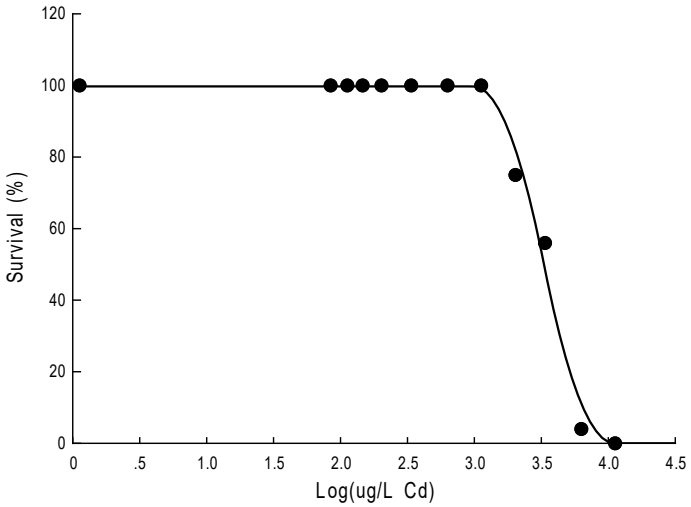
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.1	4.0929	0	4.0929	4.0929
S	3.9	3.8909	0	3.8909	3.8909
Y0	100	100	0	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	12384	12384	12384	0	4.0929
20	9963.5	9963.5	9963.5	0	3.9984
10	8929	8929	8929	0	3.9508
5	8263.1	8263.1	8263.1	0	3.9171
0	6852.8	6852.8	6852.8	0	3.8359

LC50:LC5 = 1.499

Notes: Acceptable model fit.

Sunderman et al. 1991	
Species: *Xenopus laevis*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-101	
Test: Single	
Cd, (µg/L)	**%Survival**
1.12	100
84.3	100
112	100
146	100
202	100
337	100
630	100
1124	100
2023	75
3372	56
6295	4
11241	0



LC50:LC5 = 2.290

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.5	3.5203	1.87E-02	3.478	3.5627
S	2	1.8999	0.22982	1.38	2.4198
Y0	100	99.696	1.5247	96.247	103.14

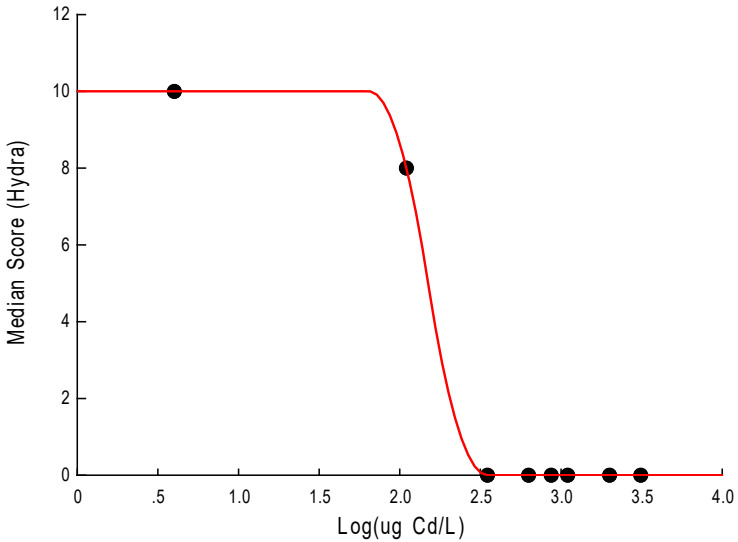
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	3314	3006.1	3653.4	1.87E-02	3.5203
20	2122.7	1800.8	2502.2	3.16E-02	3.3269
10	1695.9	1338.9	2148.1	4.54E-02	3.2294
5	1447	1061.3	1972.8	5.95E-02	3.1605
0	986.31	583.98	1665.8	0.10062	2.994

Notes: Acceptable model fit.

Appendix B.2

Test Information, C-R Data and Resulting TRAP models for Acute Cadmium Toxicity Tests Unacceptable for TAF and MAF Calculation

Karntanut and Pascoe 2000	
Species: *Hydra vulgaris*	
Test Endpoint: 96 hr survival	
C-R Curve Label: Cd-Acute-1	
Test: 15°C	
Cd, µg/L	**Median Score**
0	10
4	10
110	8
350	0
630	0
870	0
1100	0
2000	0
3120	0



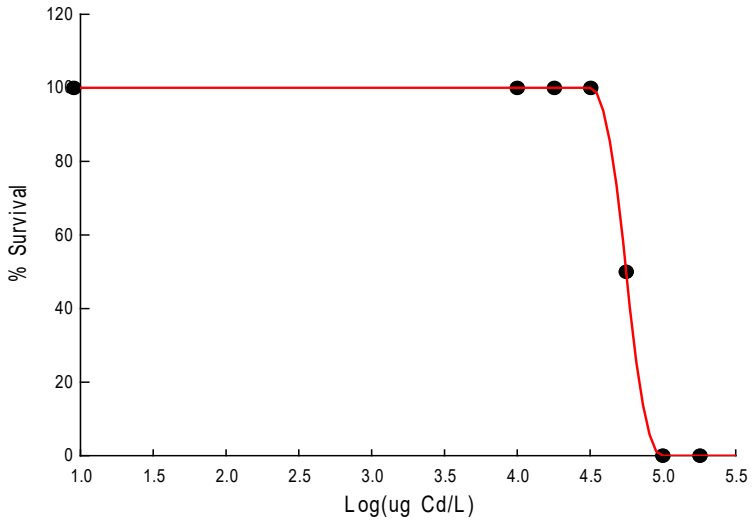
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.1734	2.1765	5.263E-08	2.1765	2.1765
S	2.625	2.7205	1.06E-06	2.7205	2.7205
Y0	10	10	1.269E-11	10	10

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	150.14	150.14	150.14	5.3E-08	2.1765
20	110	110	110	9.4E-13	2.0414
10	94.038	94.038	94.038	1.1E-12	1.9733
5	84.17	84.17	84.17	1.2E-12	1.9252
0	64.405	64.405	64.405	1.5E-12	1.8089

LC50:LC5 = 1.784

Notes: TRAP Flagged for IP (No Unique Solution).

Rathore and Khangarot 2002	
Species: *Tubifex tubifex*	
Test Endpoint: 96 hr survival	
C-R Curve Label: Cd-Acute-3	
Test: 20°C	
Cd, µg/L	**%Survival**
5	100
10000	100
18000	100
32000	100
56000	50
100000	0
180000	0



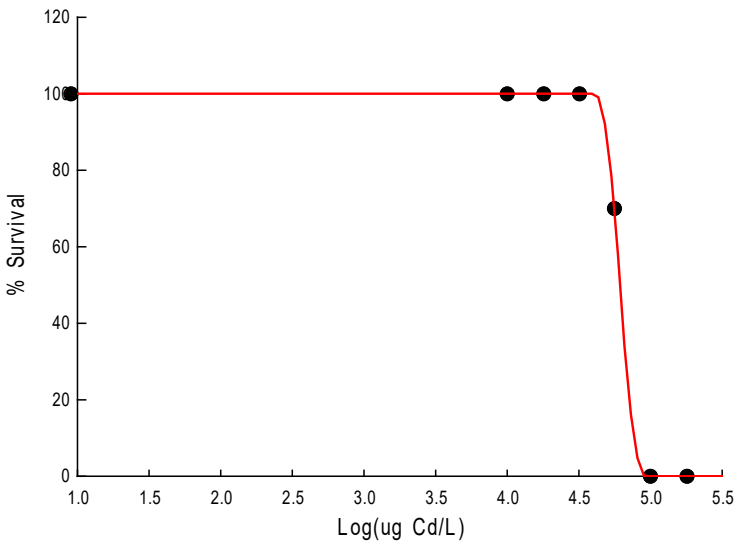
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.75	4.7482			
S	4.1	4.115			
Y0	100	100			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50.0	56000.0				4.7
20.0	45590.0				4.7
10.0	41101.0				4.6
5.0	38196.0				4.6
0.0	32002.0				4.5

LC50:LC5 = 1.466

Notes: TRAP Flagged for IP (No Unique Solution).

Rathore and Khangarot 2002	
Species: *Tubifex tubifex*	
Test Endpoint: 96 hr survival	
C-R Curve Label: Cd-Acute-4	
Test: 25°C	
Cd, µg/L	**%Survival**
5	100
10000	100
18000	100
32000	100
56000	70
100000	0
180000	0



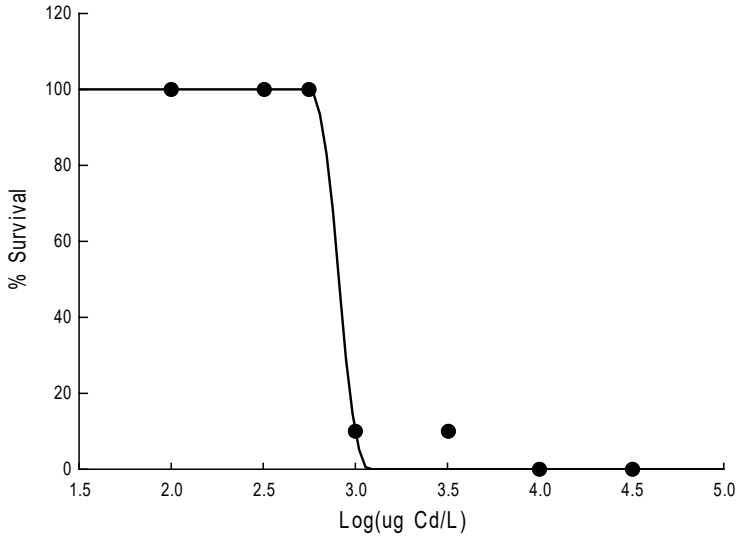
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.8	4.7877			
S	5.7	5.6999			
Y0	100	100			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50.0	61339.0				4.8
20.0	52875.0				4.7
10.0	49063.0				4.7
5.0	46534.0				4.7
0.0	40953.0				4.6

LC50:LC5 = 1.318

Notes: TRAP Flagged for IP (No Unique Solution)

Rathore and Khangarot 2003	
Species: *Tubifex tubifex*	
Test End Point: 96 hr survival	
C-R Curve Label: Cd-Acute-7	
Test: Hardness = 173 mg/L	
Cd, µg/L	**%Survival**
100	100
320	100
560	100
1000	10
3200	10
10000	0
32000	0



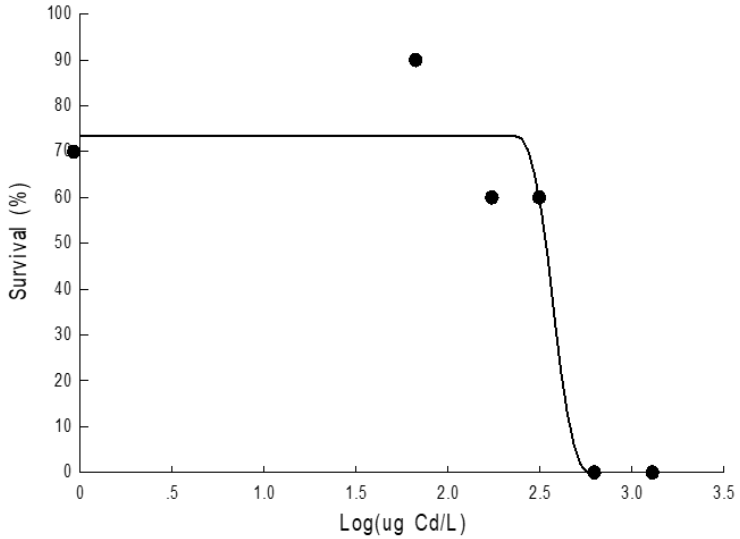
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.9	2.9108			
S	3.5	6.1995			
Y0	100	100			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50.0	814.4				2.9
20.0	710.5				2.9
10.0	663.2				2.8
5.0	631.7				2.8
0.0	561.7				2.7

LC50:LC5= 1.289

Notes: Poor model fit (at high level effects) with inadequate partials between 0% and 90% effect.

Pais 2012	
Species: *Lymnaea stagnalis*	
Test Endpoint: 96 hr survival	
C-R Curve Label: Cd-Acute-11	
Test: Juvenile, 18mm	
Cd, µg/L	**%Survival**
0.5	70
67	90
174	60
315	60
628	0
1301	0



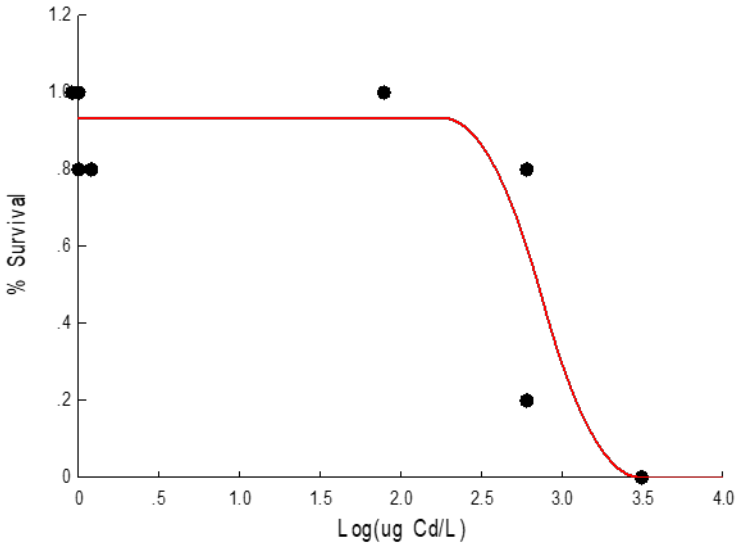
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.5	2.5741			
S	4.5	5.2389			
Y0	80	73.333			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	375.05				2.5741
20	319.1				2.5039
10	294.150				2.469
5	277.690				2.444
0	241.66				2.38

LC50:LC5 = 1.351

Notes: Not core data. Unacceptable noise at low level effects.

Mebane et al 2012		
Species: *Gyralus sp*		
Test End Point: 96 hr survival		
C-R Curve Label: Cd-Acute-13		
Test: Single		
Cd, µg/L	**Fish**	**Survivors**
0.5	10	10
0.5	10	10
0.5	10	10
1.2	10	8
1.2	10	8
1.2	10	8
79	10	10
79	10	10
79	10	10
605	10	8
605	10	8
605	10	2
3130	10	0
3130	10	0
3130	10	0



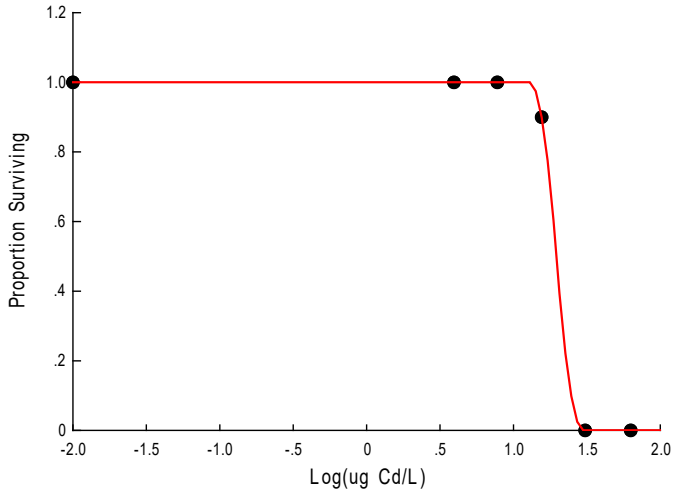
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.7682	2.876			
StDev	0.37379	0.24931			
Y0	0.9333	0.9333			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	751.68				2.876
20	448.32				2.6516
10	345.51				2.5385
5	287.39				2.4585
0	184.23				2.2654

LC50:LC5 = 2.616

Notes: TRAP Flagged for IP (No Unique Solution)

Wang et al. 2010d	
Species: *Lampsilis rafinesqueana* (5-d old juv.)	
Test End Point: 96 hr Survival	
C-R Curve Label: Cd-Acute-15	
Test: Single	
Cd, µg/L	**Proportion Surviving**
0.011	100
3.93	100
7.765	100
15.55	90
30.75	0
62.85	0



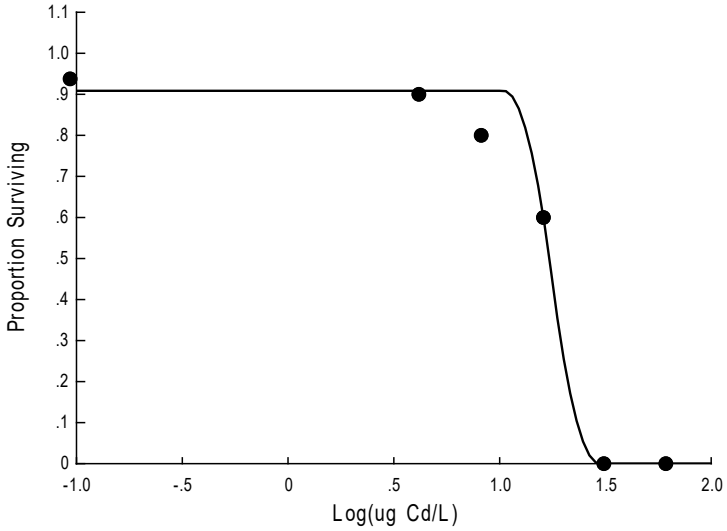
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.25	1.29			
StDev	0.14	0.07			
Y0	1.00	1.00			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**19.61**				1.29
20	16.81				1.23
10	15.55				1.19
5	**14.72**				1.17
0	12.89				1.11

LC50:LC5= 1.332

Notes: TRAP Flagged for IP (No Unique Solution)

Wang et al. 2010d	
Species: *Lampsilis siliquoidea* (5-d old juv.)	
Test End Point: 96 hr Survival	
C-R Curve Label: Cd-Acute-16	
Test: Single	
Cd, µg/L	**%Survival**
0.00	93.75
4.00	90
8.00	80
16.00	60
32.00	0
64.00	0



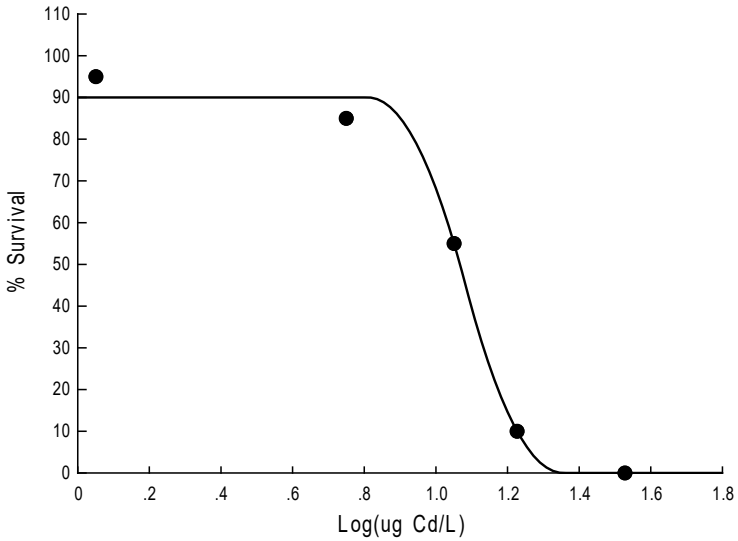
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.20	1.25			
StDev	0.15	0.09			
Y0	0.92	0.91			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**17.64**				1.25
20	14.58				1.16
10	13.24				1.12
5	**12.37**				1.09
0	10.50				1.02

LC50:LC5= 1.426

Notes: Poor model fit.

Shaw et al. 2006	
Species: *Daphnia ambigua* (<24 h old)	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Cd-Acute-18	
Test: Single	
Cd, µg/L	**%Survival**
1	95
6	85
11	55
17	10
34	0



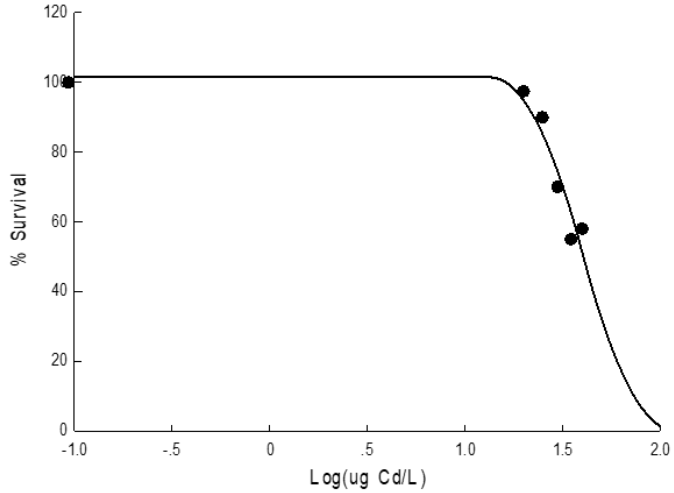
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.1	1.083	0.016536	1.0118	1.1541
S	3.7	3.6724	0.7657	0.37788	6.9669
Y0	95	90	3.5355	74.788	105.21

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	12.105	10.276	14.26	0.016536	1.083
20	9.6134	7.1347	12.953	0.030098	0.98288
10	8.5592	5.2255	14.02	0.049807	0.93243
5	7.8844	3.3319	18.657	0.086939	0.89677
0	6.4663	1.0264	40.738	0.18578	0.81066

LC50:LC5 = 1.535

Notes: Poor model fit.

Jemec et al 2007	
Species: *Daphnia magna* (<24 h old)	
Test End Point: 48 hr survival	
C-R Curve Label: Cd-Acute-20	
Test: Single	
Cd, µg/L	**%Survival**
0.05	100
20	97.5
25	90
30	70
35	55
40	58

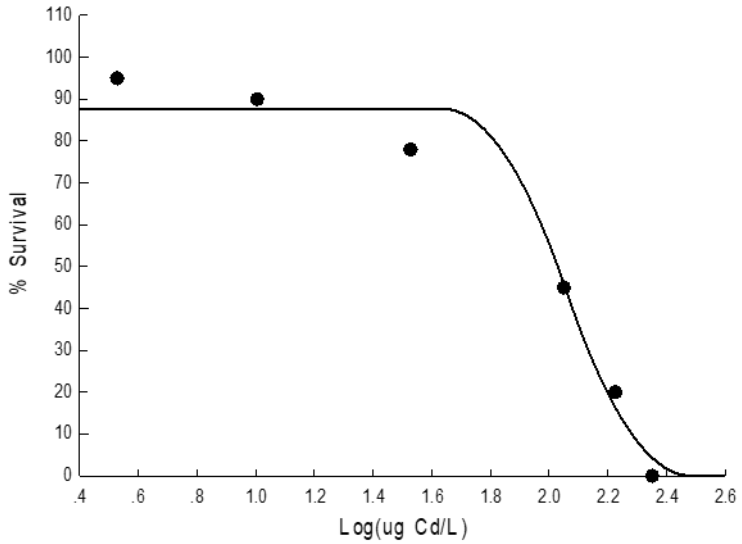


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.6	1.6048	0.031561	1.5044	1.7053
S	2.1	2.112	0.65339	0.032677	4.1914
Y0	100	101.47	7.0559	79.019	123.93
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	40.257	31.945	50.732	0.031561	1.6048
20	26.966	17.955	40.5	0.055505	1.4308
10	22.035	12.301	39.471	0.079552	1.3431
5	19.103	9.3472	39.039	0.097538	1.2811
0	13.532	4.7713	38.379	0.14226	1.1314

LC50:LC5= 2.107

Notes: Not core data. No treatment with greater than 50% effect.

Xie et al. 2007	
Species: *Daphnia magna* (24 h old)	
Test End Point: 48 hr Immobilization	
C-R Curve Label: Cd-Acute-21	
Test: Single	
Cd, µg/L	**%Survival**
3.3723	95
10.1169	90
33.723	78
112.41	45
168.615	20
224.82	0



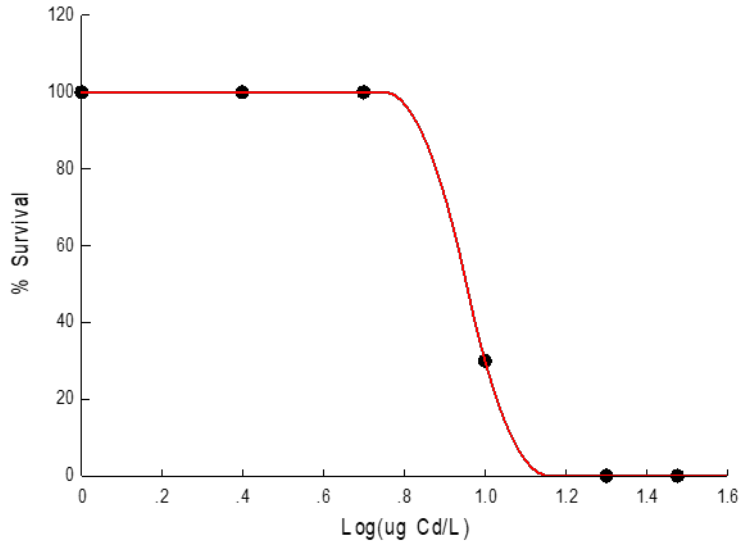
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.05	2.0613	3.84E-02	1.94E+00	2.1836
S	2.35	2.3647	0.76172	-5.95E-02	4.7888
Y0	87.7	87.659	4.5498	73.179	102.14

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	115.160	86.903	152.600	0.038	2.061
20	80.513	43.253	149.870	0.085	1.906
10	67.225	23.847	189.510	0.141	1.828
5	59.175	11.476	305.140	0.224	1.772
0	43.492	9.042	209.200	0.214	1.638

LC50:LC5= 1.946

Notes: Poor Model Fit.

Tan and Wang 2011	
Species: *Daphnia magna* (7 d old)	
Test End Point: 48 hr Survival	
C-R Curve Label: Cd-Acute-23	
Test: Ca 0.46, pH 8.1	
Cd, µg/L	**%Survival**
1	100
2.5	100
5	100
10	30
20	0
30	0

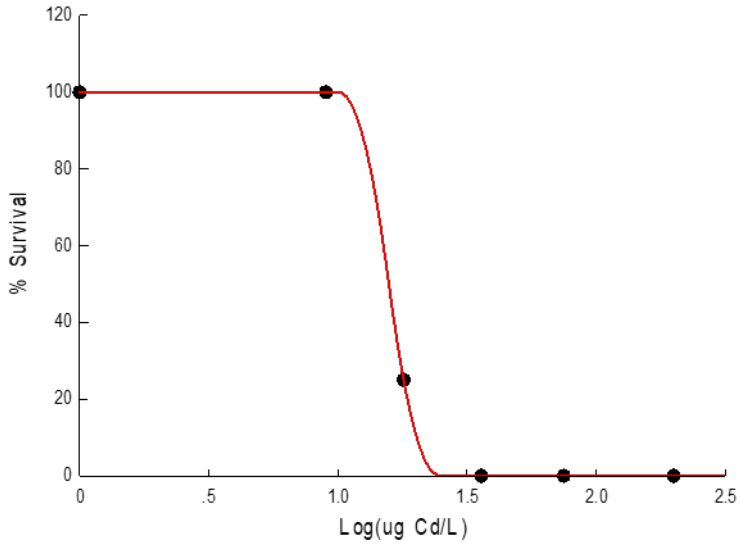


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.95	0.954			
S	4.9	4.9			
Y0	100	100			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	8.995				0.954
20	7.568				0.879
10	6.937				0.841
5	6.523				0.814
0	5.622				0.750

LC50:LC5= 1.379

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Tan and Wang 2011	
Species: *Daphnia magna* (7 d old)	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Cd-Acute-24	
Test: Ca 19, pH 8.1	
Cd, µg/L	**%Survival**
1	100
9	100
18	25
36	0
75	0
200	0

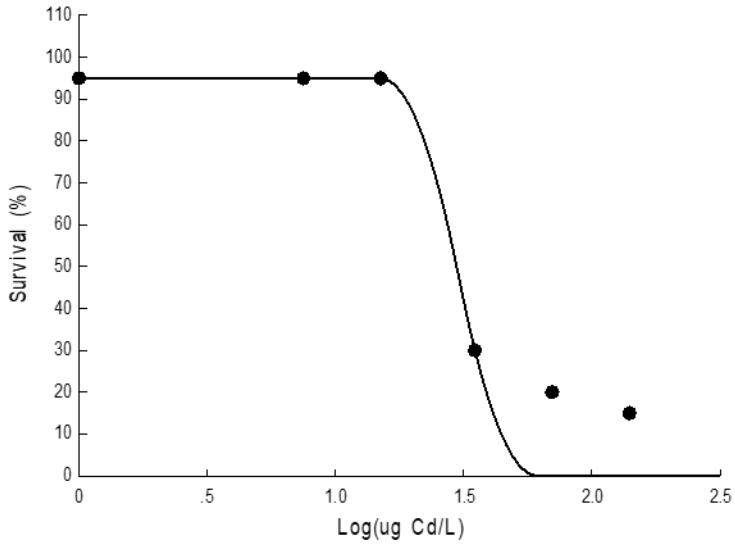


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.2	1.1984			
S	5	5.1474			
Y0	100	100			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	15.790				1.198
20	13.396				1.127
10	12.330				1.091
5	11.629				1.066
0	10.095				1.004

LC50:LC5= 1.358

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Tan and Wang 2011	
Species: *Daphnia magna* (7 d old)	
Test End Point: 48 hr Survival	
C-R Curve Label: Cd-Acute-25	
Test: Ca 192, pH 8.1	
Cd, µg/L	**%Survival**
1	95
7.5	95
15	95
35	30
70	20
140	15



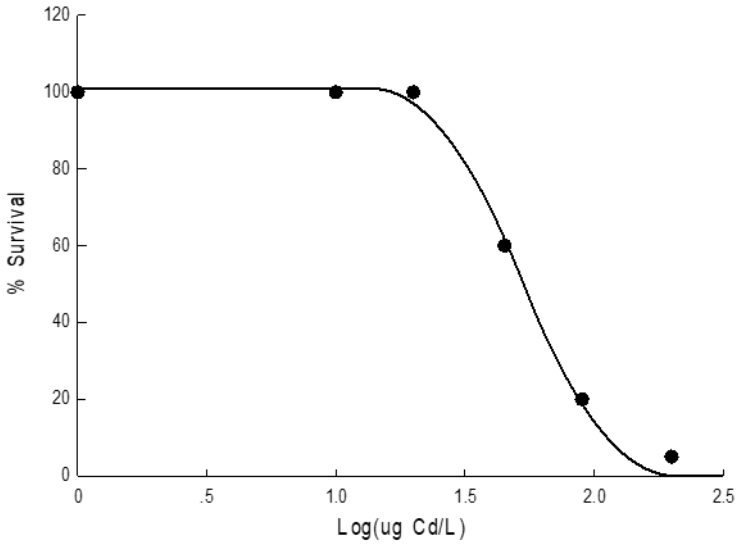
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.5	1.4813	3.9374	-11.049	14.012
S	2.8	3.2687	204.53	-647.63	654.17
Y0	95	95	10.206	62.519	127.48

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	30.288	8.92E-12	1.028E+14	3.9374	1.4813
20	23.379	2.82E-34	1.9412E+36	10.972	1.3688
10	20.519	0	Infinity	14.518	1.3122
5	18.71	0	Infinity	17.026	1.2721
0	14.974	0	Infinity	23.08	1.1753

LC50:LC5= 1.619

Notes: Not core data. Poor model fit at tail.

Tan and Wang 2011	
Species: *Daphnia magna* (7 d old)	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Cd-Acute-26	
Test: Ca 19, pH 7.0	
Cd, µg/L	**%Survival**
1	100
10	100
20	100
45	60
90	20
200	5



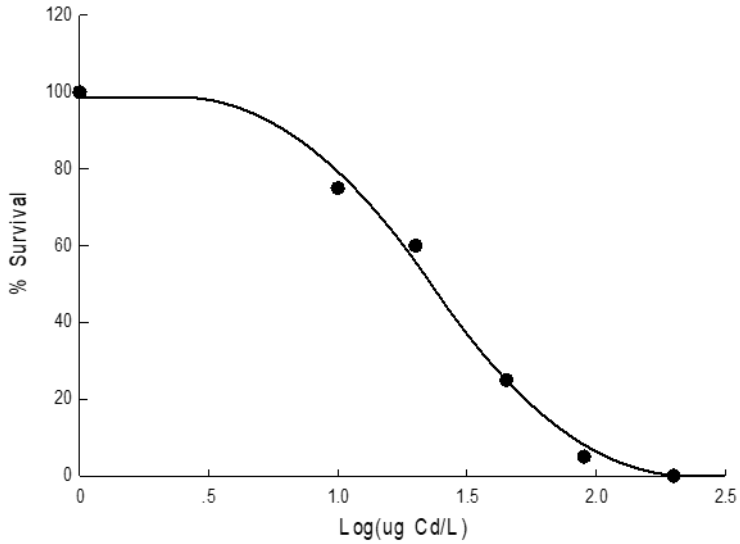
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.75	1.7243	2.23E-02	1.65E+00	1.7952
S	1.7	1.7004	0.20544	1.0466	2.3542
Y0	100	100.96	2.4792	93.073	108.85

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	53.005	45.020	62.407	0.022	1.724
20	32.223	24.512	42.359	0.037	1.508
10	25.074	17.824	35.274	0.047	1.399
5	20.999	14.512	30.386	0.050	1.322
0	13.684	9.094	20.593	0.056	1.136

LC50:LC5 = 2.524

Notes: Not core data.

Tan and Wang 2011	
Species: *Daphnia magna* (7 d old)	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Cd-Acute-27	
Test: Ca 19, pH 8.2	
Cd, µg/L	**%Survival**
1	100
10	75
20	60
45	25
90	5
200	0



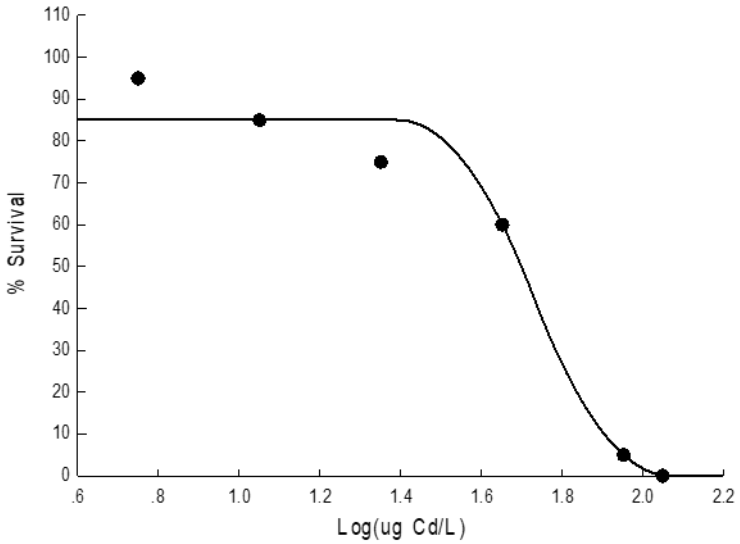
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.35	1.368	3.87E-02	1.24E+00	1.491
S	1	1.0142	0.11118	0.66043	1.3681
Y0	100	98.681	3.9012	86.266	111.1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	23.332	17.575	30.976	0.039	1.368
20	10.129	6.270	16.363	0.065	1.006
10	6.652	3.554	12.450	0.086	0.823
5	4.941	2.451	9.961	0.096	0.694
0	2.410	1.114	5.214	0.105	0.382

LC50:LC5 = 4.722

Notes: Not core data. No effect within area of concern.

Shaw et al. 2006	
Species: *Daphnia pulex* (<24 h old)	
Test Endpoint: 48 hr Survival	
C-R Curve Label: Cd-Acute-28	
Test: Single	
Cd, µg/L	**%Survival**
5.6205	95
11.241	85
22.482	75
44.964	60
89.928	5
112.41	0

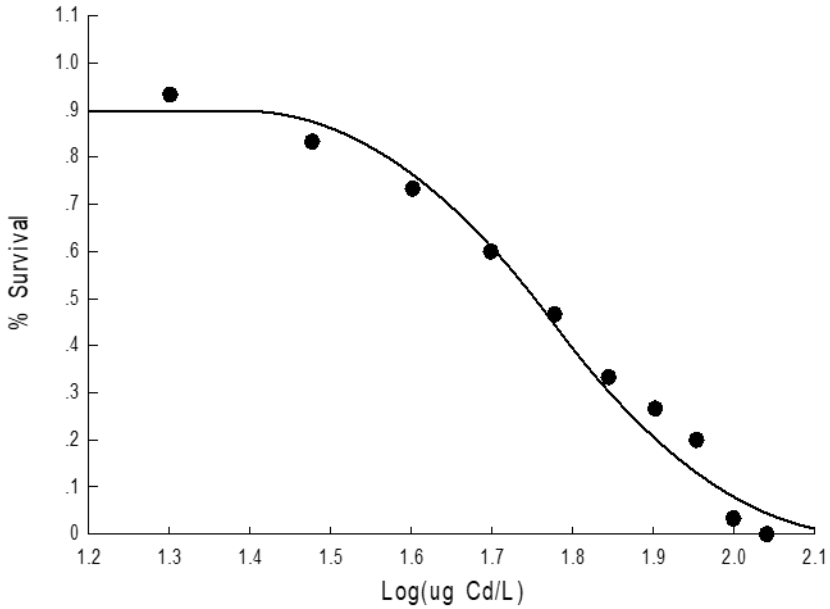


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.7	1.7316	0.041918	1.5982	1.865
S	3	2.96	1.0103	-0.25542	6.1753
Y0	95	85	4.7142	69.997	100
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	53.903	39.647	73.284	0.041918	1.7316
20	40.498	26.872	61.034	0.055973	1.6074
10	35.064	20.08	61.228	0.076072	1.5449
5	31.667	17.558	57.112	0.08048	1.5006
0	24.761	13.171	46.548	0.086139	1.3938

LC50:LC5 = 1.702

Notes: Poor model fit.

Sowdeswari et al. 2012	
Species: *Macrobrachium rosenbergii* (post-larvae)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-29	
Test: Single	
Cd, µg/L	**%Survival**
20	93.4
30	83.4
40	73.4
50	60
60	47
70	33.4
80	27.7
90	20
100	4



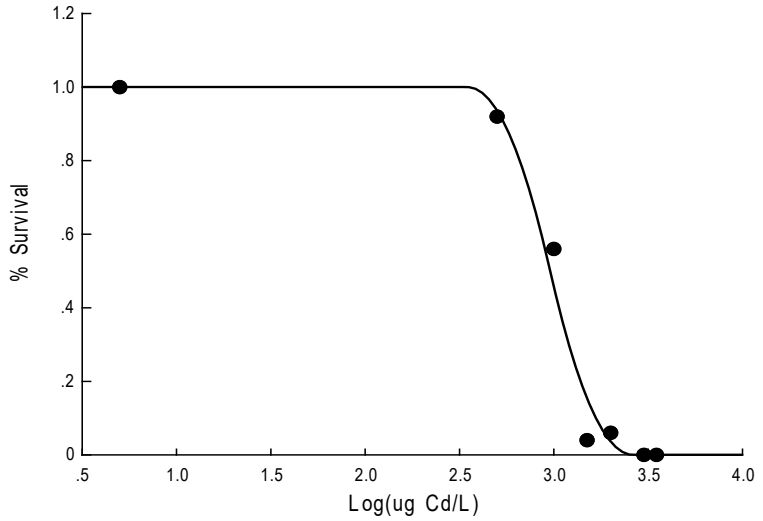
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.75	1.7762	2.54E-02	1.7249	1.8275
StDev	0.15	0.15749	2.24E-02	0.12332	0.21799
Y0	0.93333	0.89823	4.77E-02	0.76162	0.971

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	59.73	53.077	67.218	0.02535	1.7762
20	43.093	35.328	52.566	0.041774	1.6344
10	36.555	28.397	47.057	0.051693	1.5629
5	32.54	23.856	44.386	0.061921	1.5124
0	24.571	16.042	37.635	0.077772	1.3904

LC50:LC5 = 1.836

Notes: No core data.

Naqvi and Howell 1993	
Species: *Procambarus clarkia* (juvenile)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-31	
Test: Single	
Cd, µg/L	**Proportion Surviving**
5	1.00
500	0.92
1000	0.56
1500	0.04
2000	0.06
3000	0.00

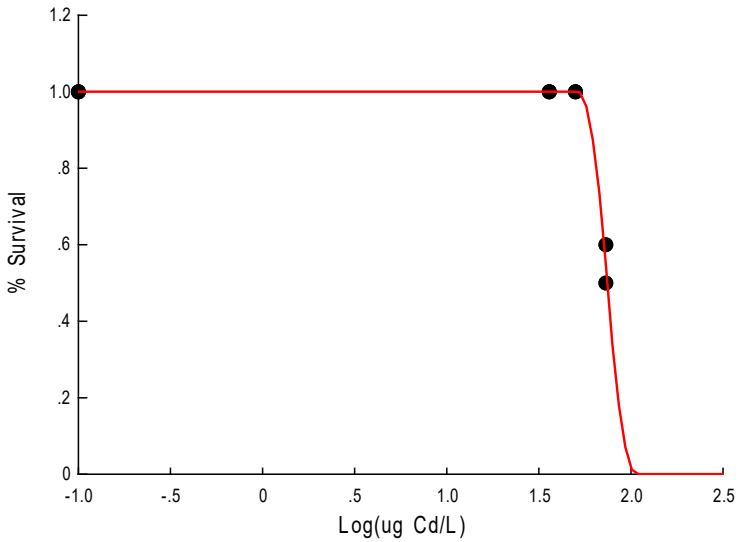


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.9646	2.9807	0.0201	2.9407	3.0207
StDev	0.20942	0.17871	0.016714	0.15112	0.21873
Y0	1	0.9999	0.0014172	0.92869	1
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	956.57	872.39	1048.9	0.0201	2.9807
20	660.43	578.31	754.2	0.028718	2.8198
10	547.94	465.21	645.39	0.035012	2.7387
5	480.17	397.72	579.72	0.03987	2.6814
0	349.12	271.12	449.55	0.05162	2.543

LC50:LC5 = 1.992

Notes: No core data.

Mebane et al. 2012	
Species: *Baetis tricaudatus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-32	
Test: #4	
Cd, µg/L (dissolved)	**%Survival**
0.1	100
0.1	100
36	100
36	100
50	100
50	100
73	50
73	60

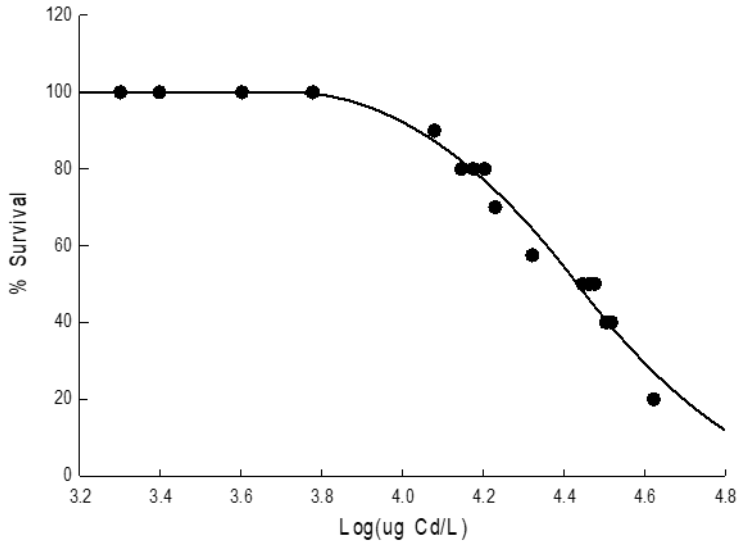


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.8723	1.8714			
StDev	0.080147	0.064299			
Y0	1	0.9999			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	74.372				1.8714
20	65.091				1.8135
10	60.862				1.7843
5	58.038				1.7637
0	51.75				1.7139

LC50:LC5 = 1.281

Notes: TRAP Flagged for IP (No Unique Solution).

Clubb et al. 1975	
Species: *Drunella grandis*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-33	
Test: Single	
Cd, µg/L (dissolved)	**%Survival**
2000	100
2500	100
4000	100
6000	100
12000	90
14000	80
15000	80
16000	80
17000	70
21000	57.5
28000	50
29000	50
30000	50
32000	40
33000	40
42000	20



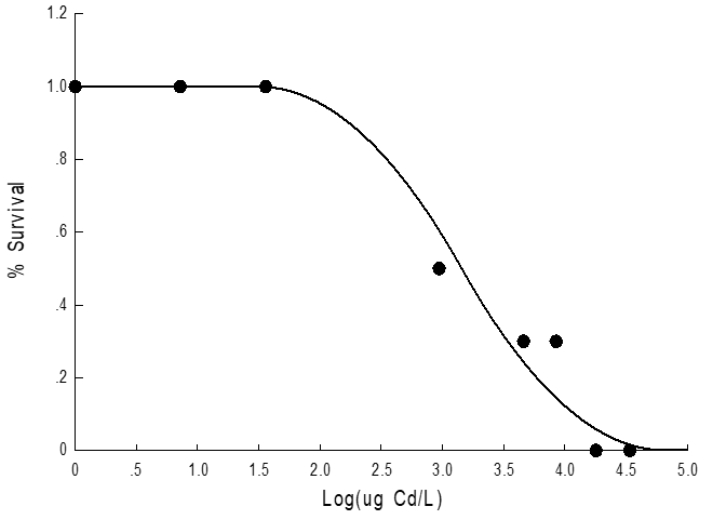
LC50:LC5 = 3.085

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.4	4.4342	1.34E-02	4.4052	4.4632
S	1.4	1.3976	0.10789	1.1645	1.6307
Y0	100	99.921	1.9925	95.616	104.23

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	27178	25421	29056	1.34E-02	4.4342
20	14833	13025	16893	2.61E-02	4.1712
10	10932	9111.6	13115	3.66E-02	4.0387
5	8809.8	7020.1	11056	4.57E-02	3.945
0	5232.3	3486.6	7852.2	8.16E-02	3.7187

Notes: No core data.

Leonhard et al. 1980	
Species: *Hexagenia rigida* (nymph)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-34	
Test: Single	
Cd, µg/L	**# Survival**
1	10
7.2	10
36	10
940	5
4600	3
8500	3
18000	0
34000	0

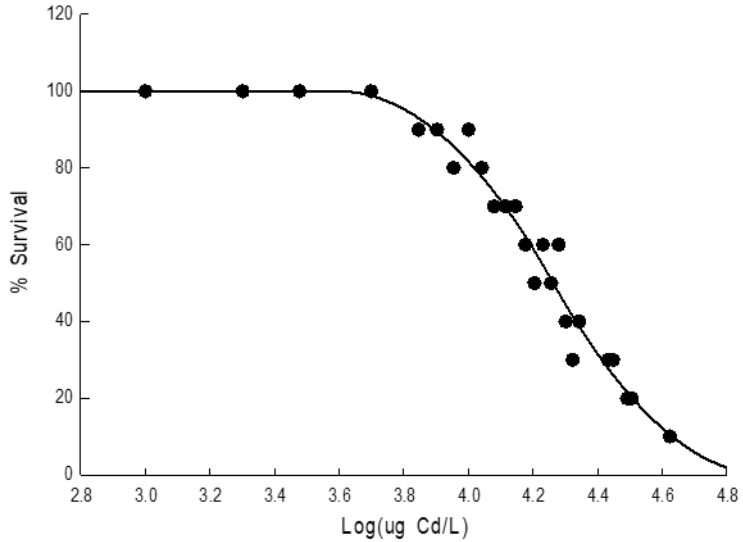


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3	3.1583	0.15126	2.843	3.4737
StDev	0.5	0.67992	0.1078	0.51985	0.98304
Y0	1	0.9999	2.22E-03	0.83385	1
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1439.9	696.67	2976.2	0.15126	3.1583
20	351.73	125.93	982.42	0.20841	2.5462
10	172.86	49.015	609.63	0.24713	2.2377
5	104.6	24.395	448.53	0.27608	2.0195
0	31.108	3.9272	246.42	0.34948	1.4929

LC50:LC5 = 13.77

Notes: No effect within area of concern.

Clubb et al. 1975	
Species: *Pteronarcella badia*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-36	
Test: Single	
Cd, µg/L	**% Survival**
1000	100
2000	100
3000	100
5000	100
7000	90
8000	90
9000	80
10000	90
11000	80
12000	70
13000	70
14000	70
15000	60
16000	50
17000	60
18000	50
19000	60
20000	40
21000	30
22000	40
27000	30
28000	30
31000	20
32000	20
42000	10



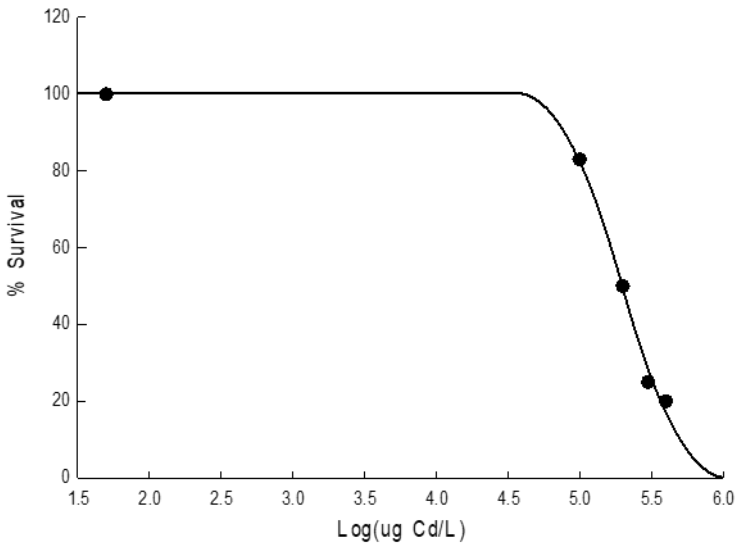
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.3	4.2626	1.48E-02	4.2318	4.2933
S	1.5	1.5019	0.11425	1.265	1.7388
Y0	100	99.97	2.6172	94.542	105.4

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	18306	17054	19649	1.48E-02	4.2626
20	10420	9095.2	11938	2.85E-02	4.0179
10	7843.9	6486.4	9485.5	3.98E-02	3.8945
5	6416.8	5046.1	8159.8	5.03E-02	3.8073
0	3951.6	2629.4	5938.6	8.53E-02	3.5968

LC50:LC5 = 2.853

Notes: Not core data.

Lee et al. 2006a	
Species: *Chironomus riparius* (3rd instar)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-37	
Test: Single	
Cd, µg/L	**% Survival**
50	100
100000	83
200000	50
300000	25
400000	20

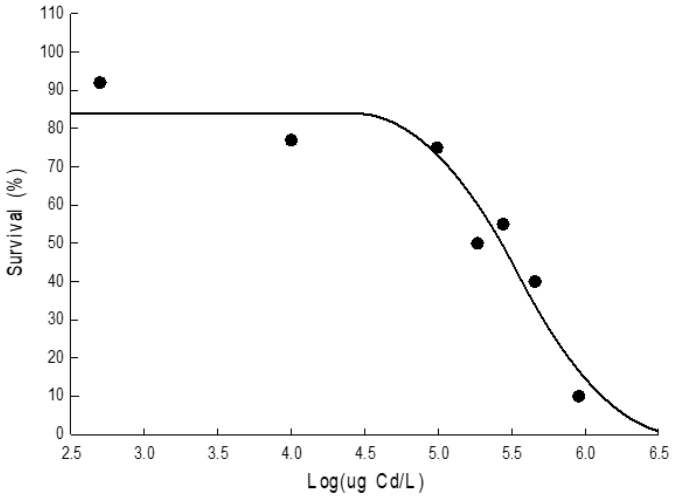


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	5.3	5.2966	0.02241	5.2002	5.3931
S	1.35	1.3695	0.13085	0.80651	1.9325
Y0	100	100.19	3.1867	86.48	113.9
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	197990	158570	247210	0.02241	5.2966
20	106720	70244	162150	0.042219	5.0283
10	78163	44336	137800	0.057231	4.893
5	62713	31091	126500	0.070821	4.7974
0	36851	9799	138580	0.1337	4.5664

LC50:LC5 = 3.157

Notes: Not core data.

Gillis and Wood 2008	
Species: *Chironomus riparius* (3rd-4th instar)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-38	
Test: Hardness = 10 mg/L	
Cd, µg/L	**% Survive**
500	92
10000	77
98000	75
185000	50
277000	55
456000	40
905000	10



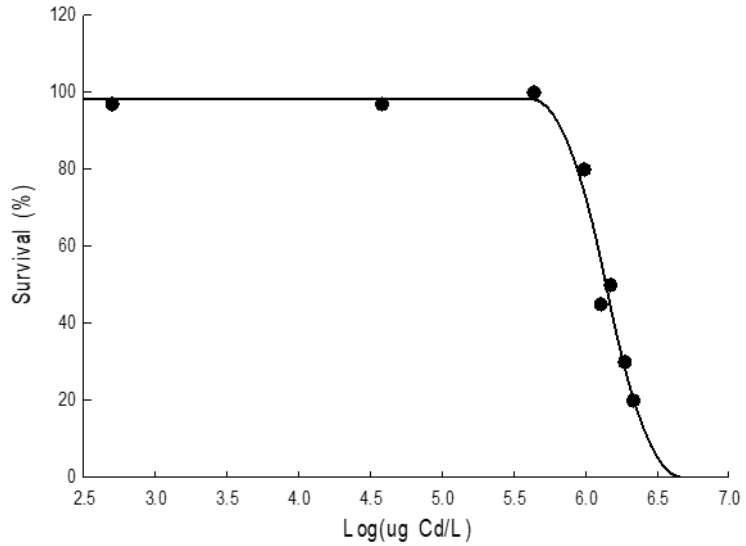
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	5.5	5.543	0.0914	5.2893	5.7968
S	0.85	0.89538	0.26239	0.16688	1.6239
Y0	84.5	83.951	6.3798	66.238	101.66

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	349170	194650	626320	0.0914	5.543
20	135690	48289	381280	0.16161	5.1325
10	84267	19571	362820	0.22836	4.9257
5	60168	9278.4	390170	0.29242	4.7794
0	26680	793.12	897510	0.54993	4.4262

LC50:LC5 = 5.803

Notes: Not core data. Unacceptable noise at low level effects.

Gillis and Wood 2008	
Species: *Chironomus riparius* (3rd-4th instar)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-39	
Test: Hardness = 140 mg/L	
Cd, µg/L	**% Survive**
500	97
38000	97
437000	100
979000	80
1279000	45
1495000	50
1879000	30



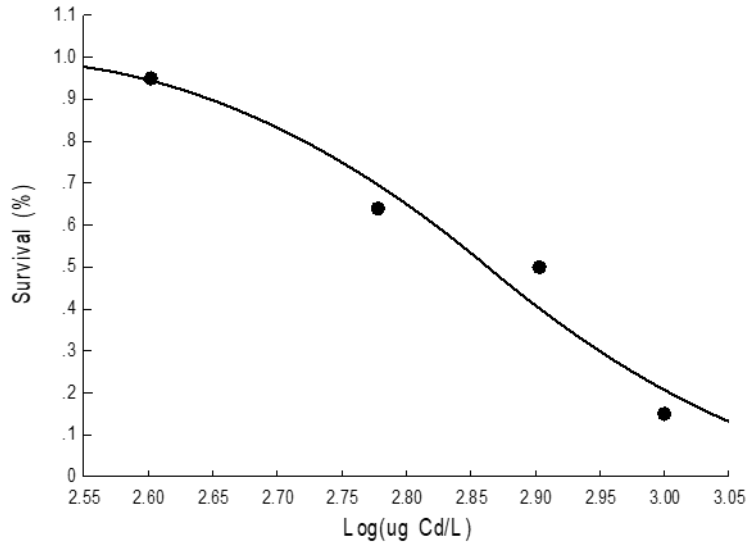
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	6	6.1476	0.023267	6.0878	6.2074
S	2	1.9067	0.35684	0.98942	2.824
Y0	98	98.286	3.7936	88.534	108.04

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1404700	1224000	1612100	0.023267	6.1476
20	901190	671190	1210000	0.049783	5.9548
10	720550	471230	1101800	0.071748	5.8577
5	615130	354960	1066000	0.092894	5.789
0	419870	129060	1366000	0.19931	5.6231

LC50:LC5 = 2.284

Notes: Not core data.

Pardue and Wood 1980	
Species: *Pectinatella magnifica* (ancenstrulae 2-3 d)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-40	
Test: Single	
Cd, µg/L	**Survival**
400	0.95
600	0.64
800	0.50
1000	0.15

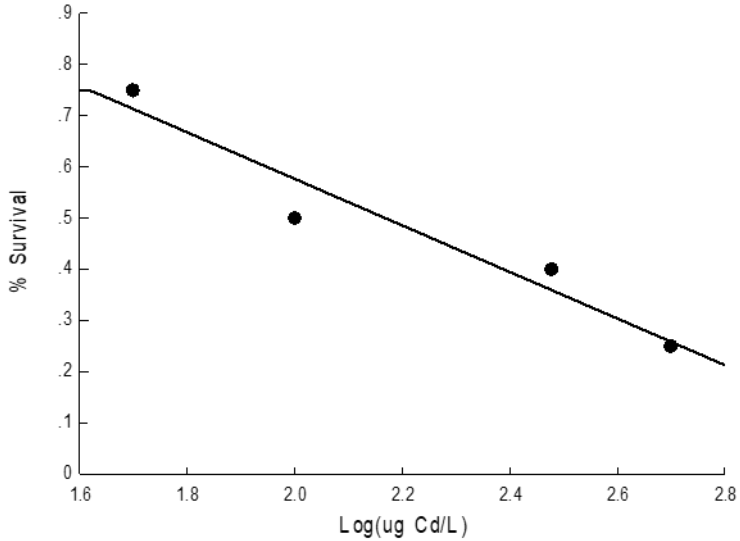


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3	2.8646	0.058164	2.735	2.9942
StDev	0.15	0.15581	0.072734	0.10887	0.27343
Y0	0.95	0.99268	0.17007	0.68005	1
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	732.09	543.21	986.64	0.058164	2.8646
20	530.02	276.7	1015.2	0.11977	2.7243
10	450.39	178.74	1134.9	0.1581	2.6536
5	401.42	122.41	1316.4	0.18864	2.6036
0	304.03	30.809	3000.1	0.27813	2.4829

LC50:LC5 = 1.824

Notes: No effect within area of concern.

Pardue and Wood 1980	
Species: *Lophopodella carteri* (ancenstrulae 2-3 d)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-41	
Test: Single	
Cd, µg/L	**Survival**
50	0.75
100	0.50
300	0.40
500	0.25

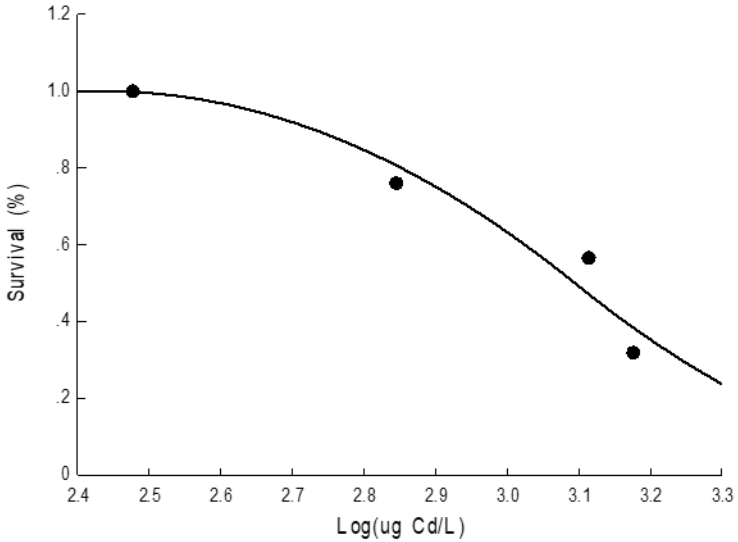


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	2.416	2.1586	1.4776	-1.1338	5.451
StDev	0.97068	0.80552	1.0785	0.56283	1.4136
Y0	0.75	0.9999	1.2223	0.69134	1
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	144.07	0.073484	282460	1.4776	2.1586
20	27.125	9.76E-06	75375000	2.7341	1.4334
10	11.691	3.18E-09	4.2935E+10	3.7676	1.0679
5	6.4478	1.01E-12	4.1207E+13	4.6833	0.80941
0	1.5327	9.42E-25	2.4933E+24	6.773	0.18546

LC50:LC5 = 22.34

Notes: No effect within area of concern.

Pardue and Wood 1980	
Species: *Plumatella emarginata* (ancenstrulae 2-3 d)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-42	
Test: Single	
Cd, µg/L	**Survival**
300	1.00
700	0.76
1300	0.57
1500	0.32



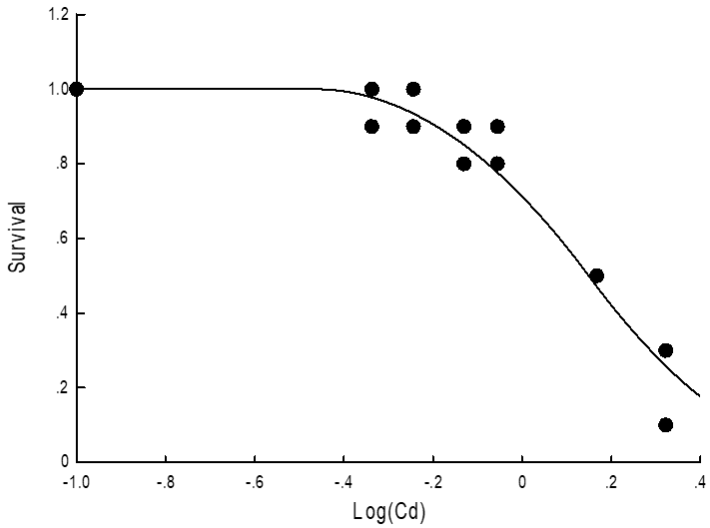
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3	3.0941	0.046809	2.9989	3.1893
StDev	0.3	0.26926	0.098725	0.18814	0.47254
Y0	1	0.9999	0.025305	0.69134	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1241.9	997.4	1546.4	0.046809	3.0941
20	710.68	435.34	1160.2	0.099327	2.8517
10	536.41	252.97	1137.4	0.14217	2.7295
5	439.65	163.05	1185.5	0.17508	2.6431
0	271.98	40.378	1832	0.26168	2.4345

LC50:LC5 = 2.825

Notes: No effect within area of concern.

Mebane et al. 2012	
Species: *Oncorhynchus clarkii lewisi*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-43	
Test: #20	
Cd, µg/L	**Survival**
0.10	1.00
0.10	1.00
0.57	1.00
0.57	0.90
0.46	0.90
0.46	1.00
0.74	0.80
0.74	0.90
0.88	0.90
0.88	0.80
1.47	0.50
1.47	0.50
2.10	0.10
2.10	0.30



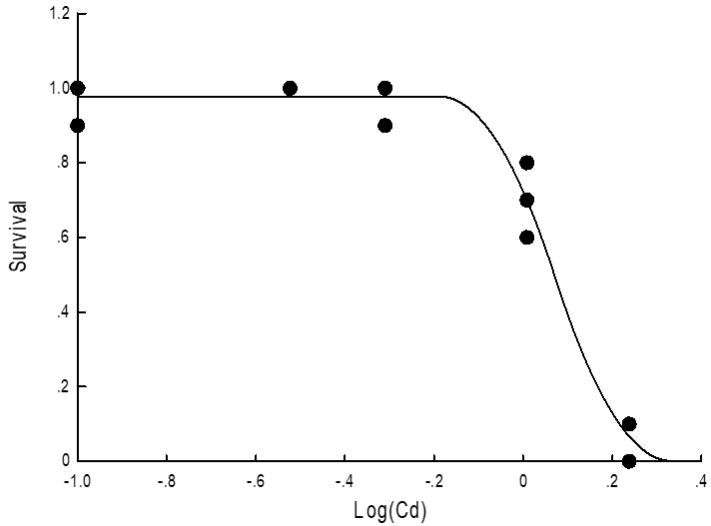
LC50:LC5 = 2.640

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.15	0.14903	0.042782	0.062147	0.23592
StDev	0.25	0.2517	0.039059	0.1934	0.36056
Y0	1	0.9999	0.002235	0.83149	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.4094	1.1538	1.7215	0.042782	0.14903
20	0.83642	0.70035	0.99894	0.037043	-0.07757
10	0.64301	0.51427	0.80398	0.045142	-0.19178
5	0.5339	0.40525	0.70338	0.053996	-0.27254
0	0.34079	0.21434	0.54184	0.081499	-0.46751

Notes: Not core data.

Mebane et al. 2012	
Species: *Oncorhynchus clarkii lewisi*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-44	
Test: #21	
Cd, µg/L	**Survival**
0.10	1.00
0.10	0.90
0.10	1.00
0.30	1.00
0.30	1.00
0.30	1.00
0.49	1.00
0.49	0.90
0.49	1.00
1.02	0.70
1.02	0.80
1.02	0.60
1.73	0.00
1.73	0.10
1.73	0.10



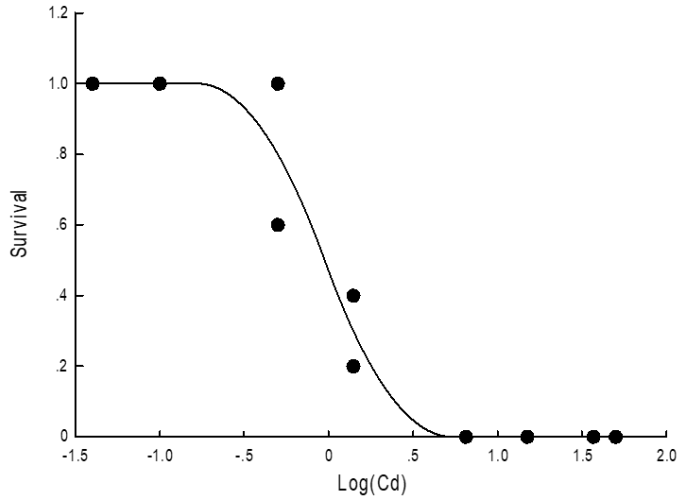
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.075	0.072996	0.023484	0.024112	0.12188
StDev	0.105	0.10679	0.020721	0.077638	0.17097
Y0	1	0.97778	0.015538	0.92202	0.9973

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.183	1.0571	1.324	0.023484	0.072996
20	0.9481	0.7986	1.1256	0.034407	-0.02315
10	0.84801	0.67962	1.0581	0.042132	-0.0716
5	0.78368	0.60039	1.0229	0.048159	-0.10586
0	0.64777	0.42653	0.98376	0.062878	-0.18858

LC50:LC5 = 1.510

Notes: Not core data.

Mebane et al. 2012	
Species: *Oncorhynchus clarkii lewisi*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-45	
Test: #23	
Cd, µg/L	**Survival**
0.04	1.00
0.04	1.00
0.5	1.00
0.5	0.60
1.4	0.40
1.4	0.20
6.5	0.00
6.5	0.00
15	0.00
15	0.00
37	0.00
37	0.00
50	0.00
50	0.00



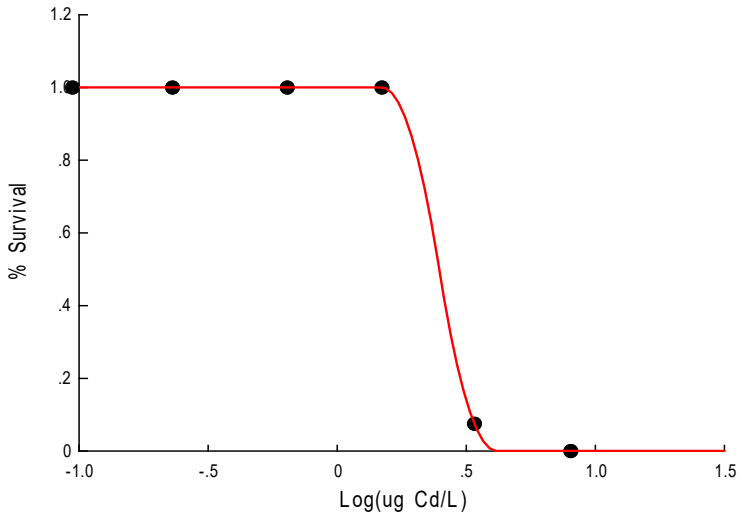
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.024	-0.023852	0.10458	-0.25688	0.20917
StDev	0.3	0.3078	0.14217	0.21506	0.54016
Y0	1	0.9999	0.002236	0.83138	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.94656	0.55351	1.6187	0.10458	-0.02385
20	0.50008	0.22058	1.1338	0.15083	-0.30096
10	0.36256	0.11018	1.193	0.20375	-0.44062
5	0.28882	0.061248	1.3619	0.24632	-0.53938
0	0.1668	0.0086686	3.2097	0.35926	-0.77779

LC50:LC5 = 3.277

Notes: Not core data.

Brinkman 2012	
Species:*Oncorhynchus clarkii virginalis* (fry, 0.26 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-46	
Test: Single	
Cd, µg/L	**%Survival**
0.05	100
0.23	100
0.64	100
1.49	100
3.4	7.5
8.03	0

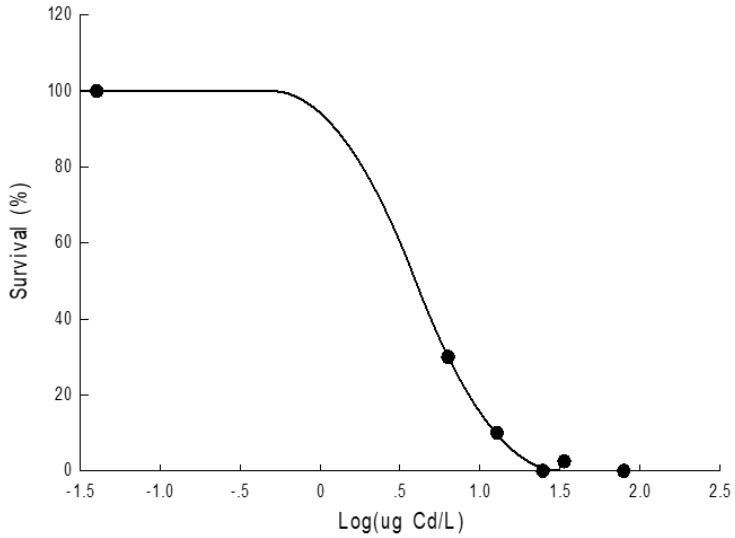


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.4	0.39534			
S	9.00E-02	9.07E-02			
Y0	1	0.9999			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**2.4851**				0.39534
20	2.0592				0.31371
10	1.8731				0.27256
5	**1.7517**				0.24347
0	1.4902				0.17323

LC50:LC5 = 1.419

Notes: TRAP Flagged for IP (No Unique Solution).

Davies et al. 1993	
Species: *Oncorhynchus mykiss* (36 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-50	
Test: Acute 1 – 200 mg/L hardness	
Cd, (µg/L)	**%Survival**
0.04	100
6.33	30
12.8	10
24.8	0
33.8	2.5
79.6	0

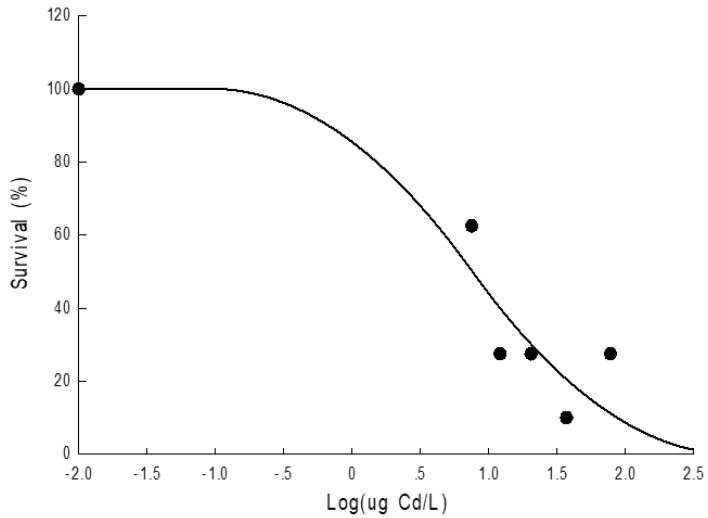


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.64996	0.59852	0.034248	0.48953	0.70751
S	1.2815	1.1042	0.11539	0.73694	1.4714
Y0	100	100	1.5226	95.154	104.85
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	3.9675	3.087	5.0993	0.034248	0.59852
20	1.8435	0.94376	3.6011	0.091372	0.26565
10	1.2528	0.47853	3.2799	0.13134	0.097882
5	0.95335	0.38834	2.3404	0.12256	-0.02075
0	0.49301	0.10909	2.228	0.20583	-0.30714

LC50:LC5 = 4.162

Notes: No effect within area of concern.

Davies et al. 1993	
Species: *Oncorhynchus mykiss* (36 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-51	
Test: Acute 1 – 400 mg/L hardness	
Cd, (µg/L)	**%Survival**
0.01	100
7.56	62.5
12.2	27.5
20.6	27.5
37.4	10
78.6	27.5



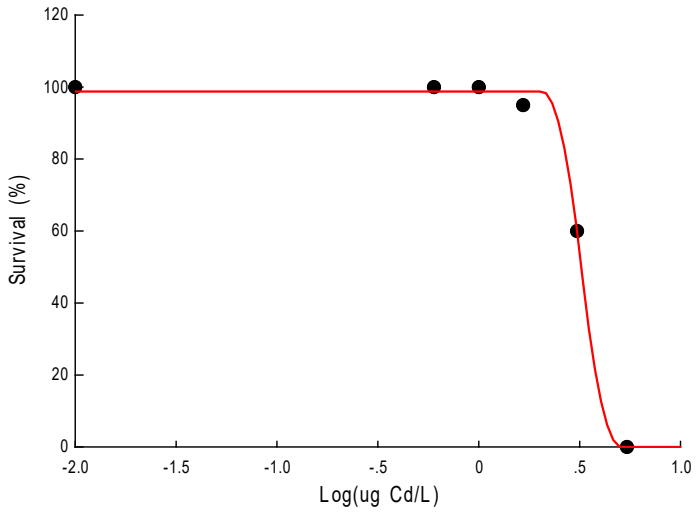
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.95406	0.88398	0.2764	0.004223	1.7637
S	0.87533	0.52249	0.2868	-0.39024	1.4352
Y0	100	100.03	15.165	51.772	148.3

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	7.6556	1.0098	58.041	0.27644	0.88398
20	1.5154	0.01166	196.95	0.66421	0.18052
10	0.66986	0.000398	1128.1	1.0138	-0.17402
5	0.37609	1.02E-05	13830	1.4346	-0.42471
0	0.093336			3.7468	-1.03

LC50:LC5 = 20.36

Notes: Not core data. Large SE for slope (S). No effect within area of concern.

Davies et al. 1993	
Species: *Oncorhynchus mykiss* (36 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-52	
Test: Acute 2 – 50 mg/L hardness	
Cd, (µg/L)	**%Survival**
0.01	100
0.60	100
1.00	100
1.66	95
3.07	60
5.42	0



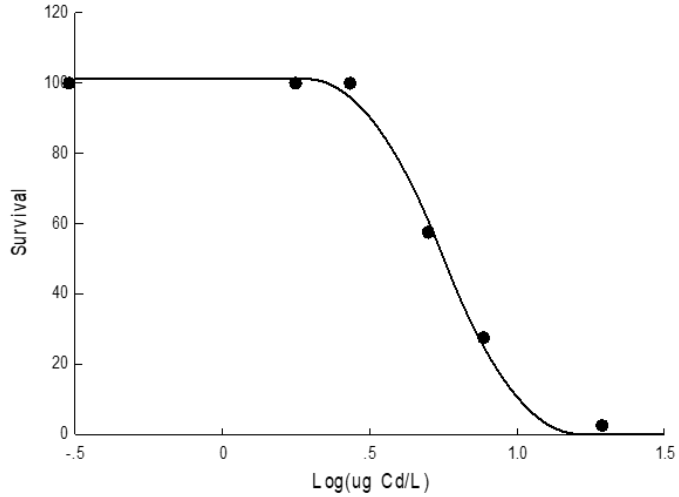
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.5	0.50947			
S	4	5.1094			
Y0	98.75	98.75			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	3.232				0.50947
20	2.7386				0.43754
10	2.5193				0.40128
5	2.3749				0.37564
0	2.0595				0.31375

LC50:LC5 = 1.361

Notes: TRAP Flagged for IP (No Unique Solution).

Davies et al. 1993	
Species: *Oncorhynchus mykiss* (36 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-54	
Test: Acute 2 – 400 mg/L hardness	
Cd, (µg/L)	**%Survival**
0.2	100
1.77	100
2.71	100
4.99	57.5
7.7	27.5
19.4	2.5

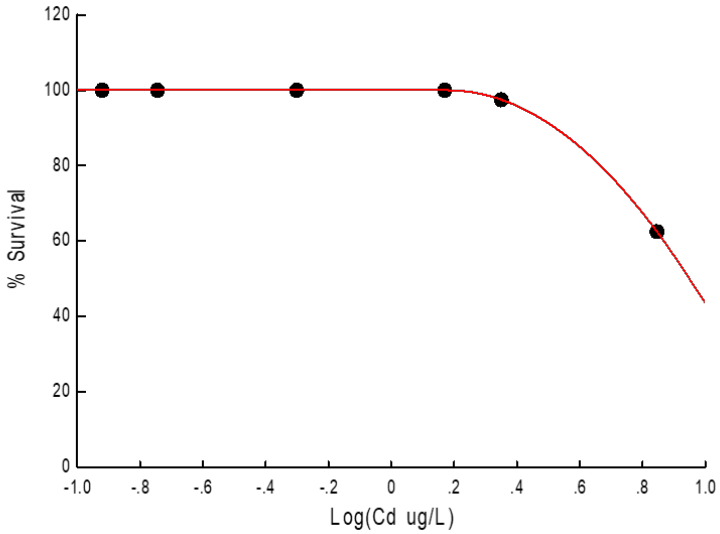


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.75	0.74834	1.71E-02	0.69398	0.80271
S	2.15	2.1566	0.28046	1.2641	3.0492
Y0	100	101.17	2.5925	92.923	109.42
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	5.602	4.9429	6.349	1.71E-02	0.74834
20	3.7837	3.0214	4.7384	3.07E-02	0.57792
10	3.1047	2.272	4.2426	4.26E-02	0.49202
5	2.6995	1.8205	4.003	5.38E-02	0.43129
0	1.926	0.94721	3.9162	9.68E-02	0.28466

LC50:LC5 = 2.075

Notes: Not core data.

Davies and Brinkman 1994b	
Species: *Oncorhynchus mykiss* (fry, 2.5 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-56	
Test: Acute 1 – aged hard (258 mg/L hardness)	
Cd, (µg/L)	**%Survival**
0.12	100
0.18	100
0.5	100
1.48	100
2.24	97.5
7.02	62.5

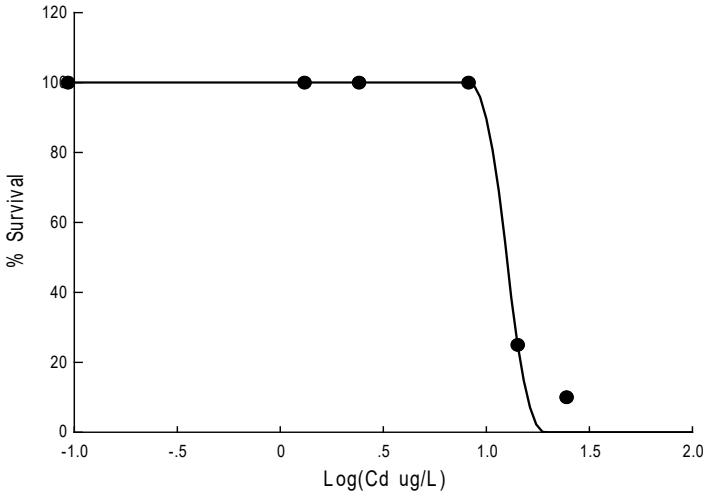


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.95	0.9498	0	0.9498	0.9498
S	1.3	1.295	0	1.295	1.295
Y0	99.5	100	0	100	100
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	8.9083	8.9083	8.9083	0	0.9498
20	4.6341	4.6341	4.6341	0	0.66597
10	3.3337	3.3337	3.3337	0	0.52292
5	2.641	2.641	2.641	0	0.42177
0	1.5051	1.5051	1.5051	0	0.17757

LC50:LC5 = 3.373

Notes: TRAP Flagged for IP (No Unique Solution).

Davies and Brinkman 1994b	
Species: *Oncorhynchus mykiss* (fry, 2.5 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-57	
Test: Acute 1 - unaged hard (281 mg/L hardness)	
Cd, (µg/L)	**%Survival**
0.08	100
1.31	100
2.41	100
8.2	100
14.2	25
24.5	10

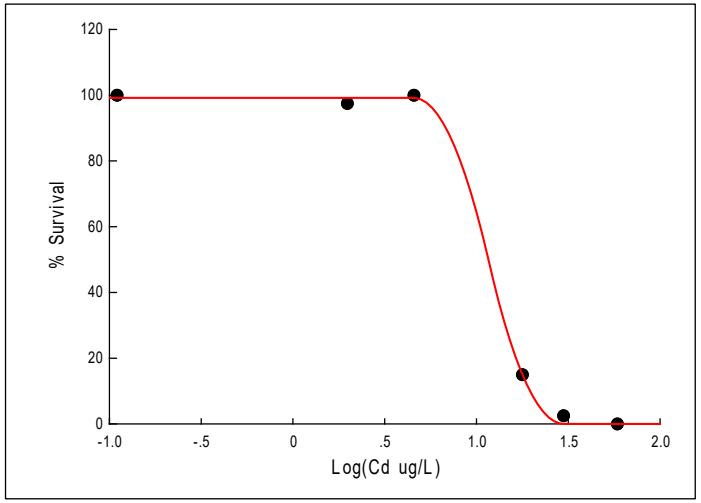


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.1	1.099			
S	5.4	5.4998			
Y0	100	100			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	12.561				1.099
20	10.77				1.0322
10	9.9661				0.99852
5	9.4342				0.97471
0	8.2644				0.91721

LC50:LC5 = 1.331

Notes: Poor model fit at low level effects (other, more certain, *O. mykiss* ratios available).

Davies and Brinkman 1994b	
Species: *Oncorhynchus mykiss* (fry, 2.5 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-59	
Test: Acute 2 - aged hard (276 mg/L hardness)	
Cd, (µg/L)	**%Survival**
0.11	100
1.98	97.5
4.56	100
17.8	15
29.8	2.5
58.6	0



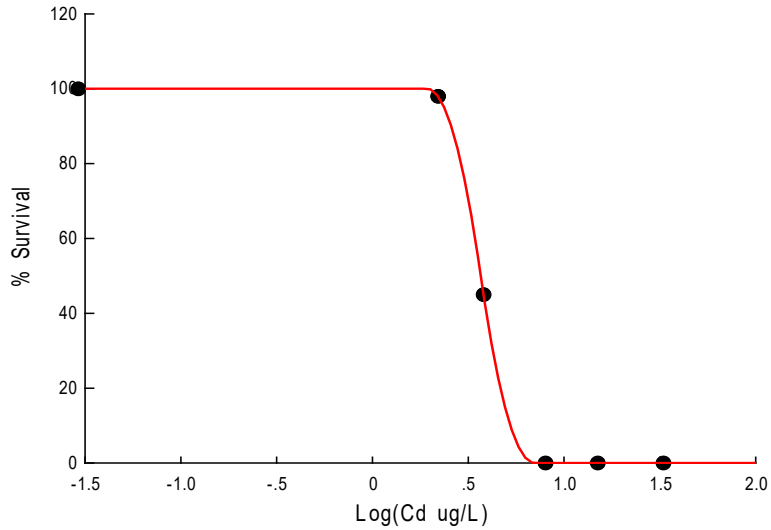
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.07	1.0665	0.71961	-1.2236	3.3566
S	2.45	2.4445	9.5526	-27.956	32.845
Y0	100	99.166	1.2859	95.074	103.26

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	11.655	0.059755	2273.1	0.71961	1.0665
20	8.2442	3.3466	20.309	0.12303	0.91615
10	6.9242	3.4934	13.724	0.093361	0.84037
5	6.1205	2.7367	13.688	0.10984	0.78678
0	4.5438	0.017702	1166.3	0.75709	0.65742

LC50:LC5 = 1.904

Notes: TRAP Flagged for IP (No Unique Solution).

Besser et al. 2007	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-67	
Test: Acute 2 (swim up fry)	
Cd, (µg/L)	**%Survival**
0.02	100
2.2	98
3.8	45
8	0
15	0
33	0



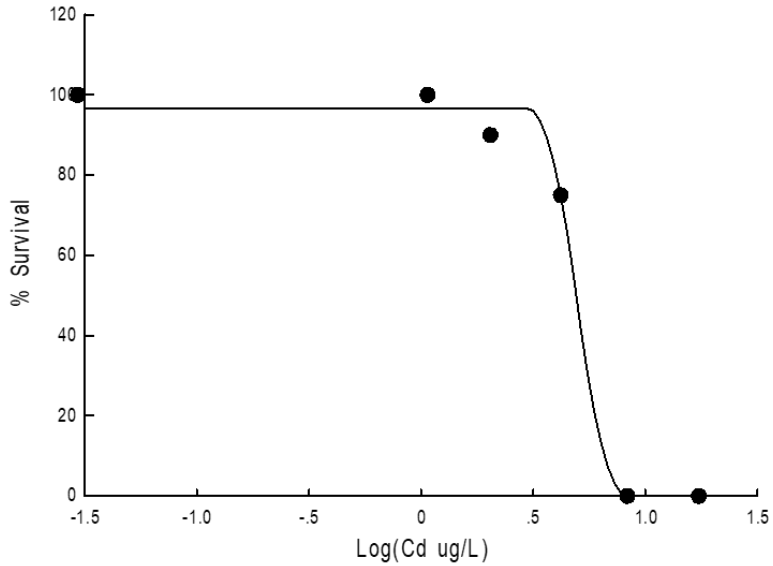
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.565	0.56548	0	0.56548	0.56548
S	3.6	3.5866	0	3.5866	3.5866
Y0	100	100	0	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	3.6768	3.6768	3.6768	0	0.56548
20	2.904	2.904	2.904	0	0.463
10	2.5784	2.5784	2.5784	0	0.41135
5	2.3704	2.3704	2.3704	0	0.37483
0	1.9349	1.9349	1.9349	0	0.28666

LC50:LC5 = 1.551

Notes: TRAP Flagged for IP (No Unique Solution).

Bresser et al 2007	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-68	
Test: Acute 4 (juvenile)	
Cd, (µg/L)	**%Survival**
0.02	100
1.07	100
2.04	90
4.2	75
8.32	0
17.35	0

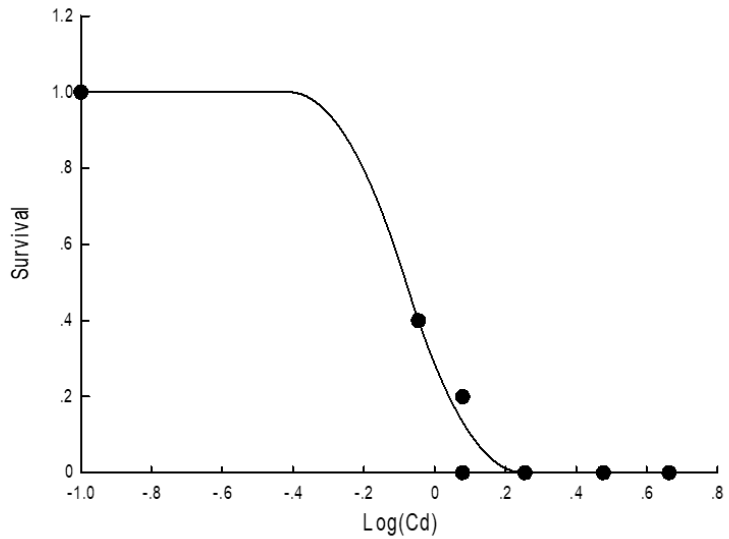


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.697	0.69701	7.6449	-23.632	25.026
S	4.48	4.4804	464.38	-1473.4	1482.3
Y0	97	96.667	2.7217	88.005	105.33
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	4.9775	2.33E-24	1.06E+25	7.6449	0.69701
20	4.1207	3.5969	4.7208	1.86E-02	0.61497
10	3.7465	3.1758	4.4198	2.26E-02	0.57363
5	3.5026	2.9259	4.1931	2.46E-02	0.54439
0	2.9772	2.4119	3.6751	2.87E-02	0.47381

LC50:LC5 = 1.421

Notes: Large SE for X50 and slope (S). Poor model fit.

Mebane et al. 2012	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-69	
Test: Test 8, LNF water	
Cd, (µg/L)	**Survival**
0.1	1.00
0.1	1.00
0.1	1.00
0.9	0.40
0.9	0.40
0.9	0.40
1.2	0.00
1.2	0.20
1.2	0.20
1.8	0.00
1.8	0.00
1.8	0.00
3	0.00
3	0.00
3	0.00
4.6	0.00
4.6	0.00
4.6	0.00



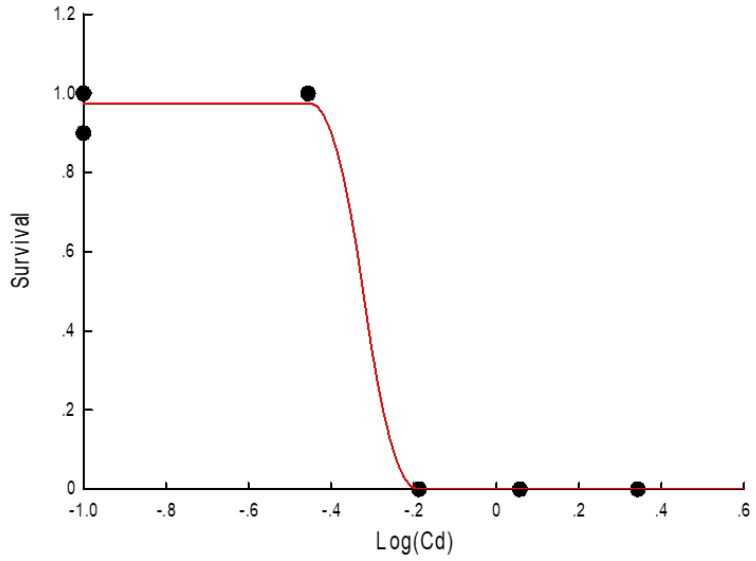
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.0806	-0.080646	0.043707	-0.17803	0.016741
StDev	0.135	0.13488	0.055789	0.094245	0.23671
Y0	1	0.9999	0.0018257	0.88411	1

LC50:LC5 = 1.682

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.83053	0.66369	1.0393	0.043707	-0.080646
20	0.62794	0.37589	1.049	0.094558	-0.20208
10	0.5454	0.26185	1.136	0.12552	-0.26328
5	0.49367	0.19349	1.2595	0.14877	-0.30656
0	0.38811	0.07057	2.1345	0.20711	-0.41104

Notes: Not core data. No effect within area of concern.

Mebane et al. 2012	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-70	
Test: Test 9, LNF water	
Cd, (µg/L)	**Survival**
0.1	1.00
0.1	0.90
0.35	1.00
0.35	1.00
0.65	0.00
0.65	0.00
1.14	0.00
1.14	0.00
2.20	0.00
2.20	0.00

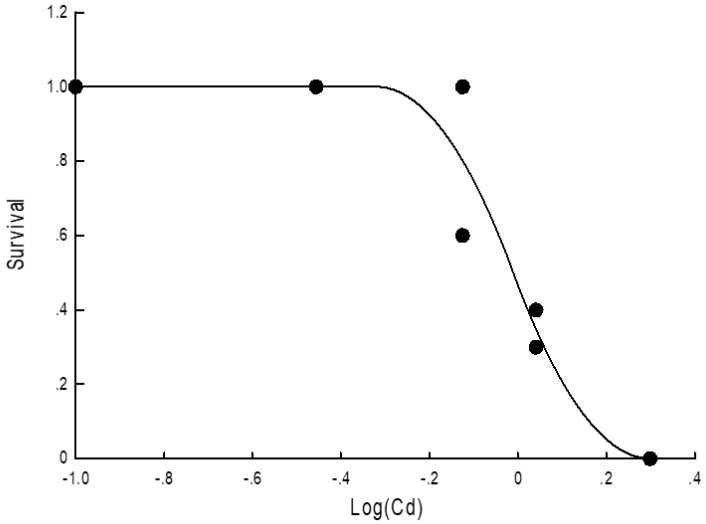


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.32	-0.32091			
StDev	0.055	0.052798			
Y0	0.975	0.975			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.47763				-0.32091
20	0.42811				-0.36845
10	0.40513				-0.3924
5	0.38963				-0.40934
0	0.35462				-0.45024

LC50:LC5 = 1.266

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Mebane et al. 2012	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-71	
Test: Test 10, SF-km9 water	
Cd, (µg/L)	**Survival**
0.1	1.00
0.1	1.00
0.35	1.00
0.35	1.00
0.75	1.00
0.75	0.60
1.10	0.40
1.10	0.30
1.99	0.00
1.99	0.00

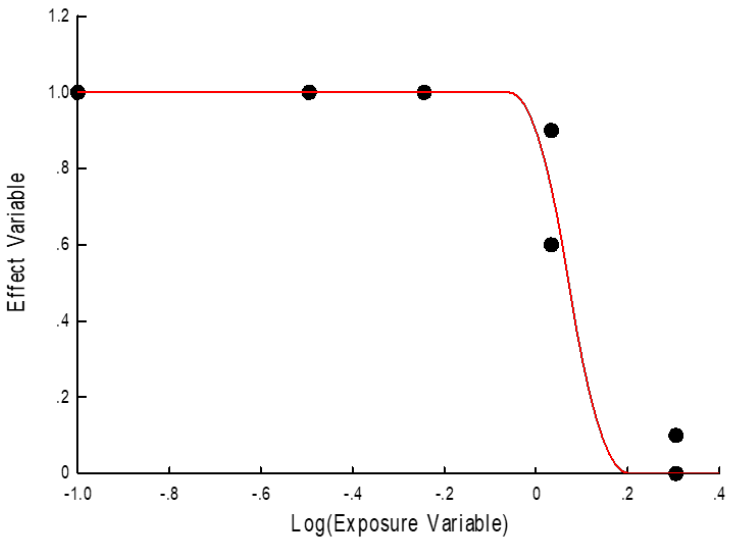


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.01	-0.01021	0.029512	-0.07211	0.051691
StDev	0.1275	0.12663	0.038821	0.088479	0.22223
Y0	1	0.9999	0.001581	0.91171	1
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.97676	0.84701	1.1264	0.029512	-0.01021
20	0.75125	0.61912	0.91157	0.037967	-0.12422
10	0.65815	0.51404	0.84266	0.045188	-0.18168
5	0.59937	0.44549	0.80641	0.050539	-0.22231
0	0.4782	0.29575	0.77319	0.063259	-0.32039

LC50:LC5 = 1.630

Notes: Not core data.

Mebane et al. 2012	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-72	
Test: Test 11, SF-km16 water	
Cd, (µg/L)	**Survival**
0.1	1.00
0.1	1.00
0.32	1.00
0.32	1.00
0.57	1.00
0.57	1.00
1.08	0.90
1.08	0.60
2.02	0.00
2.02	0.10

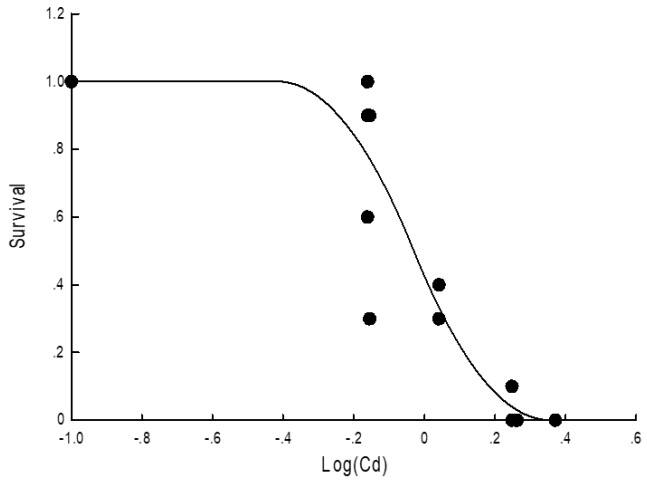


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.086403	0.071477			
StDev	0.025	0.053028			
Y0	1	0.9999			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.1789				0.071477
20	1.0562				0.023736
10	0.99925				-0.00032
5	0.96086				-0.01734
0	0.87415				-0.05841

LC50:LC5 = 1.227

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Mebane et al. 2012	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-73	
Test: Test 13, SFH-km8 water	
Cd, (µg/L)	**Survival**
0.1	1.00
0.10	1.00
0.10	1.00
0.69	1.00
0.69	0.60
0.69	0.90
0.70	0.30
0.70	0.90
0.70	0.90
1.10	0.40
1.10	0.30
1.10	0.40
1.77	0.10
1.77	0.10
1.77	0.00
1.83	0.00
1.83	0.00
1.83	0.00
2.35	0.00
2.35	0.00
2.35	0.00



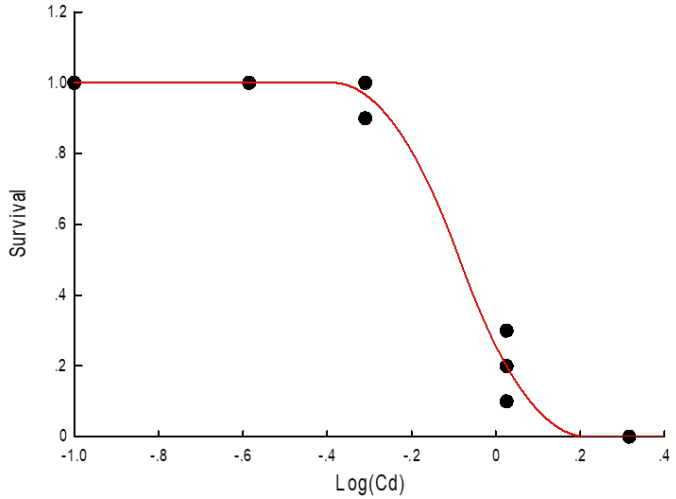
LC50:LC5 = 1.837

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-3.00E-02	-2.98E-02	2.12E-02	-7.23E-02	1.27E-02
StDev	1.60E-01	1.58E-01	1.77E-02	1.29E-01	0.20208
Y0	1	0.9999	1.83E-03	0.88411	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.93367	0.8466	1.0297	2.12E-02	-2.98E-02
20	0.67342	5.84E-01	0.77656	3.05E-02	-1.72E-01
10.0000	0.5712	0.4787	0.6815	0.0372	-0.2432
5.0000	0.5084	0.4145	0.6236	0.0423	-0.2938
0	3.84E-01	2.91E-01	5.06E-01	5.42E-02	-0.4159

Notes: Not core data. Unacceptable noise at low level effects.

Mebane et al. 2012	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-74	
Test: Test 14, SFH-km8 water	
Cd, (µg/L)	**Survival**
0.10	1.00
0.10	1.00
0.10	1.00
0.26	1.00
0.26	1.00
0.26	1.00
0.49	1.00
0.49	0.90
0.49	1.00
1.06	0.10
1.06	0.20
1.06	0.30
2.07	0.00
2.07	0.00
2.07	0.00



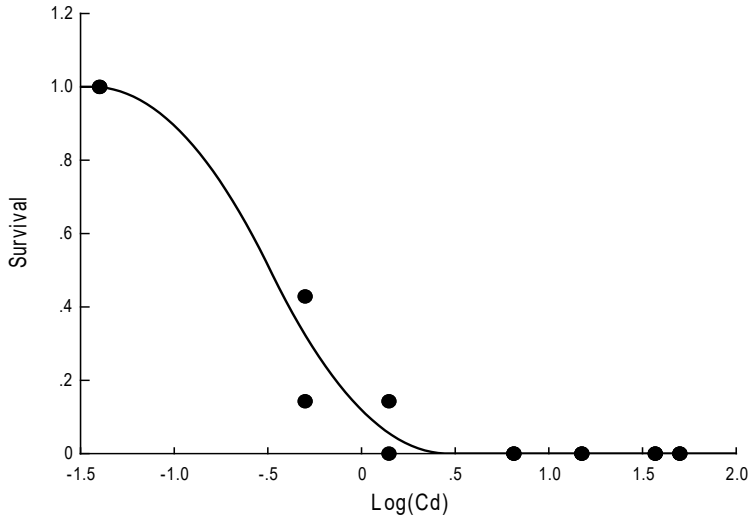
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-8.50E-02	-8.57E-02	2.66E-02	-1.41E-01	-3.05E-02
StDev	1.25E-01	1.23E-01	1.91E-02	9.48E-02	0.17642
Y0	1	0.9999	1.29E-03	0.94017	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.82091	0.72296	0.93212	2.66E-02	-8.57E-02
20	0.63579	5.54E-01	0.73015	2.82E-02	-1.97E-01
10.0000	0.5590	0.4742	0.6589	0.0325	-0.2526
5.0000	0.5103	0.4218	0.6174	0.0365	-0.2922
0	4.10E-01	3.09E-01	5.43E-01	4.83E-02	-0.38766

LC50:LC5 = 1.609

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Mebane et al. 2012	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-75	
Test: (Kootenai strain), Test 15, LNF water	
Cd, (µg/L)	**Survivors**
0.04	1.00
0.04	1.00
0.5	0.14
0.5	0.43
1.4	0.14
1.4	0.00
6.5	0.00
6.5	0.00
15	0.00
15	0.00
37	0.00
37	0.00
50	0.00
50	0.00



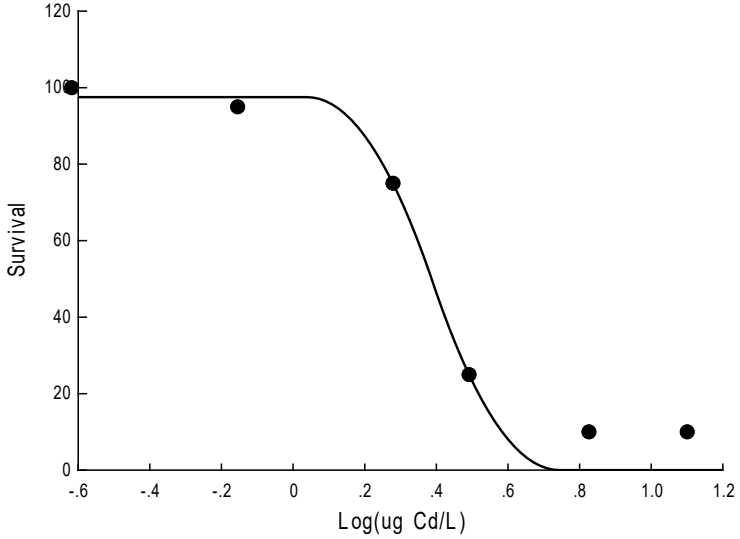
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-5.00E-01	-4.87E-01	2.34E-01	-1.01E+00	3.54E-02
StDev	3.90E-01	3.88E-01	2.04E-01	2.71E-01	0.6804
Y0	1	0.9999	3.07E-02	0.69134	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.32612	9.80E-02	1.085	2.34E-01	-4.87E-01
20	0.14599	1.49E-02	1.433	4.21E-01	-8.36E-01
10	0.0974	0.0044	2.1548	0.5298	-1.0116
5	0.0731	0.0014	3.9051	0.6318	-1.1360
0	3.66E-02	5.27E-05	2.54E+01	7.95E-01	-1.4363

LC50:LC5 = 4.460

Notes: Not core data. Large SE for steepness. No effect within area of concern.

Davies and Brinkman 1994c	
Species: *Salmo trutta* (fingerling)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-77	
Test: Single	
Cd, (µg/L)	**%Survival**
0.2	100
0.7	95
1.9	75
3.1	25
6.7	10
12.6	10



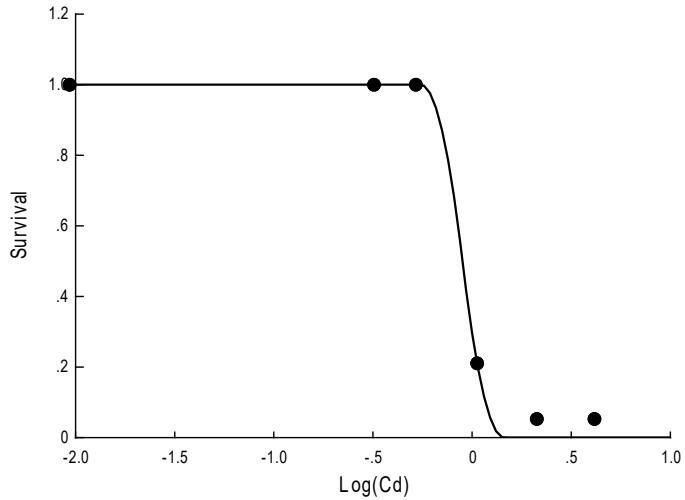
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.4	0.39152	3.44E-02	0.28192	0.50112
S	3	2.8433	0.85323	0.12798	5.5587
Y0	97.5	97.5	5.9512	78.561	116.44

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.4633	1.9139	3.1704	3.44E-02	0.39152
20	1.8292	1.225	2.7313	5.47E-02	0.26226
10	1.5744	0.92095	2.6914	7.32E-02	0.19711
5	1.4159	0.7233	2.7718	9.17E-02	0.15104
0	1.096	0.13786	8.7134	0.28292	3.98E-02

LC50:LC5 = 1.740

Notes: No effect within area of concern. No effect plateau is average of control and first treatment, but next partial is 25% effect.

Stratus Consulting 1999	
Species: *Salvelinus confluentus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-78	
Test: Bank 1- 32 mg/L hardness; 76.1 mg fish	
Cd, (µg/L)	**Proportion surviving**
0.0065	100
0.32	100
0.52	100
1.06	21
2.12	5
4.14	5

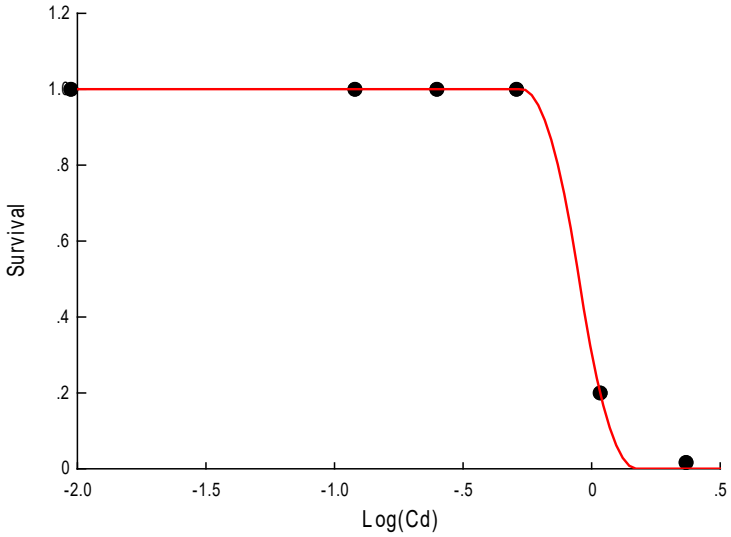


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.0055	-0.048305			
S	0.05	0.085567			
Y0	1	0.9999			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.89474				-0.048305
20	0.74931				-0.12534
10	0.68523				-0.16417
5	0.64325				-0.19162
0	0.5522				-0.2579

LC50:LC5 = 1.391

Notes: Poor model fit (at high level effects) with inadequate partials between 0% and 79% effect.

Stratus Consulting 1999	
Species: *Salvelinus confluentus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-81	
Test: Bank 3- 33.2 mg/L hardness; 218 mg fish	
Cd, (µg/L)	**Proportion surviving**
0.0065	100
0.12	100
0.25	100
0.51	100
1.08	20
2.33	2

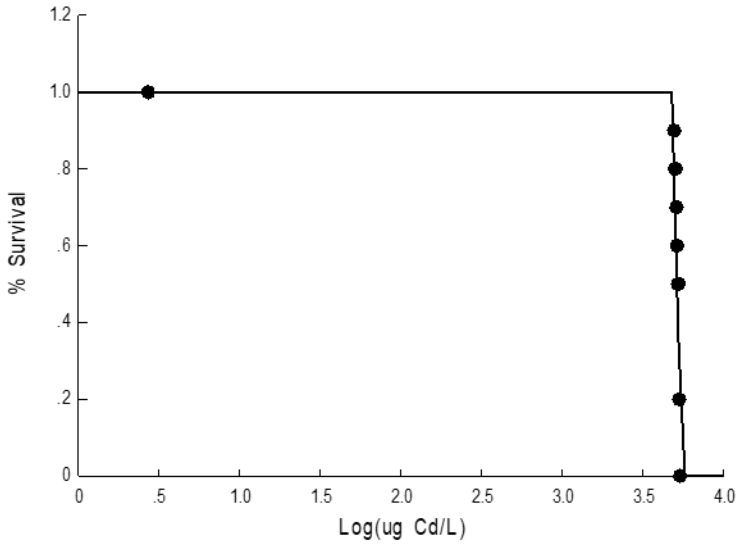


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	-0.00311	-0.048589			
S	0.08	0.091071			
Y0	1	0.9999			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	0.89415				-0.048589
20	0.74032				-0.13058
10	0.67313				-0.1719
5	0.62933				-0.20112
0	0.53497				-0.27167

LC50:LC5 = 1.421

Notes: TRAP Flagged for IP (No Unique Solution).

Yorulmazlar and Gul 2003	
Species: *Ctenopharyngodon idellus* (18 mm, 17g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-84	
Test: Single	
Cd, (µg/L)	**Proportion surviving**
2.696071	100
4906.85	90
4960.771	80
5014.693	80
5068.614	70
5122.536	60
5176.457	50
5230.378	50
5284.3	20
5338.221	0



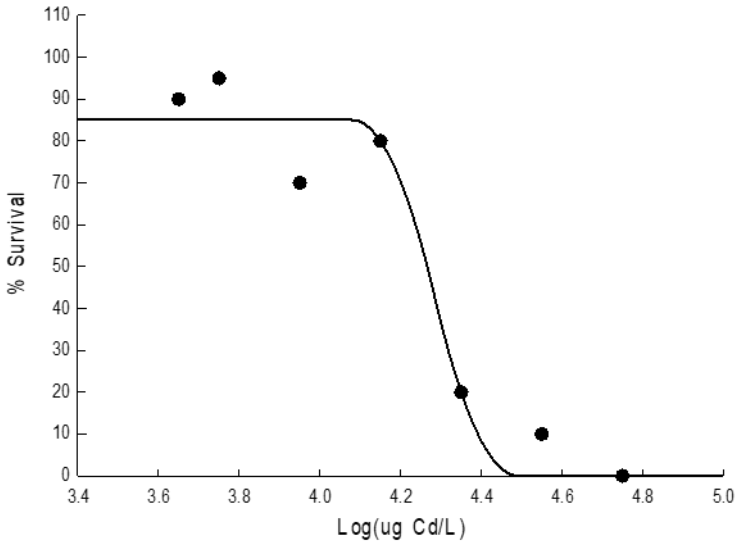
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.71	3.7118	0.002193	3.7074	3.7162
StDev	0.014	0.013909	0.00273	0.010081	0.02242
Y0	1	0.9999	0.003207	0.69138	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	5149.9	5097.7	5202.7	0.002193	3.7118
20	5003.6	4931.2	5077	0.003011	3.6993
10	4931.4	4832.1	5032.6	0.003986	3.693
5	4881	4757.5	5007.7	0.004773	3.6885
0	4761.4	4554.2	4977.9	0.00689	3.6777

LC50:LC5 = 1.055

Notes: Not core data. Curve slope based on arbitrary breakpoint.

Vergauwen 2012; Vergauwen et al. 2013	
Species: *Danio rerio*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-88	
Test: 30C	
Cd, (µg/L)	**%Survival**
4475.123	90
5633.846	95
8929.044	70
14151.58	80
22428.74	20
35547.16	10
56338.46	0



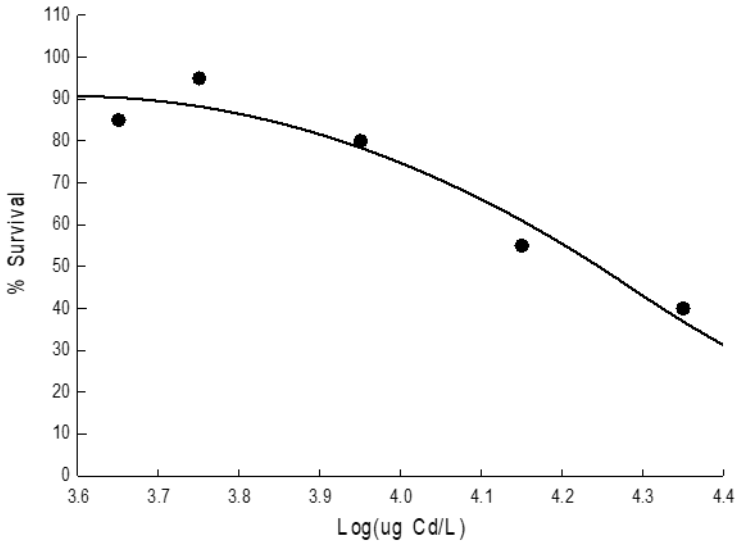
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.3	4.2861	0.038804	4.1784	4.3939
S	5	4.855	2.21	-1.2809	10.991
Y0	92.5	85	6.1237	67.998	102

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	19325	15080	24767	0.038804	4.2861
20	16234	10929	24114	0.061895	4.2104
10	14869	9115.7	24252	0.07653	4.1723
5	13973	7980.6	24465	0.087615	4.1453
0	12027	4710.5	30708	0.14662	4.0802

LC50:LC5 = 1.383

Notes: Unacceptable noise at low level effects.

Vergauwen 2012; Vergauwen et al. 2013	
Species: *Danio rerio*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-89	
Test: 36C	
Cd, (µg/L)	**%Survival**
4475.123	85
5633.846	95
8929.044	80
14151.58	55
22428.74	40



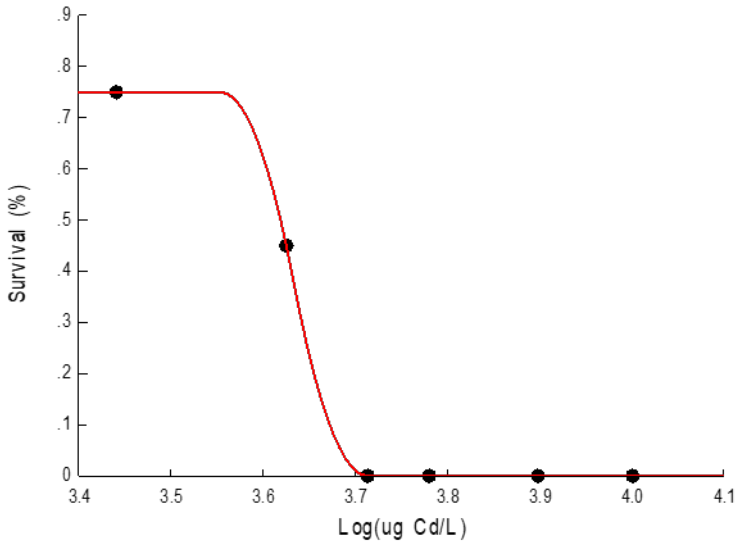
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.2727	4.2825	0.06314	4.0108	4.5541
S	1.7465	1.4415	0.60473	-1.1604	4.0435
Y0	90	90.698	9.3316	50.548	130.85

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	19163	10252	35821	0.06314	4.2825
20	10654	2697.4	42078	0.13865	4.0275
10	7925	1116.7	56242	0.1978	3.899
5	6428.8	545.21	75806	0.24905	3.8081
0	3879.4	52.614	286040	0.43407	3.5888

LC50:LC5 = 2.981

Notes: Unacceptable noise at low level effects.

Carrier 1987; Carrier and Beitinger 1988a	
Species: *Pimephales promelas* (0.8 – 2.0 g)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-90	
Test: Single	
Cd, (µg/L)	**Survival**
10	Not reported
2760	0.75
4220	0.45
5170	0.00
6030	0.00
7910	0.00
10020	0.00

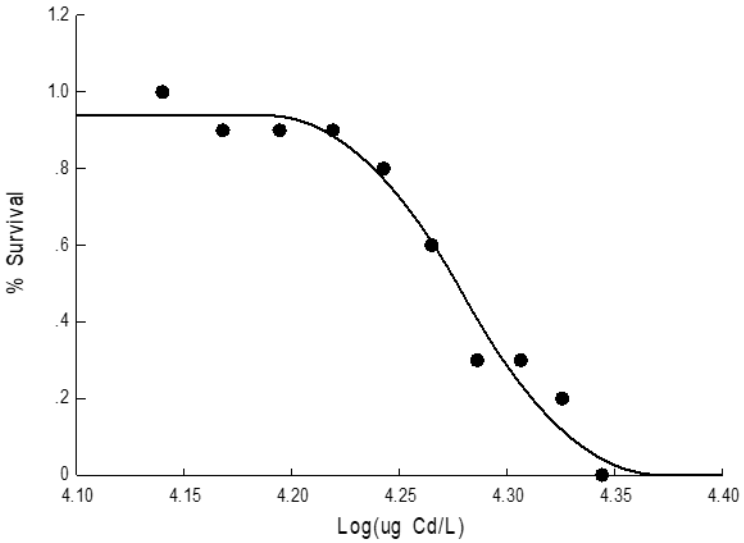


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.6336	3.6337			
StDev	0.036935	0.032561			
Y0	0.75	0.74995			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	4302.6				3.6337
20	4021.8				3.6044
10	3887.3				3.5896
5	3794.9				3.5792
0	3580.8				3.554

LC50:LC5 = 1.134

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Yilmaz et al. 2004	
Species: *Poecilia reticulata*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-91	
Test: Single	
Cd, (µg/L)	**# Survived**
13796.7761	100
14716.5612	90
15636.3463	90
16556.1314	90
17475.9164	80
18395.7015	60
19315.4866	30
20235.2717	30
21155.0567	20
22074.8418	0

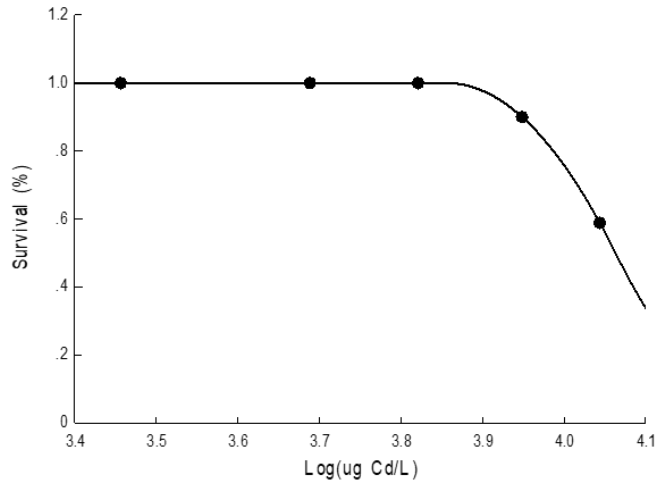


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4.28	4.2796	0.008717	4.2613	4.2979
StDev	0.04	0.037314	0.008269	0.026141	0.065063
Y0	0.925	0.93808	0.04554	0.77821	0.99404
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	19037	18252	19856	0.008717	4.2796
20	17620	16445	18879	0.013556	4.246
10	16946	15458	18578	0.016841	4.2291
5	16486	14635	18570	0.020346	4.2171
0	15424	12722	18700	0.02558	4.1882

LC50:LC5 = 1.155

Notes: Not Core data.

Carrier 1987; Carrier and Beitinger 1988b	
Species: *Lepomis cyanellus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-92	
Test: Single	
Cd, (µg/L)	**Survival**
20	Not reported
2860	100
4880	100
6620	100
8880	90
11060	58.8

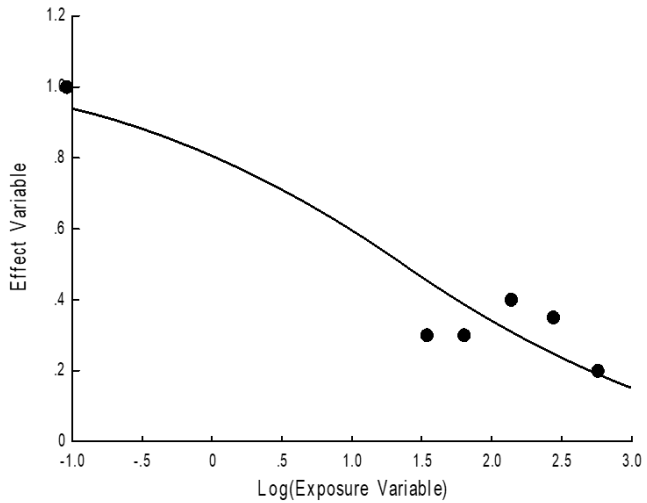


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	4	4.0629	3.33E-02	3.9887	4.1371
StDev	1.00E-01	8.45E-02	3.66E-02	5.91E-02	0.14836
Y0	1	0.9999	1.29E-03	0.94017	1
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	11559	9743.1	13713	3.33E-02	4.0629
20	9700.8	8629.4	10905	2.16E-02	3.9868
10	8880.8	7405.7	10650	3.11E-02	3.9484
5	8343.1	6458.9	10777	4.07E-02	3.9213
0	7175.4	4143	12427	6.67E-02	3.8558

LC50:LC5 = 1.385

Notes: Not core data; no effect greater than 50%.

Calfee et al. 2014	
Species: *Acipenser transmontanus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-93	
Test: 61 dph, 1.15g, 62.5 cm	
Cd, (µg/L)	**% survival**
0.02	100
34.4	30
63.5	30
138	40
276	35
575	20



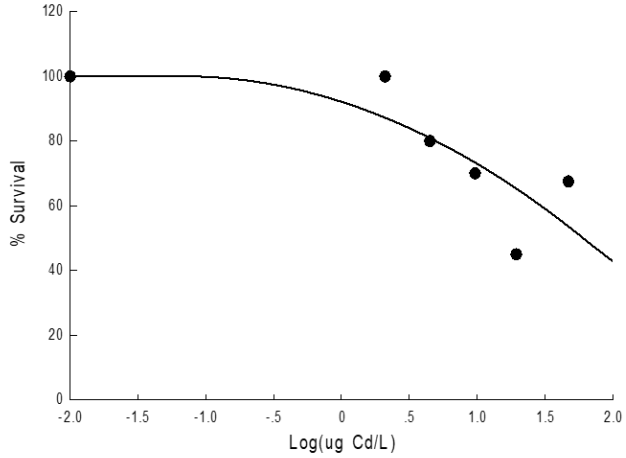
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.4	1.37	0.56	0.11	2.62
StDev	1.5	1.48	0.79	1.04	2.60
Y0	1	1.00	0.10	0.69	1.00

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	23.2360	1.296600000000	416.40	0.56	1.37
20	1.0739	0.000931030000	1238.80	1.30	0.03
10	0.2281	0.000009230500	5635.00	1.73	-0.64
5	0.0762	0.000000187190	31057.00	2.05	-1.12
0	0.0054	0.000000000000	161130000.00	2.93	-2.27

LC50:LC5 = 304.7

Notes: No effect within area of concern.

Wang et al. 2014	
Species: *Acipenser transmontanus* (larva, 27 dph)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-94	
Test: Single	
Cd, (µg/L)	**% survival**
0.01	100
2.1	100
4.49	80
9.69	70
19.5	45
47.2	67.5

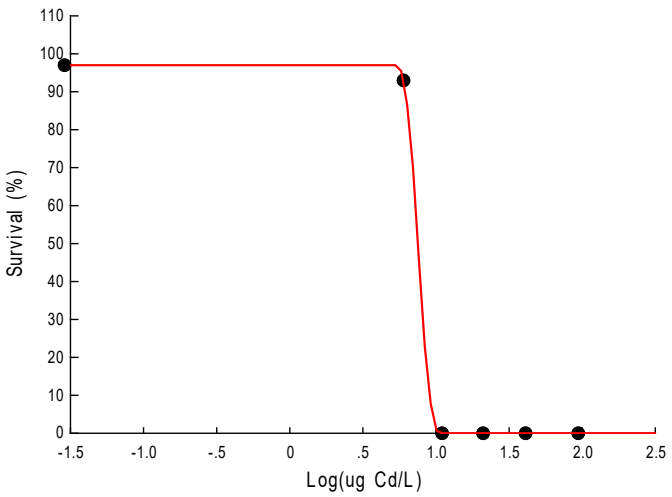


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.6	1.7813	0.41363	0.63293	2.9298
S	0.35	0.33881	0.18839	-0.18424	0.86186
Y0	100	100			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	**60.443**	4.2947	850.67	0.41363	1.7813
20	4.972	0.47783	51.736	0.36639	0.69653
10	1.4119	0.025862	77.077	0.62567	0.14979
5	**0.57967**	0.00292	115.06	0.82759	-0.23682
0	0.067583	1.35E-05	337.33	1.332	-1.1702

LC50:LC5 = 104.3

Notes: Not core data. Large SE for X50 and slope (S). No effects within area of concern.

Besser et al. 2007	
Species: *Cottus bairdii*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-95	
Test: Acute 1 - Swim up	
Cd, (µg/L)	**%Survival**
0.02	97
6	93
11	0
21	0
41	0
94	0



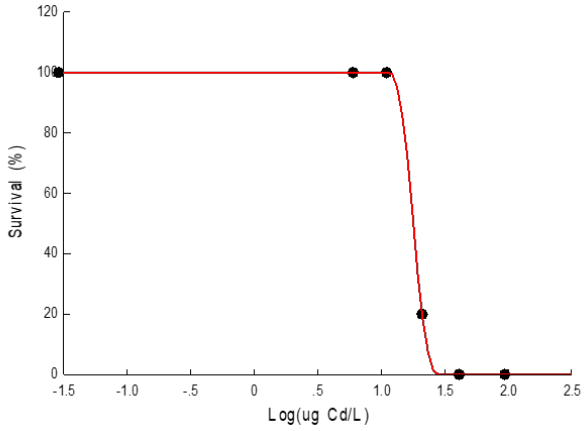
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.9	0.87943			
S	7	7.0379			
Y0	97	97			

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	7.5759				0.87943
20	6.7175				0.82721
10	6.3225				0.80089
5	6.0573				0.78228
0	5.4619				0.73735

LC50:LC5 = 1.251

Notes: TRAP Flagged for IP (No Unique Solution).

Besser et al. 2007	
Species: *Cottus bairdii*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-96	
Test: Acute 2a - juvenile	
Cd, (µg/L)	**%Survival**
0.02	100
6	100
11	100
21	20
41	0
94	0

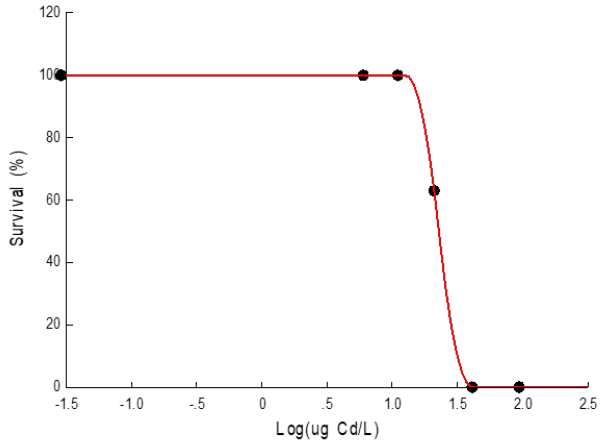


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.25	1.2537			
S	5	5.3649			
Y0	100	100			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	17.757				1.2494
20	15.014				1.1765
10	13.797				1.1398
5	12.996				1.1138
0	11.249				1.0511

LC50:LC5 = 1.366

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Besser et al. 2007	
Species: *Cottus bairdii*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-97	
Test: Acute 2b - juvenile	
Cd, (µg/L)	**%Survival**
0.02	100
6	100
11	100
21	63
41	0
94	0

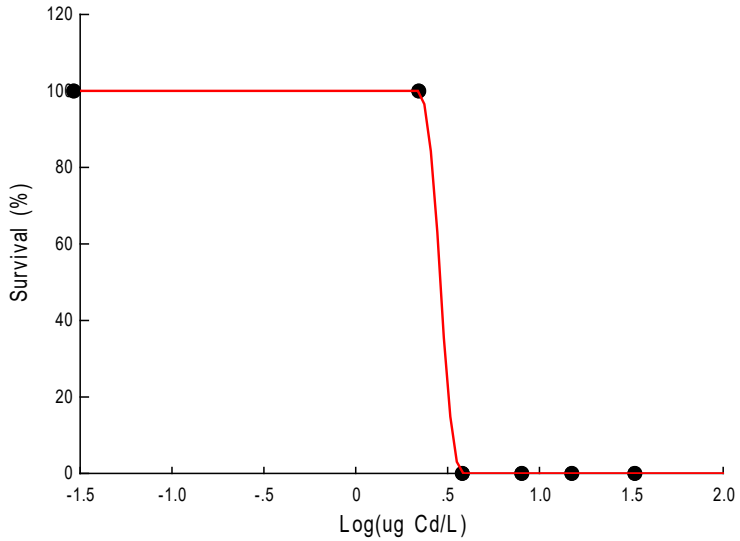


	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	1.3	1.3578			
S	2.8	3.9267			
Y0	100	100			
p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	22.794				1.3578
20	18.374				1.2642
10	16.483				1.217
5	15.264				1.1837
0	12.681				1.1031

LC50:LC5 = 1.493

Notes: Not core data. TRAP Flagged for IP (No Unique Solution)

Besser et al. 2007	
Species: *Cottus bairdii*	
Test Hardness: 103 mg/L	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-98	
Test: Acute 2 - newly hatched	
Cd, (µg/L)	**%Survival**
0.02	100
2.2	100
3.8	0
8	0
15	0
33	0



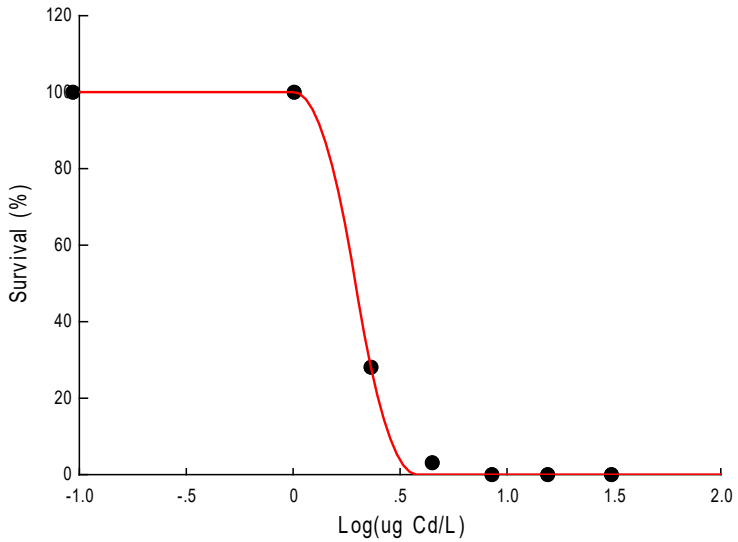
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.4611	0.4611	3.64E-08	0.4611	0.4611
S	8.1981	8.426	2.58E-06	8.426	8.426
Y0	100	100	3.31E-11	100	100

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2.8914	2.8914	2.8914	3.64E-08	0.4611
20	2.6151	2.6151	2.6151	4.30E-08	0.41748
10	2.486	2.486	2.486	4.90E-08	0.3955
5	2.3986	2.3986	2.3986	5.31E-08	0.37995
0	2.2	2.2	2.2	6.30E-08	0.34242

LC50:LC5 = 1.205

Notes: TRAP Flagged for IP (No Unique Solution).

Brinkman and Vieira 2007	
Species: *Cottus bairdii* (fry)	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-99	
Test: Single	
Cd, (µg/L)	**%Survival**
0.075	100
1.01	100
2.31	28
4.47	3
8.5	0
15.5	0
30.8	0



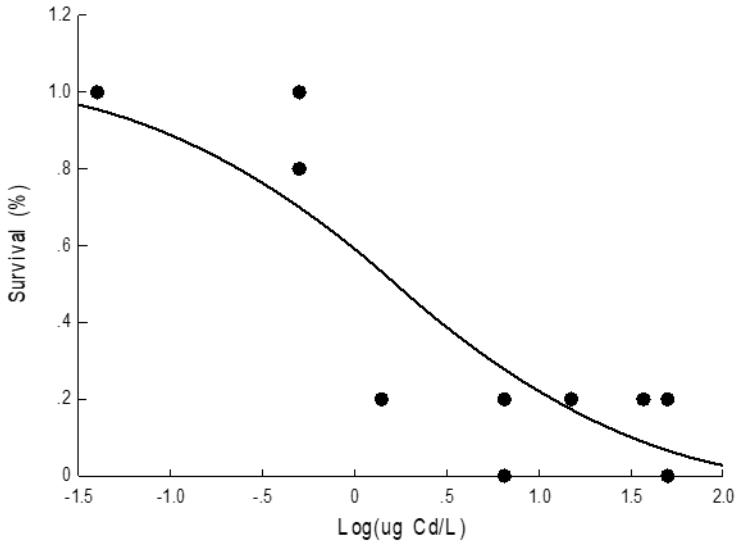
	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.35953	0.29166	5.6618	-15.428	16.011
S	2.1498	3.4794	273.75	-756.56	763.52
Y0	100	100	1.55	95.697	104.3

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.9573			5.6618	0.29166
20	1.5347			13.973	0.18603
10	1.3577			18.161	0.13279
5	1.2449			21.123	0.095143
0	1.0099			28.274	0.0042573

LC50:LC5 = 1.572

Notes: TRAP Flagged for IP (No Unique Solution).

Mebane et al. 2012	
Species: *Cottus confusus*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-100	
Test: test 16, LNF, H14	
Cd, (µg/L)	**Survivors**
0.04	5
0.04	5
0.5	5
0.5	4
1.4	1
1.4	1
6.5	0
6.5	1
15	1
15	1
37	1
37	1
50	1
50	0



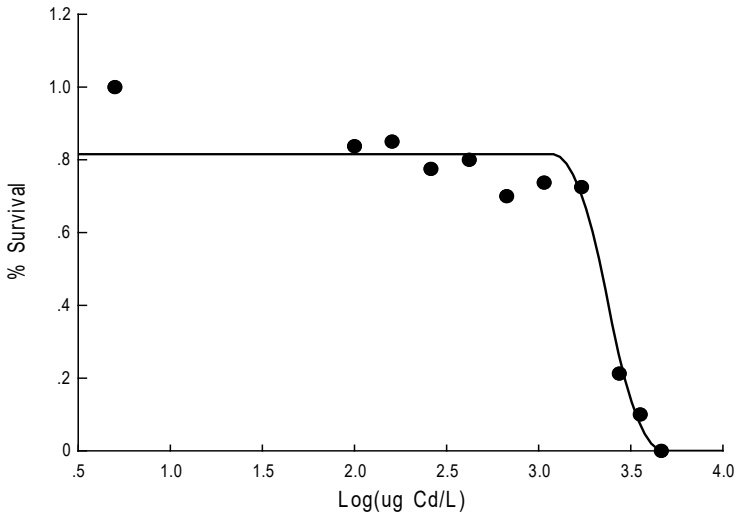
LC50:LC5 = 38.50

	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	0.09555	0.22168	0.40629	-0.68358	1.1269
StDev	0.48219	0.94663	0.33075	0.66143	1.6613
Y0	1	0.9999	0.16127	0.69134	1

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	1.666	0.20721	13.395	0.40629	0.22168
20	0.23412	0.005604	9.7811	0.68777	-0.63057
10	0.087077	0.000577	13.137	0.85815	-1.0601
5	0.043269	8.21E-05	22.81	0.99548	-1.3638
0	0.007997	1.03E-07	620.55	1.3679	-2.0971

Notes: Poor model fit.

Gungordu et al. 2010	
Species: *Xenopus laevis*	
Test Endpoint: 96 hr Survival	
C-R Curve Label: Cd-Acute-102	
Test: Single	
Cd, (µg/L)	**%Survival**
5	100
100	84
160	85
260	78
420	80
670	70
1070	74
1710	73
2740	21
3560	10
4630	0



	Initial	Final	S.E.	95% LCL	95% UCL
Log X50	3.3	3.3764	0.018487	3.3392	3.4137
StDev	0.2	0.123	0.012479	0.10267	0.15344
Y0	0.896	0.81534	0.016331	0.78083	0.84651

p	Xp	95% LCL	95% UCL	Log Xp SE	Log Xp
50	2379.3	2183.7	2592.4	0.018487	3.3764
20	1843.8	1620.6	2097.8	0.027526	3.2657
10	1621.4	1388.5	1893.5	0.032642	3.2099
5	1480.6	1242.9	1763.8	0.03637	3.1704
0	1189	947.02	1492.7	0.045288	3.0752

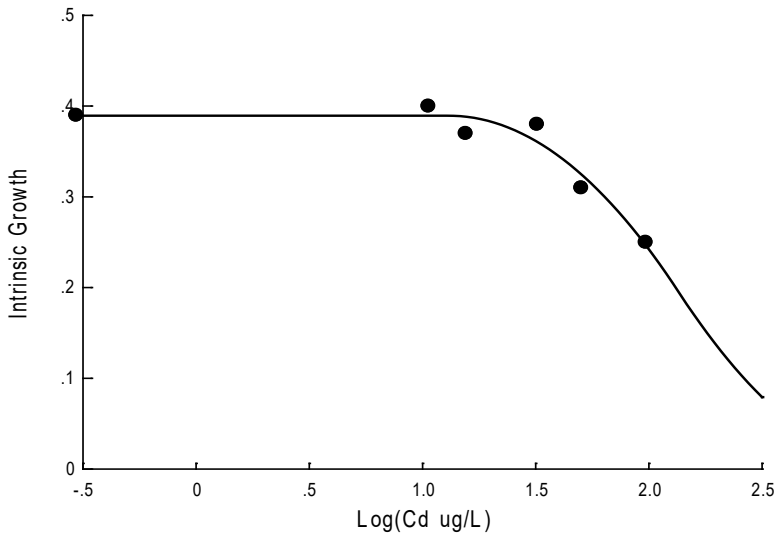
LC50:LC5 = 1.607

Notes: Poor model fit.

Appendix B.3

Test Information, C-R Data and Resulting TRAP models for Chronic Cadmium Toxicity Tests Acceptable for TAF and MAF Calculation

Niederlehner et al. 1984	
Species: *Aeolosoma headleyi*	
Test Endpoint: 14-d Intrinsic growth	
C-R Curve Label: Cd-Chronic-1	
Test: Single	
Cd, (µg/L)	**Intrinsic growth rate**
<0.5	0.39
10.6	0.40
15.5	0.37
32.0	0.38
50.2	0.31
96.7	0.25

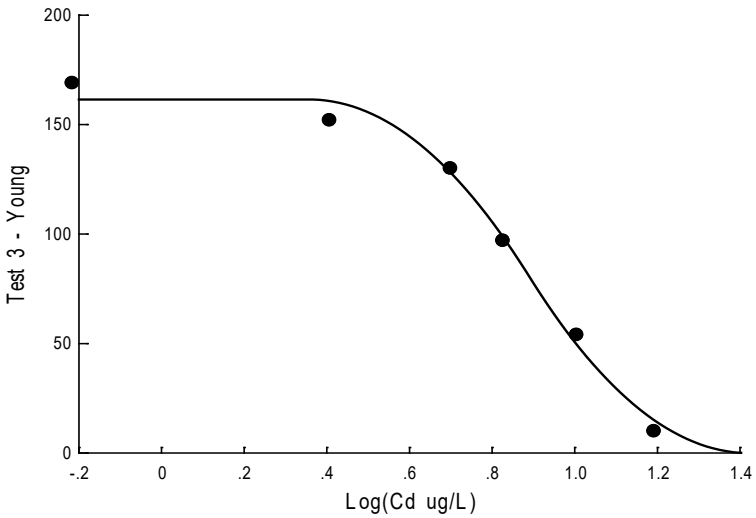


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	2.13	2.1324	0.082301	1.8705	2.3943
Slope	1	0.98324	0.26726	0.13271	1.8338
Y-intercept	0.395	0.38943	0.011694	0.35222	0.42665
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	135.64	74.208	247.91	0.082301	2.1324
20	**57.354**	34.803	94.518	0.068171	1.7586
10	37.168	16.996	81.278	0.10678	1.5702
5	**27.349**	9.8706	75.779	0.13908	1.4369
0	13.042	2.5619	66.39	0.22208	1.1153

EC20:EC5 = 2.097

Notes: Acceptable model fit.

Southwest Texas State University 2000	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 7-d Reproduction	
C-R Curve Label: Cd-Chronic-12	
Test: #3	
Cd, (µg/L)	**# Young**
0.5	169
2.55	152
5	130
6.7	97
10.1	54
15.55	10



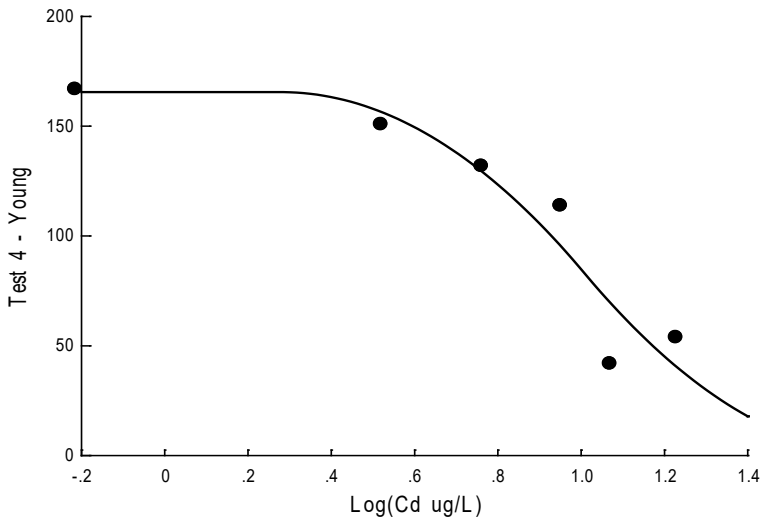
	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.9	0.88939	0.02306	0.816	0.96277
Slope	1.9	1.8781	0.25337	1.0717	2.6844
Y-intercept	169	161.48	6.0283	142.29	180.66

EC20:EC5 = 1.474

p	Xp	95% LCL	95% UCL	LogXp S.E.	LogXp
50	7.7515	6.5463	9.1785	0.02306	0.88939
20	**4.9395**	3.6743	6.6402	0.040378	0.69368
10	3.9359	2.5798	6.005	0.057649	0.59505
5	**3.352**	1.9064	5.8937	0.077012	0.5253
0	2.2747	0.87199	5.9338	0.13085	0.35692

Notes: Acceptable model fit.

Southwest Texas State University 2000	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 7-d Reproduction	
C-R Curve Label: Cd-Chronic-13	
Test: #4	
Cd, (µg/L)	**# Young**
0.5	167
3.3	151
5.75	132
8.9	114
11.7	42
16.85	54

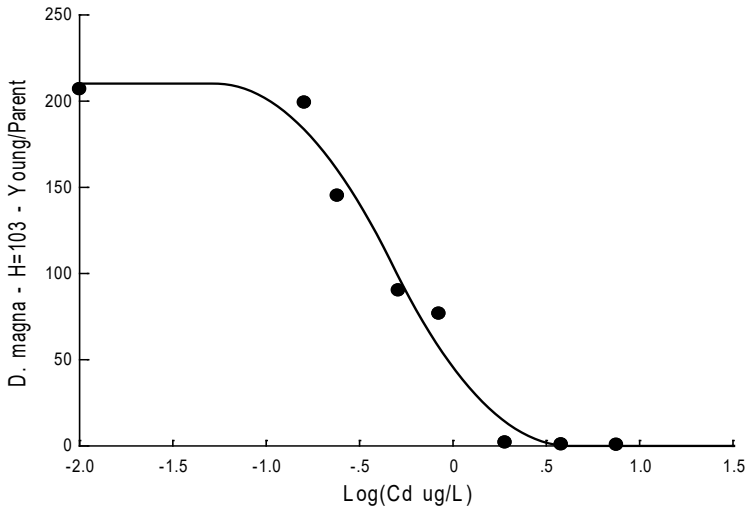


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	1	1.0092	0.079638	0.75576	1.2626
Slope	1.35	1.3692	0.54328	-0.35976	3.0981
Y-intercep	167	165.52	19.469	103.56	227.48
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	10.214	5.6985	18.308	0.079638	1.0092
20	**5.5051**	1.76	17.219	0.15562	0.74076
10	4.0315	0.83424	19.483	0.21498	0.60547
5	**3.2345**	0.45548	22.969	0.26751	0.5098
0	1.9004	0.068578	52.663	0.45332	0.27884

EC20:EC5 = 1.702

Notes: Acceptable model fit.

Chapman et al. Manuscript	
Species: *Daphnia magna*	
Test Endpoint: 21-d Reproduction	
C-R Curve Label: Cd-Chronic-15	
Test: Hardness = 103 mg/L	
Cd, (µg/L)	**Young/parent**
-	207
0.16	199.2
0.24	145.2
0.51	90.3
0.84	76.8
1.90	2.1
3.80	1
7.50	0.8

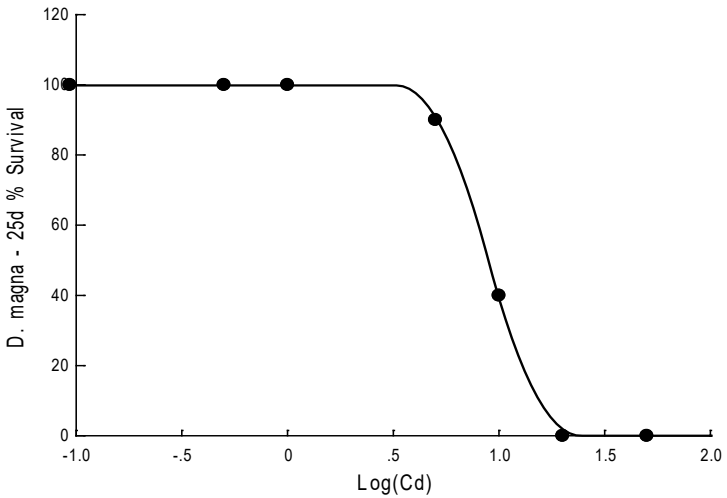


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	-0.325	-0.32427	0.061864	-0.48329	-0.16524
Slope	1.1	1.0504	0.19094	0.5596	1.5412
Y-intercept	207	210.17	14.098	173.93	246.41
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	0.47395	0.32863	0.68353	0.061864	-0.32427
20	**0.21175**	0.11276	0.39764	0.10646	-0.67417
10	0.14109	0.06259	0.31802	0.13731	-0.85052
5	**0.10587**	0.042666	0.26271	0.15354	-0.97522
0	0.052934	0.018215	0.15383	0.18023	-1.2763

EC20:EC5 = 2.000

Notes: Acceptable model fit. Large SE (x50).

Bodar et al. 1988b	
Species: *Daphnia magna*	
Test Endpoint: 25-d Survival	
C-R Curve Label: Cd-Chronic-17	
Test: Single	
Cd, (µg/L)	**% Survival**
control	100
0.5	100
1	100
5	90
10	40
20	0
50	0

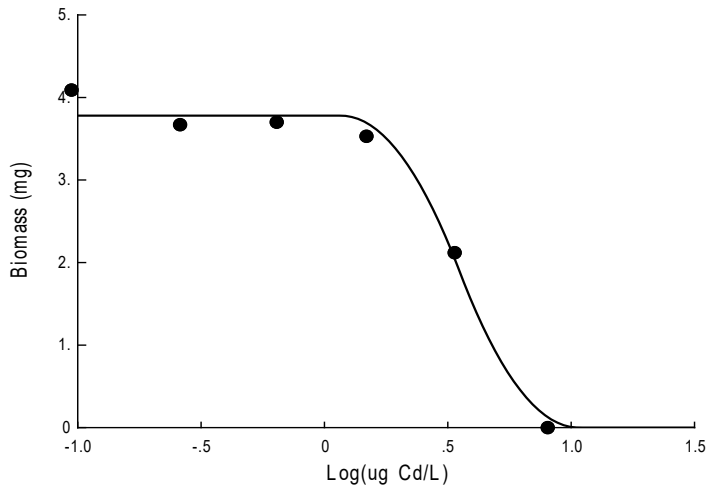


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.85036	0.95019	0.005423	0.93513	0.96525
Slope	1.121	2.2941	0.090326	2.0433	2.5449
Y-intercept	100	99.833	0.65055	98.027	101.64
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	8.9164	8.6126	9.231	0.005423	0.95019
20	**6.1656**	5.8041	6.5496	0.009451	0.78998
10	5.1195	4.7177	5.5555	0.012785	0.70923
5	**4.4888**	4.0867	4.9305	0.014681	0.65213
0	3.268	2.9273	3.6484	0.017224	0.51428

EC20:EC5 = 1.374

Notes: Acceptable model fit.

Brinkman 2012	
Species: *Oncorhynchus clarkii virginalis*	
Test Endpoint: ELS Biomass	
C-R Curve Label: Cd-Chronic-24	
Test: Single	
Cd, (µg/L)	**Biomass (g)**
<0.10 (0.05)	4.09
0.26	3.67
0.64	3.70
1.48	3.53
3.37	2.12
8.03	0.00



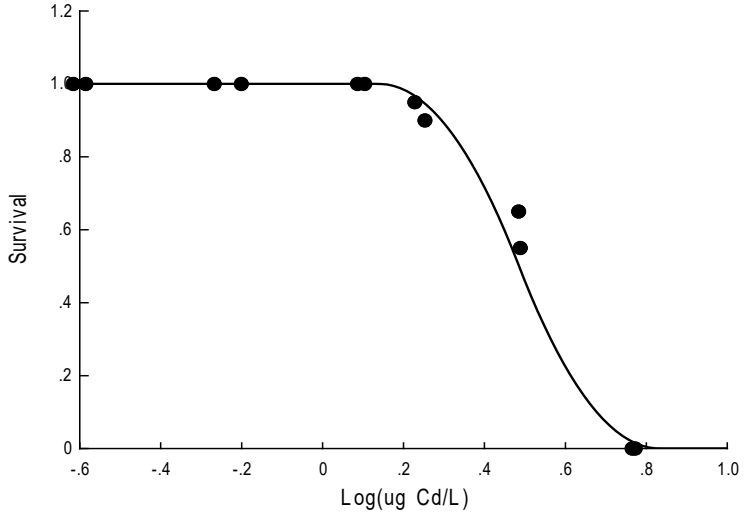
	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.5	0.54847	0.031212	0.44914	0.6478
Slope	2	2.0799	0.52697	0.40282	3.7569
Y-intercept	3.82	3.7784	0.12755	3.3725	4.1843

EC20:EC5 = 1.419

p	Xp	95% LCL	95% UCL	LogXp S.E.	LogXp
50	3.5357	2.8128	4.4443	0.031212	0.54847
20	**2.3537**	1.4878	3.7237	0.062599	0.37176
10	1.9173	0.86897	4.2304	0.10799	0.28269
5	**1.6585**	0.6207	4.4315	0.13412	0.21971
0	1.1686	0.50516	2.7034	0.11445	0.067672

Notes: Acceptable noise at low level effects.

Davies et al. 1993	
Species: *Oncorhynchus mykiss*	
Test Endpoint: LC Survival	
C-R Curve Label: Cd-Chronic-26	
Test: Hardness = 46 mg/L	
Cd, (µg/L)	**Proportion Surviving**
0.22	1.0
0.26	1.0
0.63	1.0
0.54	1.0
1.27	1.0
1.22	1.0
1.69	1.0
1.79	0.9
3.05	0.7
3.08	0.6
5.92	0.0
5.82	0.0

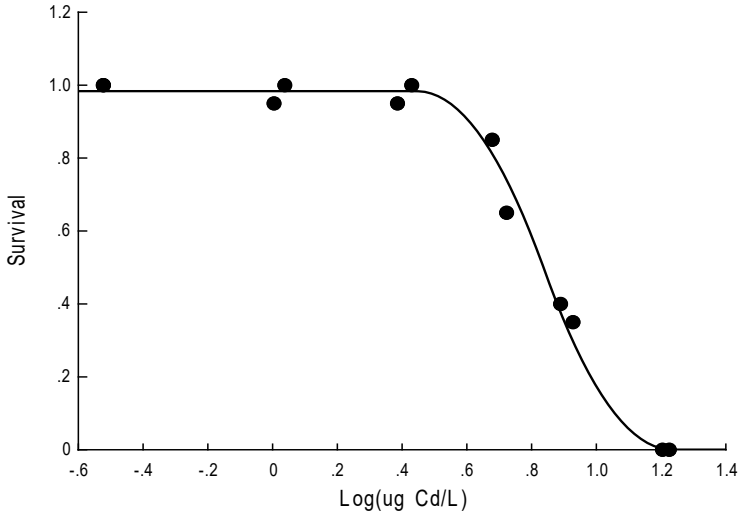


EC20:EC5 = 1.287

	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.5	0.48576	0.01931	0.44704	0.52449
StDev	0.15	0.14137	0.014451	0.11787	0.17668
Y-intercept	1	0.9999	0.00091277	0.96953	1
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	3.0603	2.7993	3.3457	0.01931	0.48576
20	**2.2829**	2.0405	2.5541	0.024059	0.35849
10	1.9694	1.7197	2.2553	0.028665	0.29434
5	**1.7741**	1.5208	2.0696	0.032161	0.24898
0	1.3787	1.1206	1.6963	0.041426	0.13947

Notes: Acceptable model fit.

Davies et al. 1993	
Species: *Oncorhynchus mykiss*	
Test Endpoint: LC Survival	
C-R Curve Label: Cd-Chronic-27	
Test: Hardness = 200 mg/L	
Cd, (µg/L)	**Proportion Surviving**
0.30	1.0
0.30	1.0
1.01	1.0
1.09	1.0
2.69	1.0
2.43	1.0
5.28	0.7
4.77	0.9
8.47	0.4
7.75	0.4
16.8	0.0
16.0	0.0



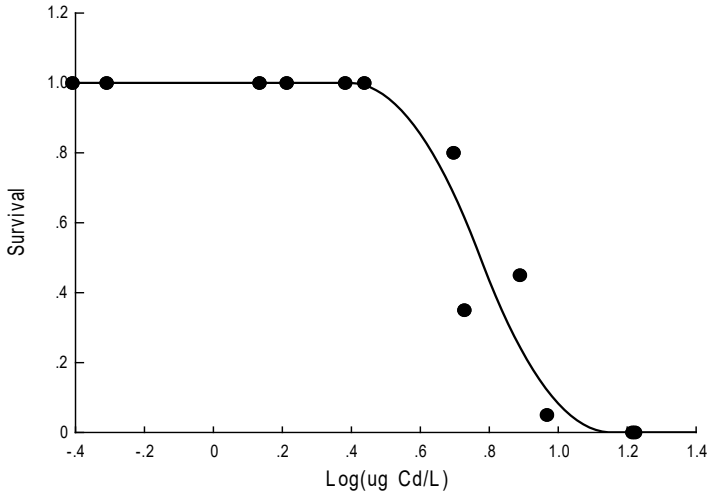
EC20:EC5 = 1.333

	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.85	0.84004	0.025422	0.78867	0.89142
StDev	0.16	0.16098	0.019872	0.12977	0.21208
Y-intercept	0.98	0.98323	0.011716	0.94097	0.99794

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	6.919	6.147	7.7878	0.025422	0.84004
20	**4.9558**	4.1756	5.8818	0.036247	0.69511
10	4.1886	3.4002	5.1599	0.04326	0.62207
5	**3.719**	2.9301	4.7202	0.04851	0.57042
0	2.7908	2.0257	3.8449	0.061068	0.44573

Notes: Acceptable model fit.

Davies et al. 1993	
Species: *Oncorhynchus mykiss*	
Test Endpoint: LC Survival	
C-R Curve Label: Cd-Chronic-28	
Test: Hardness = 400 mg/L	
Cd, (µg/L)	**Proportion Surviving**
0.49	1.0
0.39	1.0
1.63	1.0
1.36	1.0
2.41	1.0
2.74	1.0
4.97	0.8
5.34	0.4
7.74	0.5
9.27	0.1
16.4	0.0
16.7	0.0



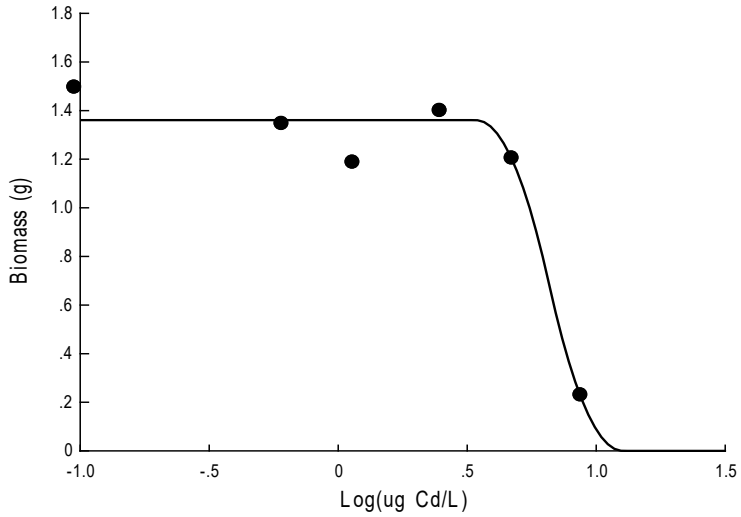
EC20:EC5 = 1.319

	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.75	0.77453	0.023732	0.72666	0.8224
StDev	0.15	0.15503	0.021917	0.12159	0.21398
Y-intercept	1	0.9999	0.00099961	0.9636	1

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	5.9501	5.3291	6.6435	0.023732	0.77453
20	**4.3147**	3.7659	4.9436	0.028703	0.63495
10	3.6695	3.0896	4.3583	0.035351	0.56461
5	**3.2724**	2.6674	4.0146	0.040953	0.51487
0	2.4819	1.8272	3.3711	0.056206	0.39478

Notes: Acceptable model fit.

Brinkman and Hansen 2004a; 2007	
Species: *Salmo trutta*	
Test Endpoint: ELS Biomass	
C-R Curve Label: Cd-Chronic-42	
Test: Hardness = 75 mg/L	
Dissolved Cd, (µg/L)	**Biomass (g)**
<0.1 (0.05)	1.499
0.60	1.349
1.13	1.190
2.46	1.403
4.68	1.207
8.64	0.233

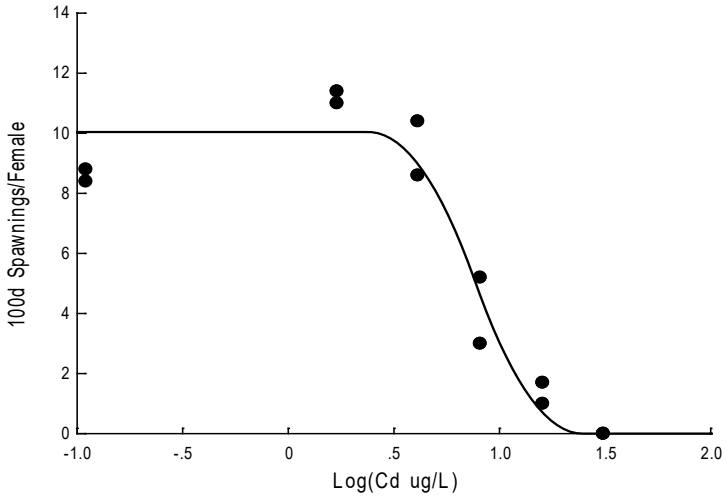


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.82	0.81905	0.038277	0.69723	0.94086
Slope	3.5	3.5303	1.0087	0.32009	6.7405
Y-intercep	1.37	1.3602	0.064673	1.1544	1.5661
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	6.5925	4.98	8.7269	0.038277	0.81905
20	**5.1872**	3.525	7.6334	0.052721	0.71494
10	4.5969	2.8782	7.3419	0.063896	0.66246
5	**4.2205**	2.4502	7.2698	0.074208	0.62536
0	3.4339	0	Infinity	28.36	0.53579

EC20:EC5 = 1.229

Notes: Acceptable noise at low level effects.

Spehar 1976	
Species: *Jordanella floridae*	
Test Endpoint: LC Reproduction	
C-R Curve Label: Cd-Chronic-48	
Test: Single	
Cd, (µg/L)	**Spawnings/female (100 d)**
0.11	8.8
0.11	8.4
1.7	11
1.7	11.4
4.1	10.4
4.1	8.6
8.1	5.2
8.1	3.0
16	1.7
16	1.0
31	0
31	0



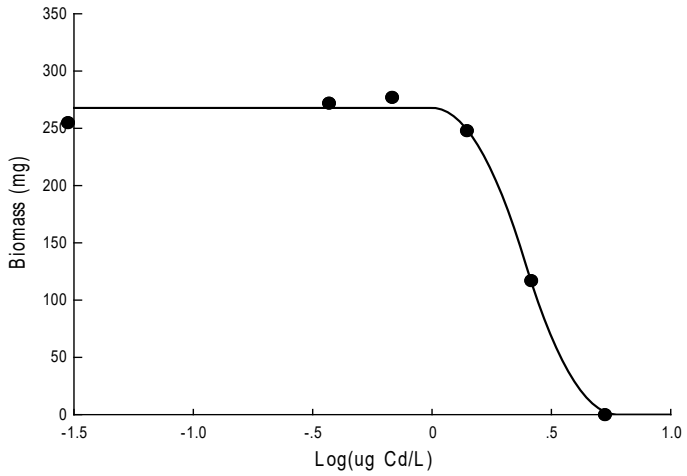
	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.9	0.88684	0.043807	0.78774	0.98594
Slope	2	1.9731	0.52585	0.78358	3.1627
Y-intercept	10	10.041	0.59217	8.701	11.38

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	7.7062	6.134	9.6814	0.043807	0.88684
20	**5.0184**	3.3774	7.4568	0.076028	0.70056
10	4.0428	2.3157	7.0582	0.10698	0.60668
5	**3.4697**	1.7093	7.0432	0.13592	0.5403
0	2.399	0.96362	5.9725	0.17511	0.38003

EC20:EC5 = 1.446

Notes: Acceptable noise at low level effects.

Besser et al. 2007	
Species: *Cottus bairdii*	
Test Endpoint: ELS Biomass	
C-R Curve Label: Cd-Chronic-52	
Test: 28-d	
Cd, (µg/L)	**Biomass (mg)**
<0.04 (0.02)	255
0.37	272
0.68	277
1.4	248
2.6	117
5.3	0

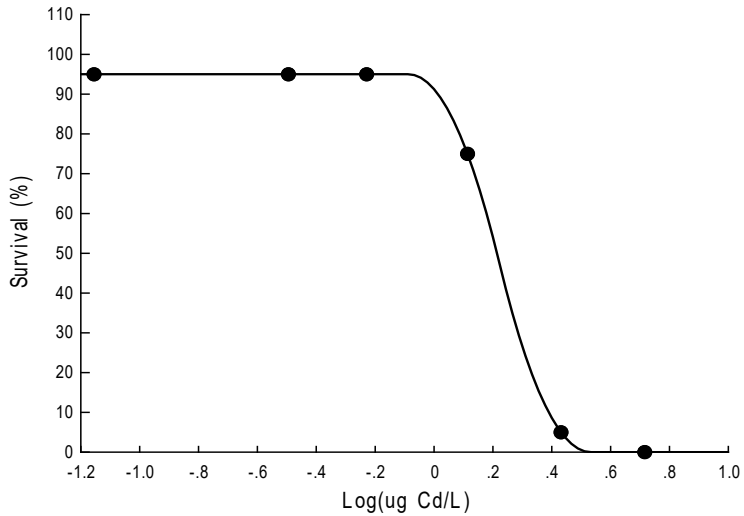


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.4	0.38853	0.014746	0.34161	0.43546
Slope	2.5	2.5793	0.3663	1.4136	3.7451
Y-intercept	268	267.79	5.4646	250.4	285.18
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	2.4464	2.1959	2.7256	0.014746	0.38853
20	**1.7621**	1.4403	2.1559	0.027523	0.24604
10	1.4935	1.1413	1.9545	0.036708	0.17422
5	**1.3287**	0.98826	1.7865	0.040399	0.12344
0	1.0019	0.70124	1.4316	0.048696	0.000837

EC20:EC5 = 1.326

Notes: Acceptable model fit.

Besser et al. 2007	
Species: *Cottus bairdii*	
Test Endpoint: ELS Survival	
C-R Curve Label: Cd-Chronic-53	
Test: 21-d	
Cd, (µg/L)	**% Survival**
0.07	95
0.32	95
0.59	95
1.3	75
2.7	5
5.2	0



	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.2	0.2225	0	0.2225	0.2225
Slope	3	3.2344	0	3.2344	3.2344
Y-intercept	95	95	0	95	95
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	1.6692	1.6692	1.6692	0	0.2225
20	**1.2849**	1.2849	1.2849	0	0.10886
10	1.1261	1.1261	1.1261	0	0.051592
5	**1.0259**	1.0259	1.0259	0	0.011094
0	0.81908	0.81908	0.81908	0	-0.08668

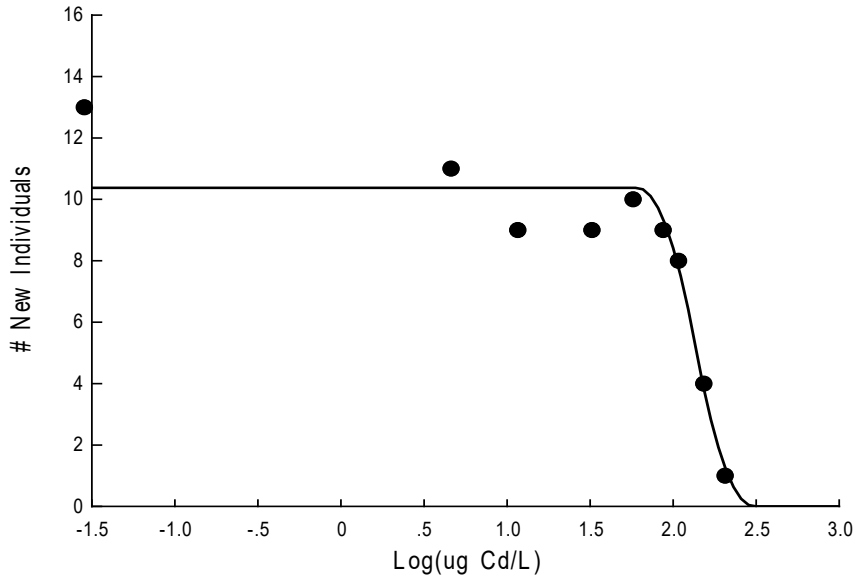
EC20:EC5 = 1.252

Notes: Acceptable model fit.

Appendix B.4

Test Information, C-R Data and Resulting TRAP models for Chronic Cadmium Toxicity Tests Unacceptable for TAF and MAF Calculation

Straus 2011	
Species: *Lumbriculus variegatus*	
Test Endpoint: 28-d LC Reproduction	
C-R Curve Label: Cd-Chronic-2	
Test: Single	
Cd, (µg/L)	**# of new individuals**
Control	13
4.6	11
11.6	9
32.4	9
57.4	10
86.9	9
107.6	8
153	4
205.3	1



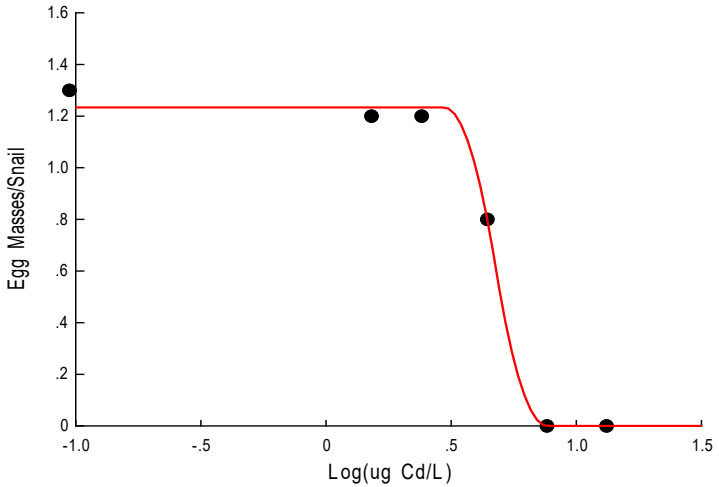
	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	2.1	2.1352	3.95E-02	2.0387	2.2318
Slope	2.8	2.8505	0.93253	0.56869	5.1323
Y-intercept	10.4	10.371	0.61422	8.8685	11.874

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	136.54	109.32	170.52	0.03945	2.1352
20	**101.46**	72.204	142.58	0.06038	2.0063
10	87.362	55.342	137.91	0.081028	1.9413
5	**78.59**	44.228	139.65	0.10204	1.8954
0	60.874	20.152	183.88	0.19621	1.7844

EC20:EC5 = 1.291

Notes: No effect within area of concern.

Holcombe et al. 1984	
Species: *Aplexa hypnorum*	
Test Endpoint: 26-d LC Reproduction	
C-R Curve Label: Cd-Chronic-3	
Test: Single (Tanks A&B)	
Cd, (µg/L)	**#egg masses/#snails**
<0.1	1.3
1.52	1.2
2.41	1.2
4.41	0.8
7.63	0
13.2	0

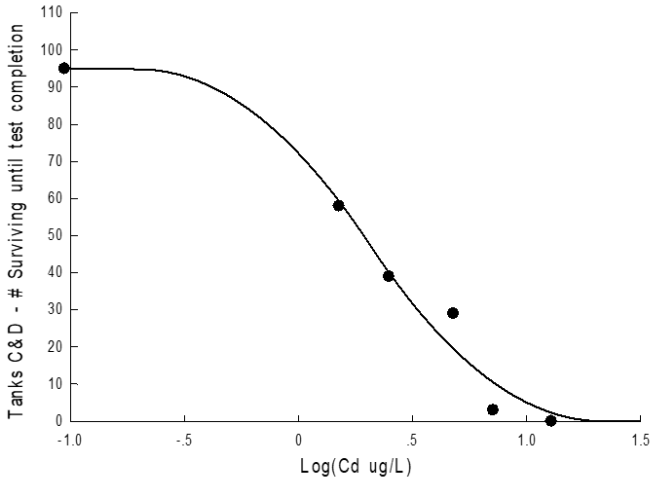


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.64316	0.67759	3.1227	-9.2602	10.615
Slope	1.7	4.878	459.43	-1457.2	1467
Y-intercept	1.2333	1.2333	0.027217	1.1467	1.3199
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	4.7598	5.4932E-10	41244000000	3.1227	0.67759
20	**4.0017**	3.5081	4.5647	0.017964	0.60225
10	3.6667	3.2057	4.1939	0.018336	0.56427
5	**3.4468**	3.0077	3.9501	0.018599	0.53742
0	2.9689	2.5636	3.4382	0.020028	0.47259

EC20:EC5 = 1.161

Notes: TRAP flagged for IP (No Unique Solution). Large SE for X50 and slope.

Holcombe et al. 1984	
Species: *Aplexa hypnorum*	
Test Endpoint: 26-d LC Reproduction	
C-R Curve Label: Cd-Chronic-4	
Test: Single (Tanks C&D)	
Cd, (µg/L)	**Total # of survivors**
<0.1	95
1.51	58
2.50	39
4.79	29
7.17	3
12.9	0

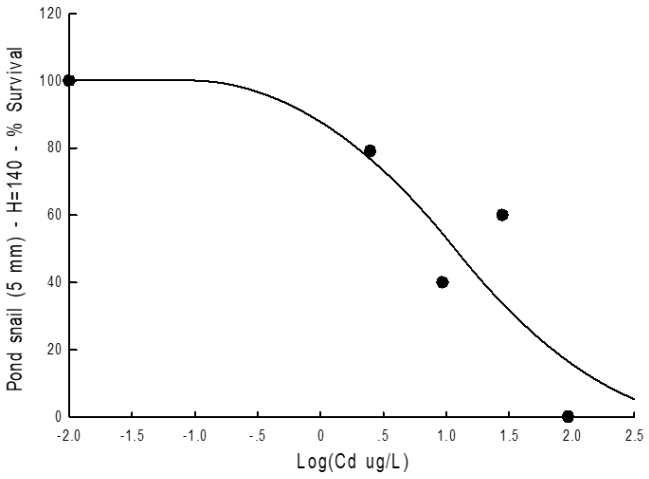


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.32	0.31565	0.07197	0.086613	0.54469
Slope	1	0.98192	0.21124	0.30965	1.6542
Y-intercept	95	94.825	7.1302	72.133	117.52
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	2.0685	1.2207	3.505	0.07197	0.31565
20	**0.87365**	0.30703	2.486	0.14271	-0.05866
10	0.56583	0.11887	2.6934	0.21292	-0.24731
5	**0.41619**	0.053424	3.2422	0.28015	-0.38071
0	0.19826	0.024346	1.6145	0.2862	-0.70276

EC20:EC5 = 2.099

Notes: No effect within area of concern.

Pais 2012	
Species: *Lymnaea stagnalis*	
Test Endpoint: 31-d Growth	
C-R Curve Label: Cd-Chronic-5	
Test: 5 mm snails	
Cd, (µg/L)	**% Survival**
0.00	100
2.50	79
9.43	40
28.3	60
94.3	0

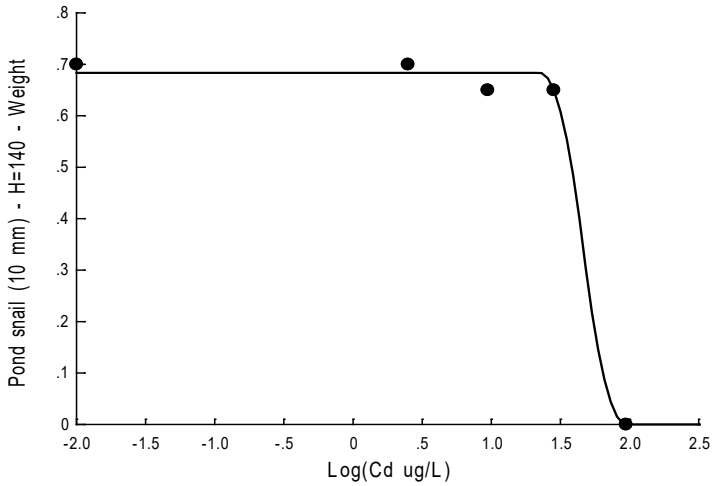


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	1.1	1.0697	0.46395	-0.92648	3.0659
Slope	0.5	0.47055	0.34276	-1.0042	1.9453
Y-intercept	100	100.14	23.973	-3.0072	203.28
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	11.741	0.11845	1163.9	0.46395	1.0697
20	**1.9437**	0.00034597	10920	0.87146	0.28863
10	0.78515	4.3007E-06	143340	1.2228	-0.10505
5	**0.4136**	7.0398E-08	2430000	1.5732	-0.38341
0	0.088013	9.2686E-15	8.3576E+11	3.0162	-1.0555

EC20:EC5 = 4.699

Notes: No effect within area of concern. Large SE for X50 and slope.

Pais 2012	
Species: *Lymnaea stagnalis*	
Test Endpoint: 31-d Growth	
C-R Curve Label: Cd-Chronic-6	
Test: 10 mm snails	
Cd, (µg/L)	**Weight (g)**
0.00	0.7
2.50	0.7
9.43	0.65
28.3	0.65
94.3	- (0)



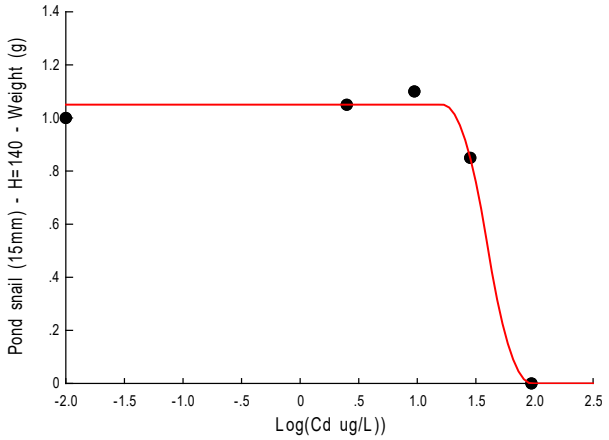
	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	1.7	1.6649	7.03E+00	-2.86E+01	31.914
Slope	2.6	3.2271	1.06E+02	-4.55E+02	4.61E+02
Y-intercept	0.7	0.68333	1.67E-02	6.12E-01	7.55E-01

p	Xp	95% LCL	95% UCL	LogXp S.E.	LogXp
50	46.23	0.00	8.E+31	7.03	1.66
20	**35.56**	22.60	55.95	0.05	1.55
10	31.16	20.10	48.30	0.04	1.49
5	**28.38**	17.69	45.52	0.05	1.45
0	22.65	12.87	39.84	0.06	1.36

EC20:EC5 = 1.253

Notes: Poor model fit at low level effects and lack of necessary partials to further evaluate acceptance of model fit.

Pais 2012	
Species: *Lymnaea stagnalis*	
Test Endpoint: 31-d Growth	
C-R Curve Label: Cd-Chronic-7	
Test: 15 mm snails	
Cd, (µg/L)	**Weight (g)**
0.00	1.00
2.50	1.05
9.43	1.10
28.3	0.85
94.3	- (0)

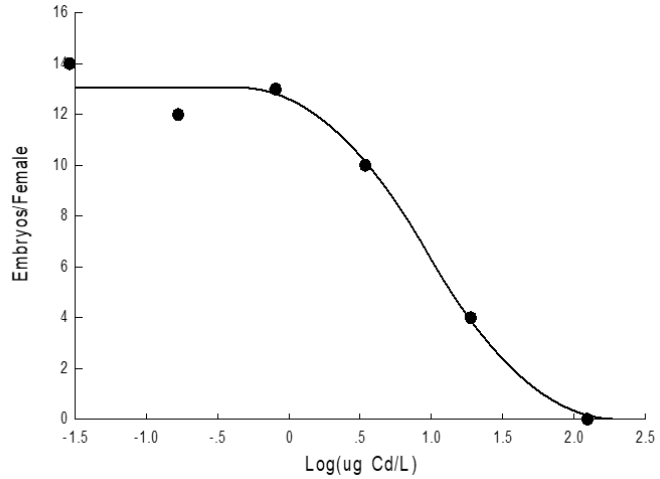


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	1.6	1.5966	4.5275	-17.883	21.077
Slope	2.5	2.6432	82.635	-352.91	358.19
Y-intercept	1.05	1.05	0.028868	0.92579	1.1742
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	39.501	1.3077E-18	1.1931E+21	4.5275	1.5966
20	**28.678**	20.903	39.346	0.031921	1.4576
10	24.405	16.791	35.471	0.037746	1.3875
5	**21.773**	14.441	32.827	0.041443	1.3379
0	16.53	10.156	26.905	0.049169	1.2183

EC20:EC5 = 1.317

Notes: TRAP flagged for IP (No unique solution); large SE for X50 and slope.

Pais 2012	
Species: *Potamopyrgus antipodarum*	
Test Endpoint: 28-d Reproduction	
C-R Curve Label: Cd-Chronic-8	
Test: Single	
Cd, (µg/L)	**Total embryos/female**
0.017	14
0.167	12
0.806	13
3.44	10
18.9	4
125.0	0

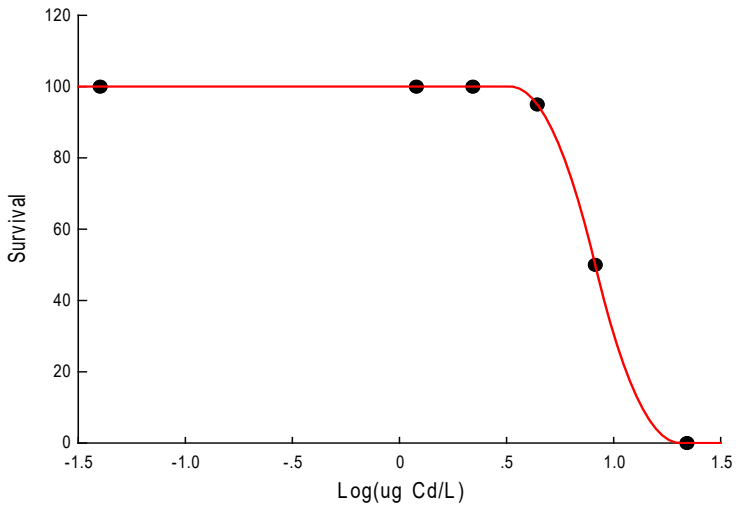


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.95	0.97564	0.092418	0.68152	1.2698
Slope	0.7	0.75559	0.1543	0.26452	1.2467
Y-intercept	15	13.053	0.54729	11.311	14.795
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	9.4545	4.8031	18.61	0.092418	0.97564
20	**3.0846**	1.0331	9.2103	0.14928	0.4892
10	1.7541	0.41306	7.4486	0.19734	0.24404
5	**1.1768**	0.22673	6.1075	0.22473	0.070686
0	0.44892	0.070714	2.8499	0.25222	-0.34783

EC20:EC5 = 2621

Notes: Not core data.

Wang et al. 2010d	
Species: *Lampsilis siliquoidea*	
Test Endpoint: 28-d juvenile survival	
C-R Curve Label: Cd-Chronic-9	
Test: single	
Cd, (µg/L)	**% Survival**
0.04	100
1.2	100
2.2	100
4.4	95
8.2	50
22	0

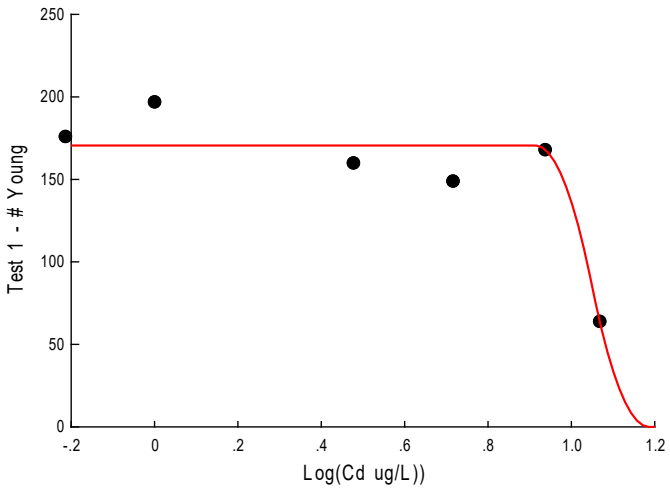


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.94562	0.91381	0	0.91381	0.91381
Slope	2.5241	2.5291	0	2.5291	2.5291
Y-intercept	98.75	100	0	100	100
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E**	**LogXp**
50	8.2	8.2	8.2	0	0.91381
20	**5.868**				0.76849
10	4.9573				0.69524
5	**4.4**				0.64345
0	3.2993				0.51842

EC20:EC5 = 1.334

Notes: TRAP flagged for IP (No Unique Solution).

Southwest Texas State University 2000	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 7-d Reproduction	
C-R Curve Label: Cd-Chronic-10	
Test: #1	
Cd, (µg/L)	**# Young**
0.5	176
1	197
3	160
5.2	149
8.65	168
11.7	64

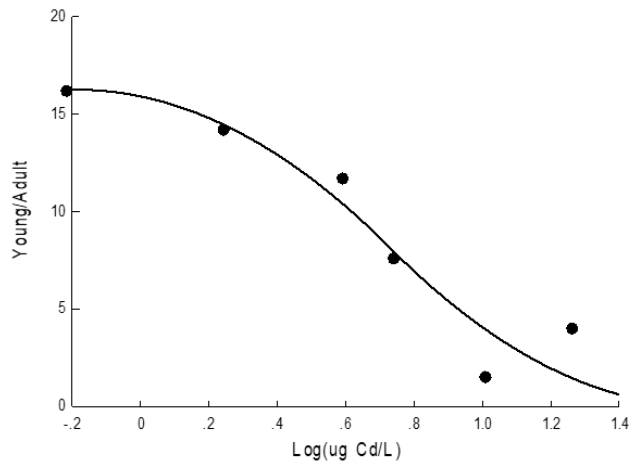


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	1	1.05	0.023475	0.97525	1.1247
Slope	7	7.3275	6.0398	-11.894	26.549
Y-intercept	170	170.51	10.428	137.32	203.7
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	11.219	9.4461	13.325	0.023475	1.05
20	**9.9954**	6.5386	15.28	0.057915	0.9998
10	9.4302	5.3338	16.673	0.077765	0.97452
5	**9.0499**	4.6101	17.766	0.092047	0.95664
0	8.1939	3.2155	20.88	0.12765	0.91349

EC20:EC5 = 1.104

Notes: TRAP flagged – IP (No unique solution); large SE for slope.

Southwest Texas State University 2000	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 7-d Reproduction	
C-R Curve Label: Cd-Chronic-11	
Test: #2	
Cd, (µg/L)	**# Young**
0.5	162
1.75	142
3.9	117
5.5	68
10.2	6
18.3	4

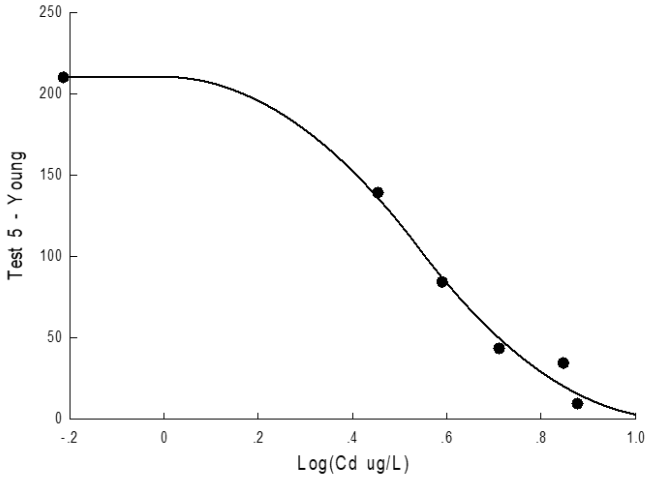


	Initial Guess	Final Est.	Standard I	95% LCL	95% HCL
Log X50	0.66893	0.73017	0.10933	0.38224	1.0781
Slope	1.3747	1.0872	0.39203	-0.16045	2.3348
Y-intercept	16.2	16.259	2.0781	9.6452	22.872
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	5.3724	2.4112	11.97	0.10933	0.73017
20	**2.4666**	0.57323	10.614	0.19914	0.39209
10	1.6661	0.21447	12.943	0.27977	0.2217
5	**1.2625**	0.088843	17.94	0.36217	0.10122
0	0.64616	0.0093279	44.761	0.57835	-0.18966

EC20:EC5 = 1.954

Notes: No effect within area of concern.

Southwest Texas State University 2000	
Species: *Ceriodaphnia dubia*	
Test Endpoint: 7-d Reproduction	
C-R Curve Label: Cd-Chronic-14	
Test: #5	
Cd, (µg/L)	**# Young**
0.5	210
2.85	139
3.9	84
5.15	43
7.05	34
7.55	9



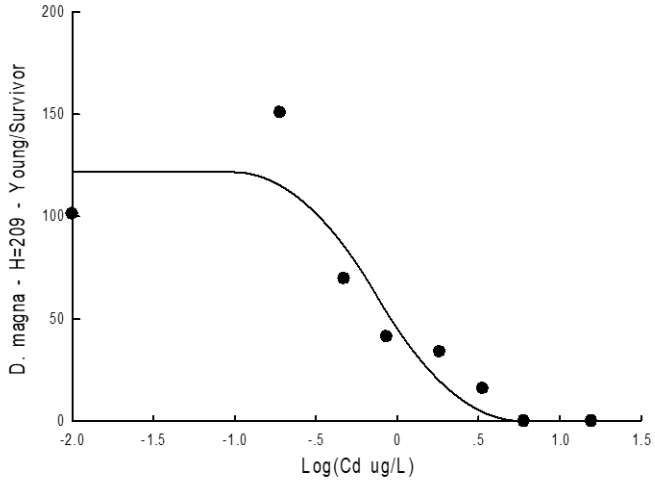
	Initial Guess	Final Est.	Standard I	95% LCL	95% HCL
Log X50	0.55	0.54004	0.024311	0.46267	0.61741
Slope	1.8	1.8368	0.23609	1.0854	2.5881
Y-intercept	210	210.66	9.9033	179.14	242.18

EC20:EC5 = 1.487

p	Xp	95% LCL	95% UCL	LogXp S.E.	LogXp
50	3.4677	2.9018	4.1439	0.024311	0.54004
20	**2.1874**	1.5563	3.0745	0.046456	0.33994
10	1.7341	1.0562	2.8473	0.067666	0.23909
5	**1.4715**	0.73805	2.934	0.094169	0.16777
0	0.98994	0.3746	2.6161	0.13261	-0.00439

Notes: No effect within area of concern.

Chapman et al. Manuscript	
Species: *Daphnia magna*	
Test Endpoint: 21-d Reproduction	
C-R Curve Label: Cd-Chronic-16	
Test: Hardness = 209 mg/L	
Cd, (µg/L)	**Young/parent**
-	82.2
0.19	134.2
0.47	22.6
0.86	34.2
1.82	4.3
3.35	2.9
6.00	1.2
15.60	0.0

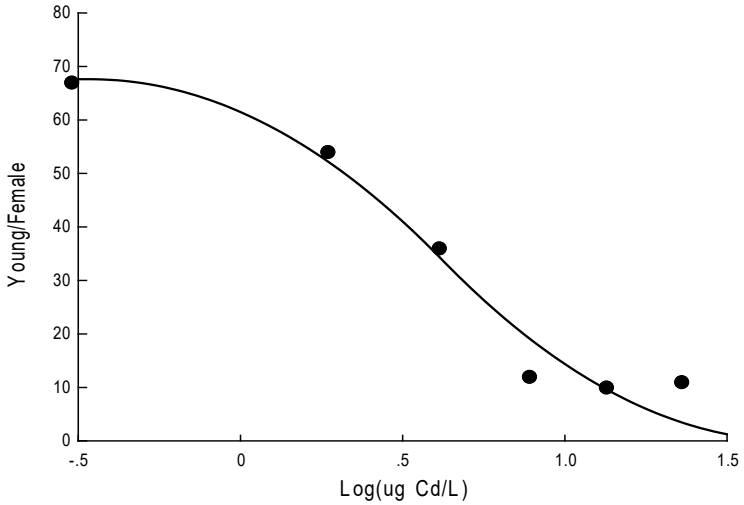


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	-0.12	-0.12416	0.15621	-0.52572	0.2774
Slope	1.1	1.1266	0.56177	-0.31751	2.5707
Y-intercep	126.2	121.71	20.027	70.229	173.19
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	0.75134	0.29804	1.8941	0.15621	-0.12416
20	**0.35448**	0.068002	1.8478	0.27895	-0.45041
10	0.24275	0.02393	2.4625	0.39144	-0.61484
5	**0.18574**	0.0098186	3.5135	0.49671	-0.73111
0	0.097319	0.0030566	3.0985	0.58467	-1.0118

EC20:EC5 = 1.909

Notes: Unacceptable noise at low level effects. Large SE for X50 and slope.

Borgmann et al. 1989a; b	
Species: *Daphnia magna*	
Test Endpoint: 21-d Reproduction	
C-R Curve Label: Cd-Chronic-18	
Test: Single	
Cd, (µg/L)	**Young/female**
0.22	67
1.86	54
4.1	36
7.78	12
13.43	10
22.92	11



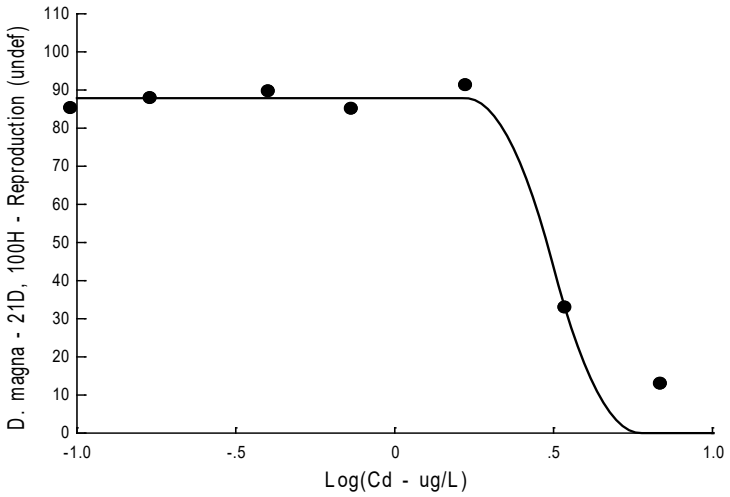
	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.6	0.62274	0.090629	0.33432	0.91116
Slope	0.9	0.92243	0.216	0.23501	1.6099
Y-intercept	67	67.591	6.0477	48.345	86.837

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	4.1951	2.1593	8.1501	0.090629	0.62274
20	**1.6761**	0.50741	5.5363	0.16306	0.22429
10	1.0555	0.19586	5.6885	0.22986	0.023472
5	**0.76115**	0.084645	6.8445	0.29973	-0.11853
0	0.34566	0.018815	6.3506	0.39723	-0.46135

EC20:EC5 = 2.202

Notes: No effect within area of concern.

Chadwick Ecological Consultants 2003	
Species: *Daphnia magna*	
Test Endpoint: 21-d Reproduction	
C-R Curve Label: Cd-Chronic-19	
Test: Hardness = 100 mg/L	
Cd, (µg/L)	**Undefined**
0.07	85.3
0.17	87.9
0.4	89.7
0.73	85.1
1.67	91.3
3.43	33
6.85	13

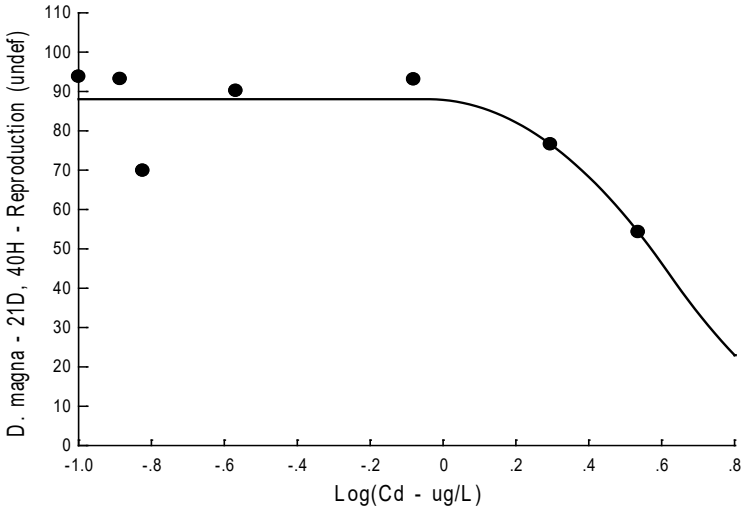


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	1	0.99662	0.12882	0.63896	1.3543
Slope	0.7	0.71766	0.27003	-0.032073	1.4674
Y-intercept	54	53.318	4.45	40.963	65.673
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	9.9224	4.3547	22.609	0.12882	0.99662
20	**3.0512**	0.69454	13.405	0.23151	0.48448
10	1.6841	0.2083	13.615	0.32692	0.22636
5	**1.1062**	0.081801	14.96	0.40738	0.043839
0	0.40105	0.0060252	26.695	0.65668	-0.3968

EC20:EC5 = 1.222

Notes: Poor model fit at high effect concentrations and lack of partials around area of concern.

Chadwick Ecological Consultants 2003	
Species: *Daphnia magna*	
Test Endpoint: 21-d Reproduction	
C-R Curve Label: Cd-Chronic-20	
Test: Hardness = 50 mg/L	
Cd, (µg/L)	**Undefined**
0.1	93.8
0.13	93.2
0.15	69.9
0.27	90.2
0.83	93.1
1.97	76.6
3.43	54.3

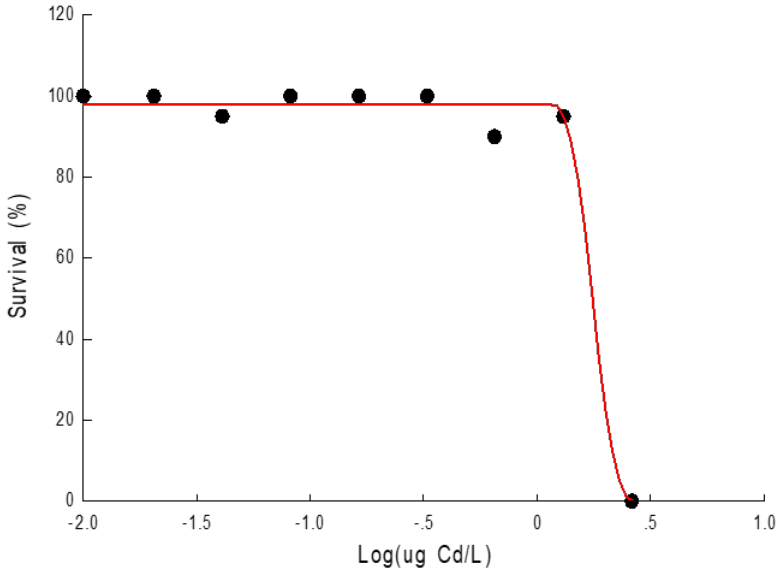


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.62	0.6173	1.29E-01	2.60E-01	0.97413
Slope	1.5	1.5183	1.12E+00	-1.58E+00	4.62E+00
Y-intercept	88.04	88.04	4.5778	75.33	100.75
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	4.1428	1.82E+00	9.42E+00	1.29E-01	0.6173
20	**2.3726**	1.1437	4.922	1.14E-01	3.75E-01
10	1.7915	0.53889	5.9558	1.88E-01	2.53E-01
5	**1.4688**	0.30368	7.1038	2.47E-01	1.67E-01
0	0.90924	7.31E-02	11.311	3.94E-01	-4.13E-02

EC20:EC5 = 1.615

Notes: Unacceptable noise at low level effects. Large SE for slope.

Jemec et al 2008	
Species: *Daphnia magna*	
Test Endpoint: 21-d Survival	
C-R Curve Label: Cd-Chronic-21	
Test: Single	
Cd, (µg/L)	**% Survival**
0	100
0.0205	100
0.041	95
0.082	100
0.164	100
0.328	100
0.65	90
1.31	95
2.62	0



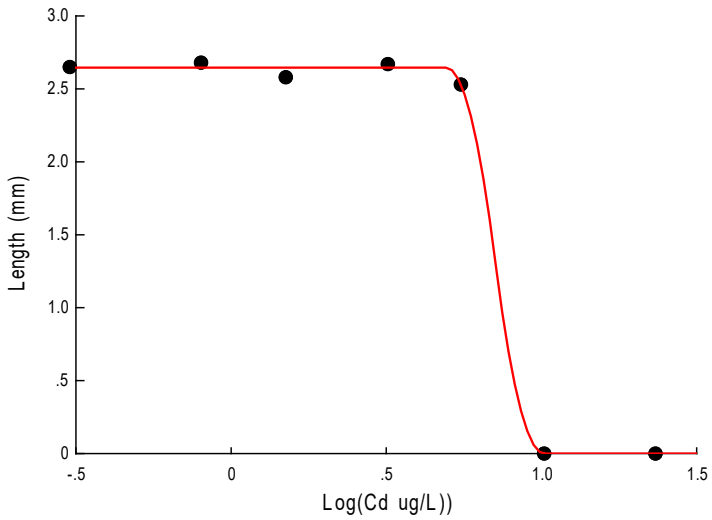
	Initial Guess	Final Est.	Standard Err	95% LCL	95% HCL
Log X50	0.25	0.24723	1.6804	-3.8645	4.359
Slope	5	5.8352	75.447	-178.78	190.45
Y-intercept	97.5	97.857	1.4869	94.219	101.5

p	Xp	95% LCL	95% UCL	LogXp S.E.	LogXp
50	1.767	0.00013662	22854	1.6804	0.24723
20	**1.5284**	1.3048	1.7903	0.028071	0.18425
10	1.4207	1.2197	1.6549	0.027079	0.1525
5	**1.3491**	1.1452	1.5894	0.02909	0.13005
0	1.1909	0.97982	1.4473	0.034621	0.07586

EC20:EC5 = 1.133

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

Niederlehner 1984	
Species: *Daphnia pulex*	
Test Endpoint: 21-d Growth	
C-R Curve Label: Cd-Chronic-22	
Test: Single	
Cd, (µg/L)	**Mean Length (mm)**
0.2	2.65
0.8	2.68
1.5	2.58
3.2	2.67
5.5	2.53
10.2	- (0)
23.3	- (0)

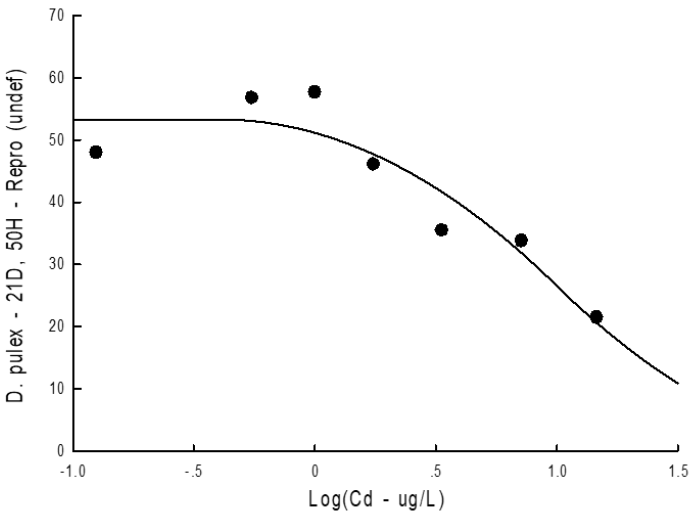


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.85	0.85113			
Slope	6.3	6.3647			
Y-intercept	2.645	2.6451			
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	7.0978			0.010292	0.85113
20	**6.2141**			0.010292	0.79338
10	5.8113			0.010292	0.76427
5	**5.5424**			0.010292	0.74369
0	4.9432			0.010292	0.69401

EC20:EC5 = 1.121

Notes: TRAP flagged for IP (No unique solution).

Chadwick Ecological Consultants 2003	
Species: *Daphnia pulex*	
Test Endpoint: 18-d Reproduction	
C-R Curve Label: Cd-Chronic-23	
Test: Table 7	
Cd, (µg/L)	**Reproduction**
0.125	48
0.55	56.8
1	57.7
1.75	46.1
3.35	35.5
7.15	33.8
14.6	21.5

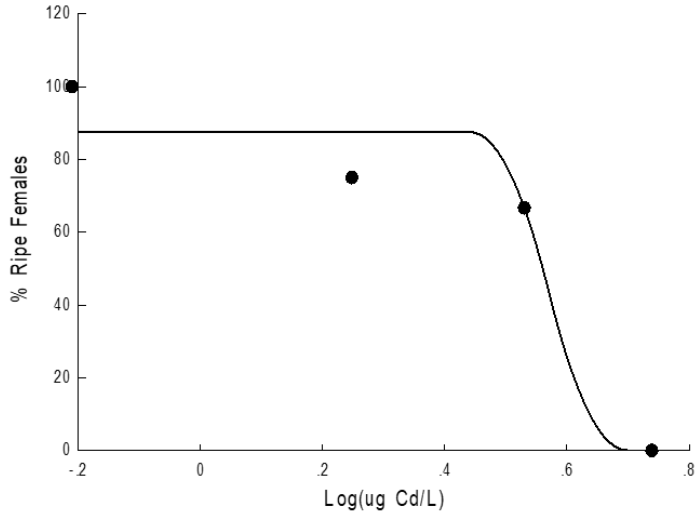


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	1	0.99662	0.12882	0.63896	1.3543
Slope	0.7	0.71766	0.27003	-0.032073	1.4674
Y-intercept	54	53.318	4.45	40.963	65.673
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	9.9224	4.3547	22.609	0.12882	0.99662
20	**3.0512**	0.69454	13.405	0.23151	0.48448
10	1.6841	0.2083	13.615	0.32692	0.22636
5	**1.1062**	0.081801	14.96	0.40738	0.043839
0	0.40105	0.0060252	26.695	0.65668	-0.3968

EC20:EC5 = 2.758

Notes: Unacceptable noise at low level effects.

Brown et al 1994	
Species: *Oncorhynchus mykiss*	
Test Endpoint: LC Reproduction	
C-R Curve Label: Cd-Chronic-25	
Test: (2 yr old) 95 week	
Cd, (µg/L)	**% Ripe Females**
0.47	100
1.77	75
3.39	66.66
5.48	0

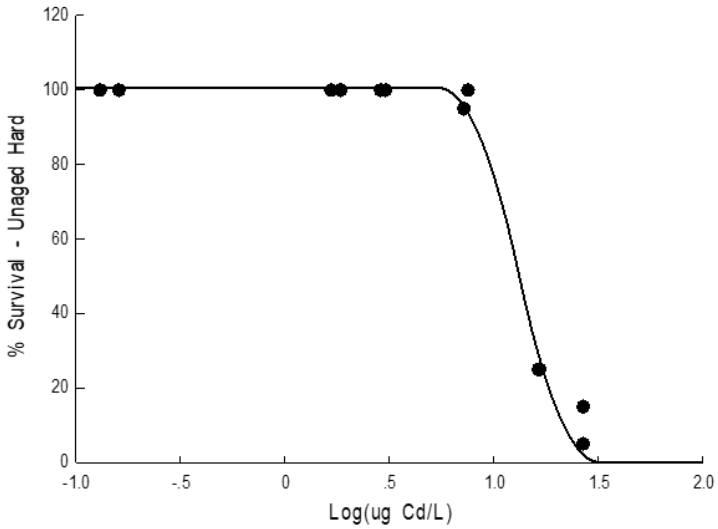


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.5	0.56993			
Slope	6	7.7976			
Y-intercept	100	87.5			
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	3.7148				0.56993
20	**3.3327**				0.5228
10	3.1553				0.49904
5	**3.0356**				0.48224
0	2.765				0.44169

EC20:EC5 = 1.098

Notes: Poor model fit.

Davies and Brinkman 1994b	
Species: *Oncorhynchus mykiss*	
Test Endpoint: ELS Survival	
C-R Curve Label: Cd-Chronic-29	
Test: 100-d; Unaged hard water (301 mg/L)	
Cd, (µg/L)	**% Survival**
0.16	100.0
0.13	100.0
1.66	100.0
1.84	100.0
2.86	100.0
3.02	100.0
7.17	95.0
7.49	100.0
16.5	25.0
16.3	25.0
26.7	15.0
26.6	5.0



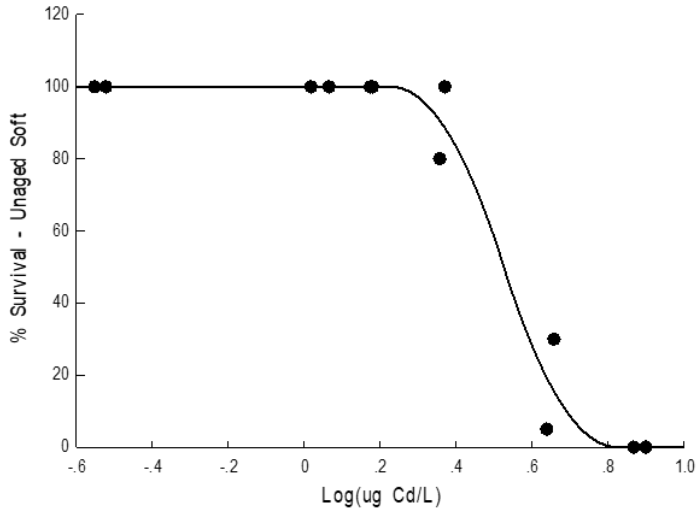
EC20:EC5 = 1.323

	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	1.2	1.1195	0.055	0.717	0.964
Slope	2.6	2.5986	2.897	-3.853	9.253
Y-intercept	99	100.57	1.268	96.628	102.370

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	13.168	11.902	14.568	0.019	1.120
20	**9.508**	8.022	11.268	0.033	0.978
10	8.068	6.498	10.018	0.042	0.907
5	**7.184**	5.617	9.188	0.047	0.856
0	5.429	4.015	7.339	0.058	0.735

Notes: Not core data.

Davies and Brinkman 1994b	
Species: *Oncorhynchus mykiss*	
Test Endpoint: ELS Survival	
C-R Curve Label: Cd-Chronic-30	
Test: 100-d; unaged soft water (29 mg/L)	
Cd, (µg/L)	**% Survival**
0.30	100.0
0.28	100.0
1.04	100.0
1.16	100.0
1.51	100.0
1.49	100.0
2.34	100.0
2.27	80.0
4.54	30.0
4.34	5.0
7.35	0.0
7.92	0.0



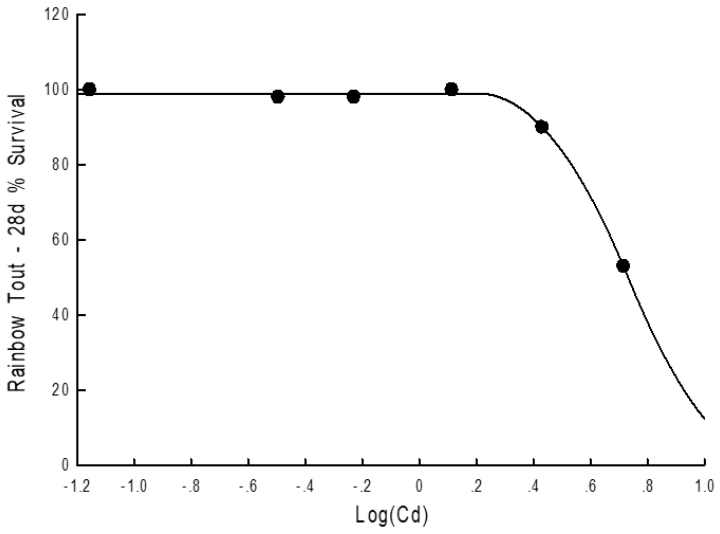
EC20:EC5 = 1.242

	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.55	0.52495	0.027	0.465	0.585
Slope	3.5	3.3613	0.628	1.941	4.781
Y-intercept	100	99.984	3.493	92.082	107.890

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	3.349	2.917	3.845	0.027	0.525
20	**2.604**	2.146	3.160	0.037	0.416
10	2.294	1.815	2.899	0.045	0.360
5	**2.097**	1.600	2.747	0.052	0.322
0	1.688	0.440	6.477	0.258	0.227

Notes: Not Core data.

Besser et al. 2007	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 28-d ELS Survival	
C-R Curve Label: Cd-Chronic-31	
Test: Single	
Cd, (µg/L)	**% Survival**
0.07	100
0.32	98
0.59	98
1.3	100
2.7	90
5.2	53

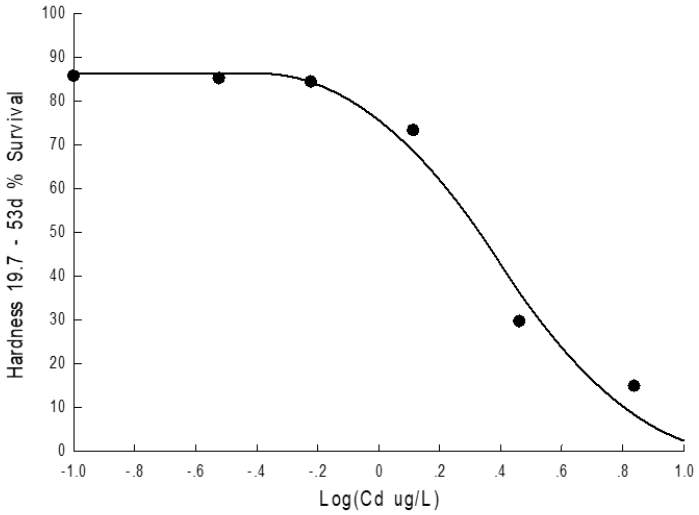


	Initial Gue	Final Est.	Standard I	95% LCL	95% UCL
Log X50	0.75	0.735	0.007039	0.7126	0.7574
Slope	1.9	1.8887	0.10991	1.539	2.2385
Y-intercept	99	99.003	0.57736	97.165	100.84
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	5.4325	5.1594	5.7201	0.007039	0.735
20	**3.4706**	3.216	3.7453	0.010395	0.5404
10	2.769	2.475	3.098	0.015321	0.44233
5	**2.3603**	2.0525	2.7143	0.019069	0.37297
0	1.6053	1.3032	1.9773	0.028444	0.20555

EC20:EC5 = 1.470

Notes: Not core data

Mebane et al. 2008	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 53-d ELS Survival	
C-R Curve Label: Cd-Chronic-32	
Test: Hardness: 19.7 mg/L	
Cd, (µg/L)	**% Survival**
<0.2	85.7
0.30	85.2
0.60	84.4
1.30	73.3
2.90	29.6
6.9	14.8

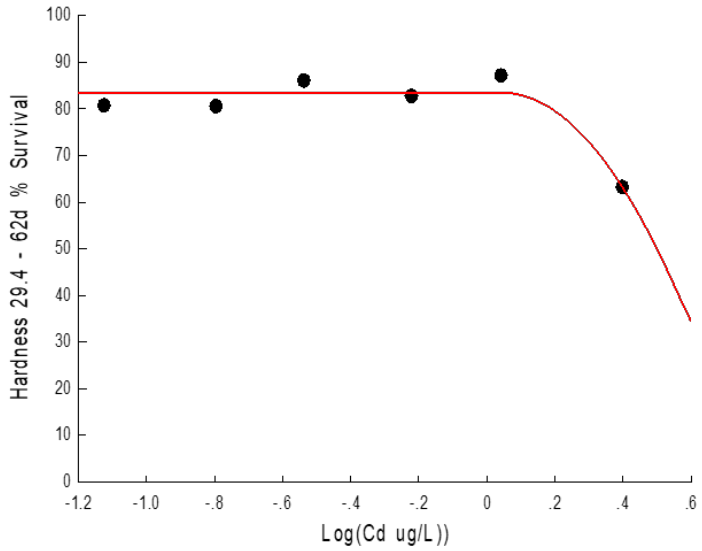


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.4	0.39531	0.053133	0.22622	0.5644
Slope	1.25	1.2701	0.25826	0.44821	2.092
Y-intercept	85	86.34	3.9762	73.686	98.993
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	2.4849	1.6835	3.6678	0.053133	0.39531
20	**1.2762**	0.65987	2.4684	0.090018	0.10593
10	0.9122	0.36789	2.2618	0.12392	-0.039911
5	**0.71938**	0.22637	2.2862	0.15779	-0.14304
0	0.4055	0.068174	2.4119	0.24332	-0.39201

EC20:EC5 = 1.774

Notes: Not core data.

Mebane et al. 2008	
Species: *Oncorhynchus mykiss*	
Test Endpoint: 62-d ELS Survival	
C-R Curve Label: Cd-Chronic-33	
Test: Hardness: 29.4 mg/L	
Cd, (µg/L)	**% Survival**
<0.15	80.8
0.16	80.6
0.29	86.1
0.6	82.8
1.1	87.2
2.5	63.3

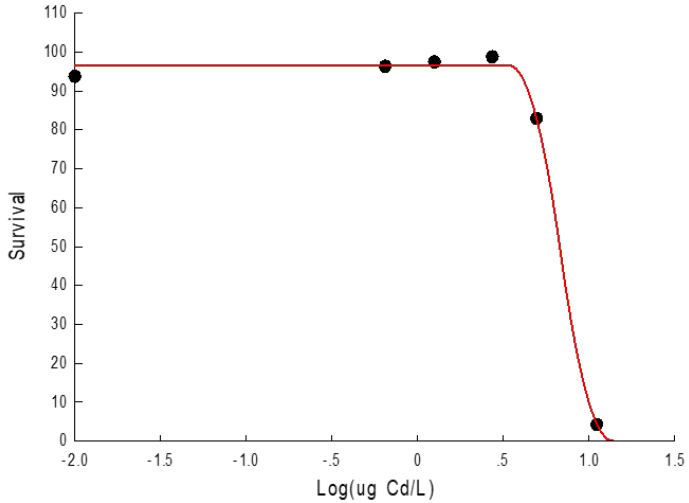


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.71943	0.55329			
Slope	1.2042	1.9588			
Y-intercept	83.5	83.486			
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	3.5751			0.29242	0.55329
20	**2.3209**			0.29242	0.36566
10	1.8668			0.29242	0.27109
5	**1.6004**			0.29242	0.20422
0	1.1035			0.29242	0.042784

EC20:EC5 = 1.450

Notes: Not core data. TRAP flagged for IP (No Unique Solution).

Wang et al. 2014	
Species: *Oncorhynchus mykiss*	
Test Endpoint: ELS Survival	
C-R Curve Label: Cd-Chronic-34	
Test: Single	
Cd, (µg/L)	**% Survival**
<0.02	93.8
0.65	96.4
1.26	97.5
2.74	98.8
4.98	83
11.2	4.3

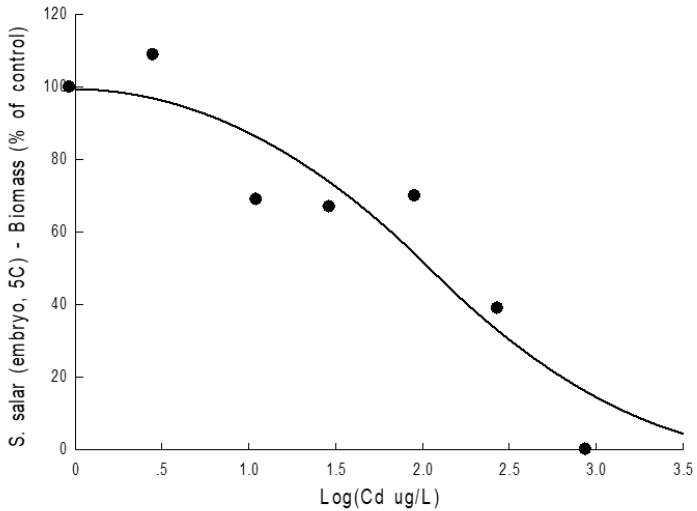


	Initial Gue	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.8	0.83824	1.21E-02	0.79979	0.87668
Slope	3	3.3257	0.24438	2.548	4.1034
Y-intercept	96.625	96.625	1.0617	93.246	100
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	6.8903	6.3065	7.528	1.21E-02	0.83824
20	**5.3422**	4.8667	5.8641	1.27E-02	0.72772
10	4.6992	4.1949	5.264	1.55E-02	0.67202
5	**4.2917**	1.2063	15.269	0.17319	0.63263
0	3.4478	2.9269	4.0615	2.24E-02	0.53755

EC20:EC5 = 1.245

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Rombough and Garside 1982	
Species: *Salmo salar*	
Test Endpoint: ELS Biomass	
C-R Curve Label: Cd-Chronic-35	
Test: (embryo, exposed from fert) - 5C	
Cd, (µg/L)	**Total Biomass (% Control)**
<1.0	100
2.8	109
11	69
29	67
90	70
270	39
870	-

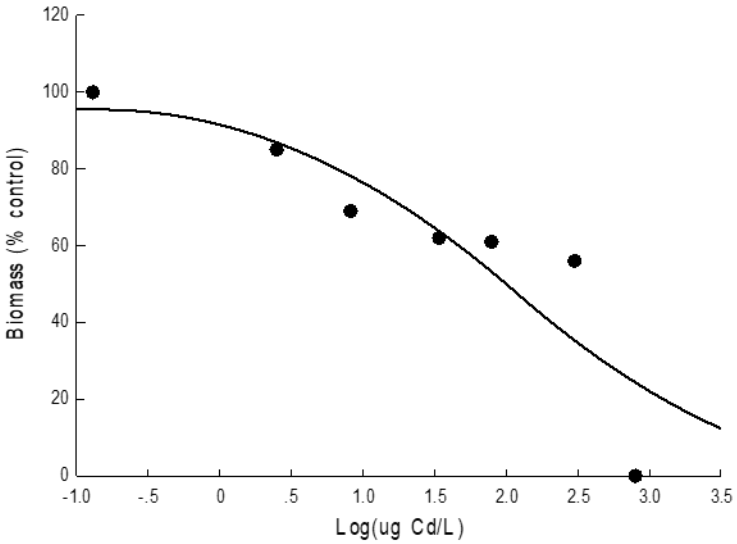


	Initial Gues	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	2.4	2.046	0.28723	1.2485	2.8434
Slope	1	0.48428	0.21063	-0.10053	1.0691
Y-intercept	80	99.415	13.868	60.912	137.92
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	111.17	17.721	697.34	0.28723	2.046
20	**19.365**	0.70155	534.55	0.519	1.287
10	8.0263	0.085062	757.35	0.71126	0.90452
5	**4.3057**	0.014297	1296.7	0.8928	0.63404
0	0.95733	5.92E-05	15487	1.5159	-0.018938

EC20:EC5 = 4.498

Notes: Not Core data. No effect within area of concern.

Rombough and Garside 1982	
Species: *Salmo salar*	
Test Endpoint: ELS Biomass	
C-R Curve Label: Cd-Chronic-36	
Test: (embryo, fert) - 8.9C	
Cd, (µg/L)	**Total Biomass (% Control)**
0.13	100
2.5	85
8.2	69
34	62
79	61
300	56
800	0

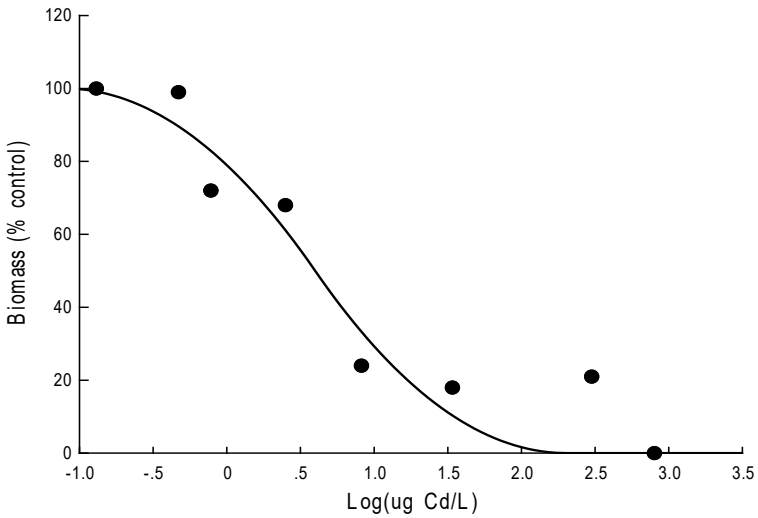


	Initial Gues	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	2	2.0712	0.43596	0.86083	3.2817
Slope	0.4	0.3442	0.17519	-0.1422	0.8306
Y-intercept	100	95.422	16.419	49.837	141.01
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	117.83	7.2582	1912.8	0.43596	2.0712
20	**10.079**	0.057509	1766.4	0.80811	1.0034
10	2.9189	0.002476	3441	1.1063	0.46523
5	**1.2153**	0.00019	7783.3	1.371	0.084671
0	0.14653	6.48E-08	331150	2.2886	-0.83407

EC20:EC5 = 8.293

Notes: Not core data. No effect within area of concern. Large SE for X50 and slope.

Rombough and Garside 1982	
Species: *Salmo salar*	
Test Endpoint: ELS Biomass	
C-R Curve Label: Cd-Chronic-37	
Test: 9.6°C	
Cd, (µg/L)	**Total Biomass (% control)**
0.13	100
0.47	99
0.78	72
2.5	68
8.2	24
34	18
79	Excluded
300	21
800	0

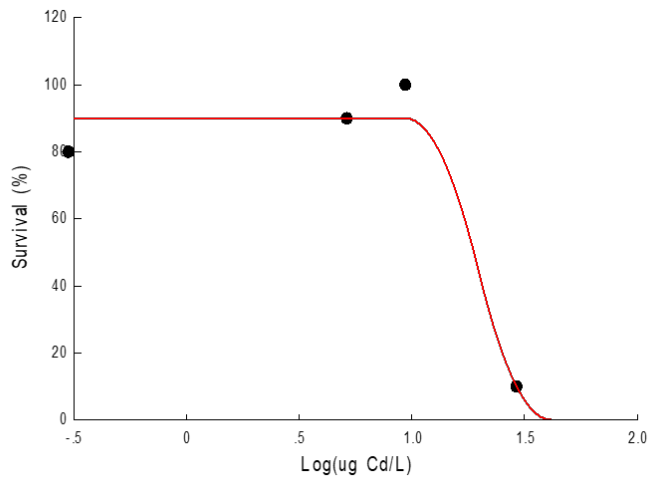


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.6	0.5999	0.13794	0.26238	0.93743
Slope	0.6	0.58586	0.14764	0.2246	0.94711
Y-intercept	100	100	0	1.00E+10	-1.00E+10
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	3.9802	1.8297	8.6582	0.13794	0.5999
20	**0.93872**	0.31795	2.7715	0.19215	-2.75E-02
10	0.45326	9.94E-02	2.0675	0.26936	-0.34365
5	**0.27087**	3.75E-02	1.9557	0.35087	-0.56723
0	7.82E-02	2.50E-03	2.4486	0.61135	-1.107

EC20:EC5 = 3.466

Notes: Poor model fit. Large SE (x50).

Brown et al 1994	
Species: *Salmo trutta*	
Test Endpoint: LC Survival	
C-R Curve Label: Cd-Chronic-38	
Test: (2 yr old) 95 week	
Cd, (µg/L)	**% Survival**
0.27	80
5.13	90
9.34	100
29.1	10

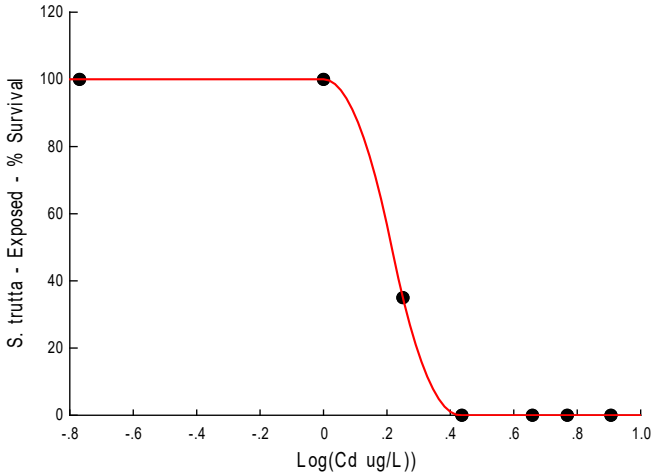


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	1.2	1.2934			
Slope	3	3.0997			
Y-intercept	90	90			
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	19.65				1.2934
20	**14.955**				1.1748
10	13.032				1.115
5	**11.824**				1.0728
0	9.3487				0.97075

EC20:EC5 = 1.265

Notes: Not core data. TRAP Flagged for IP (No Unique Solution).

Davies and Brinkman 1994a	
Species: *Salmo trutta*	
Test Endpoint: ELS Survival	
C-R Curve Label: Cd-Chronic-39	
Test: Single	
Nominal Cd, (µg/L)	**% Survival (exposed)**
0.17	100
1.00	100
1.78	35
2.73	0
4.56	0
5.87	0
8.06	0

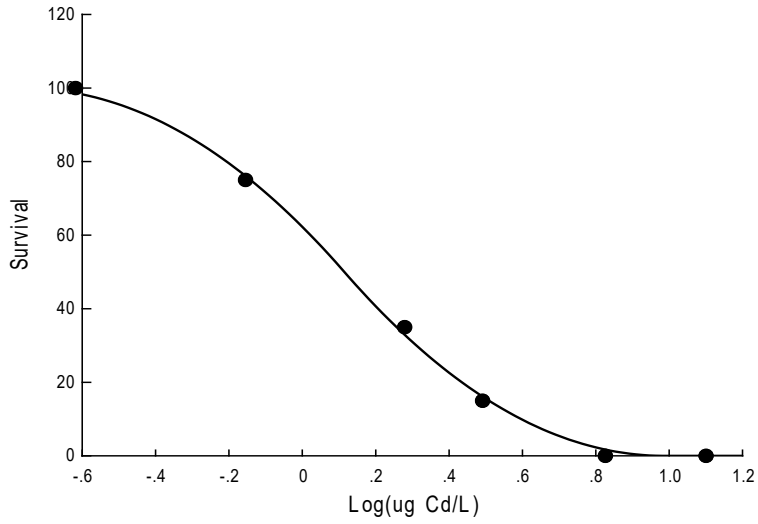


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.20721	0.21526			
Slope	3.4647	4.6457			
Y-intercept	100	100			
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	1.6416			4.1494	0.21526
20	**1.3682**			4.1494	0.13614
10	1.2482			4.1494	0.096271
5	**1.1697**			4.1494	0.068076
0	1			4.1494	6.267E-06

EC20:EC5 = 1.170

Notes: TRAP flagged for IP (No unique solution).

Davies and Brinkman 1994c	
Species: *Salmo trutta*	
Test Endpoint: 12 wk Fingerling Survival	
C-R Curve Label: Cd-Chronic-40	
Test: Single	
Cd, (µg/L)	**% Survival**
0.2	100
0.7	75
1.9	35
3.1	15
6.7	0
12.6	0

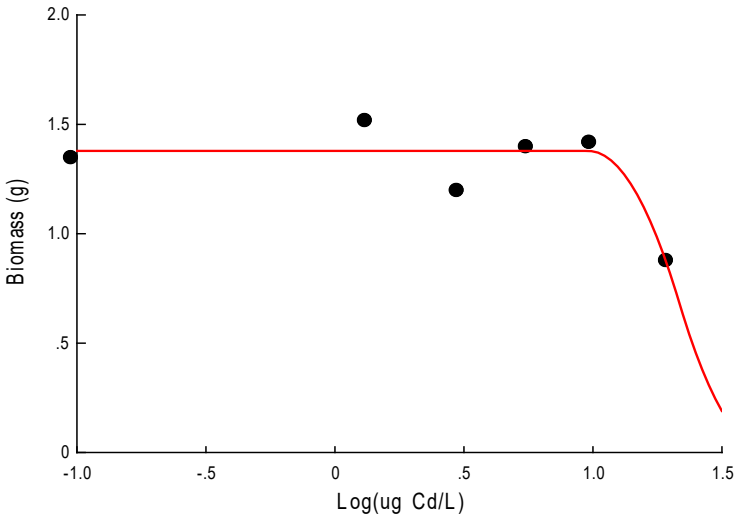


	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.10544	0.11526	1.93E-02	5.37E-02	0.17682
Slope	1.2621	1.1483	6.57E-02	0.93911	1.3574
Y-intercept	100	99.848	2.0528	93.315	106.38
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	1.3039	1.1316	1.5025	1.93E-02	0.11526
20	**0.62399**	0.48398	0.80449	3.47E-02	-0.20483
10	0.43038	0.30691	0.60352	4.61E-02	-0.36615
5	**0.33096**	0.2227	0.49185	5.41E-02	-0.48022
0	0.17554	0.11327	0.27206	5.98E-02	-0.75562

EC20:EC5 = 1.885

Notes: No effect within area of concern.

Brinkman and Hansen 2004a; 2007	
Species: *Salmo trutta*	
Test Endpoint: ELS Biomass	
C-R Curve Label: Cd-Chronic-41	
Test: Hardness = 150 mg/L	
Dissolved Cd, (µg/L)	**Biomass (g)**
<0.1 (0.05)	1.35
1.30	1.52
2.95	1.20
5.47	1.40
9.62	1.42
19.1	0.88



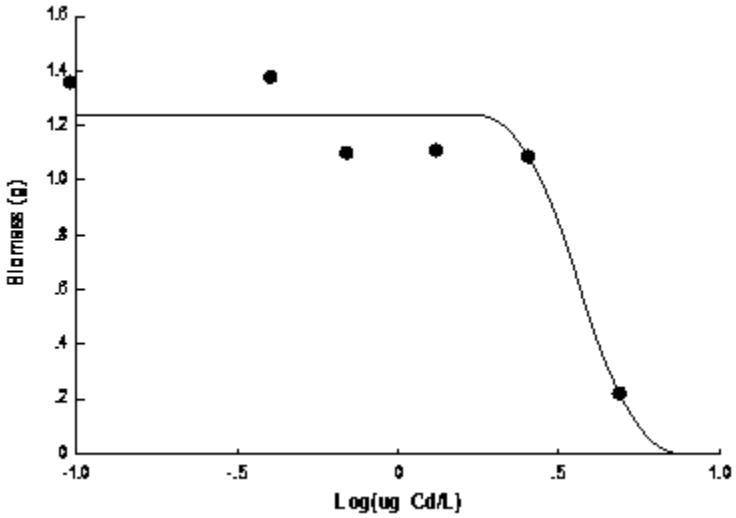
	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	1.3	1.3335	777.22	-2472.1	2474.8
Slope	2.2	2.8542	42260	-134490	134490
Y-intercep	1.4	1.378	0.067626	1.1628	1.5932

p	Xp	95% LCL	95% UCL	LogXp S.E.	LogXp
50	21.554	0	Infinity	777.22	1.3335
20	**16.023**	0	Infinity	1129.9	1.2048
10	13.799	0	Infinity	2090.5	1.1399
5	**12.415**	0	Infinity	2770.6	1.094
0	9.6199	0	Infinity	4412.2	0.98317

EC20:EC5 = 1.291

Notes: TRAP Flagged for IP (No Unique Solution).

Brinkman and Hansen 2004a; 2007	
Species: *Salmo trutta*	
Test Endpoint: ELS Biomass	
C-R Curve Label: Cd-Chronic-43	
Test: Hardness = 30 mg/L	
Dissolved Cd, (µg/L)	**Biomass (g)**
<0.1 (0.05)	1.360
0.40	1.378
0.69	1.101
1.31	1.111
2.54	1.087
4.87	0.222



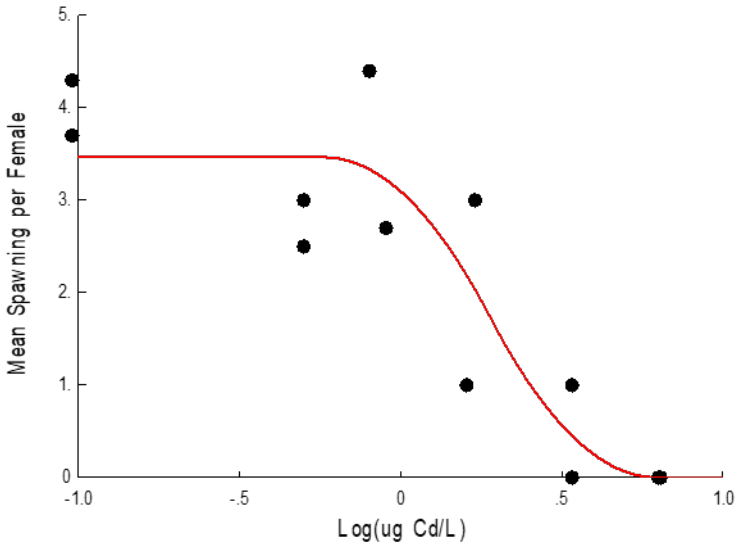
	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.56	0.56265	0.052726	0.39486	0.73045
Slope	3	3.2113	1.1863	-0.564	6.9866
Y-intercep	1.4	1.2375	0.076038	0.99551	1.4795

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	3.653	2.4823	5.3759	0.052726	0.56265
20	**2.8067**	1.6439	4.7922	0.073006	0.4482
10	2.4576	1.2792	4.7215	0.089103	0.39052
5	**2.2373**	1.0427	4.8008	0.10419	0.34973
0	1.7834	1.6703E-05	190420	1.5801	0.25126

EC20:EC5 = 1.255

Notes: Poor model fit.

Benoit et al. 1976	
Species: *Salvelinus fontinalis*	
Test Endpoint: LC Reproduction	
C-R Curve Label: Cd-Chronic-44	
Test: First Generation	
Cd, (µg/L)	**Mean Spawning per Female**
Control (0.06)	4.3
Control (0.06)	3.7
0.5	2.5
0.5	3
0.9	2.7
0.8	4.4
1.7	3
1.6	1
3.4	-
3.4	1
6.3	-
6.4	-



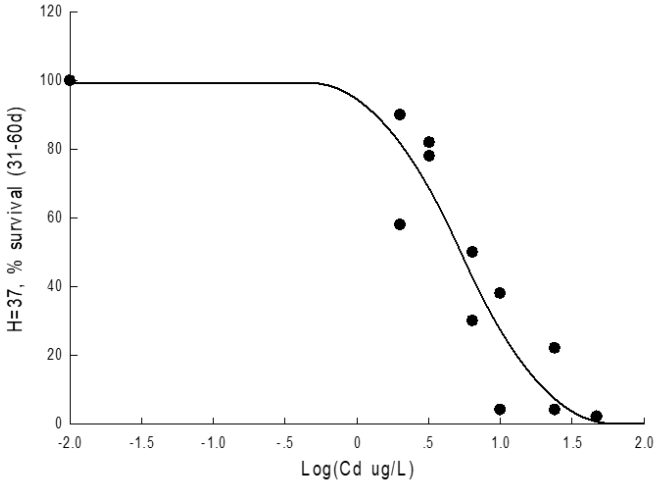
	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.3	0.27802	0.092816	0.068059	0.48799
Slope	3	1.9328	1.018	-0.37011	4.2357
Y-intercept	4	3.4658	0.39461	2.5731	4.3584

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	1.8968	1.1697	3.076	0.092816	0.27802
20	**1.2242**	0.57196	2.6203	0.1461	0.08786
10	0.98179	0.33446	2.882	0.20674	-0.00798
5	**0.83994**	0.19901	3.5451	0.27645	-0.07575
0	0.57628	0.046378	7.1606	0.48375	-0.23937

EC20:EC5 = 1.457

Notes: TRAP Flagged for IP (No Unique Solution). Large SE for slope.

Sauter et al. 1976	
Species: *Salvelinus fontinalis*	
Test Endpoint: ELS Survival	
C-R Curve Label: Cd-Chronic-45	
Test: Hardness= 37 mg/L; 31-60-d	
Cd, (µg/L)	**% Survival**
-	100
-	100
2.0	90
2.0	58
3.2	82
3.2	78
6.4	50
6.4	30
10	4
10	38
24	4
24	22
47	2
47	2

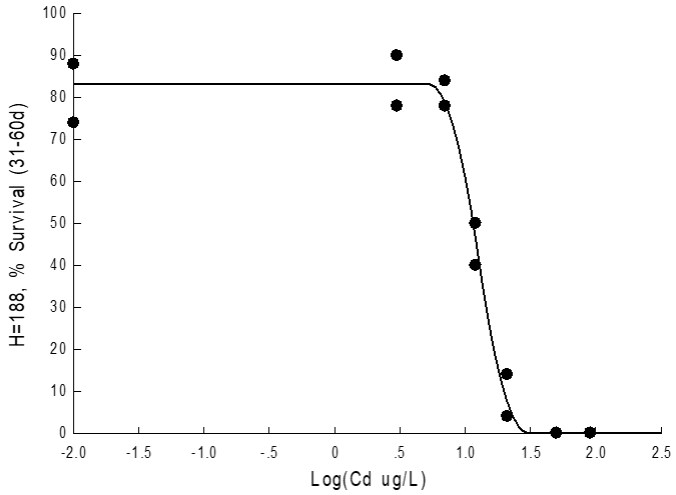


EC20:EC5 = 2.153

	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	0.75	0.72696	0.092068	0.52432	0.9296
Slope	0.95	0.94938	0.23593	0.43011	1.4687
Y-intercept	100	99.338	9.3625	78.731	119.94
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	5.3329	3.3444	8.5036	0.092068	0.72696
20	**2.1869**	0.96613	4.95	0.16119	0.33982
10	1.3954	0.46663	4.1728	0.21614	0.1447
5	**1.0156**	0.28847	3.5757	0.24836	0.0067307
0	0.47167	0.11639	1.9115	0.27612	-0.32636

Notes: Not core data.

Sauter et al. 1976	
Species: *Salvelinus fontinalis*	
Test Endpoint: ELS Survival	
C-R Curve Label: Cd-Chronic-46	
Test: Hardness= 188 mg/L; 31-60-d	
Cd, (µg/L)	**% Survival**
-	88
-	74
3	78
3	90
7	84
7	78
12	40
12	50
21	14
21	4
50	0
50	0
91	0
91	0

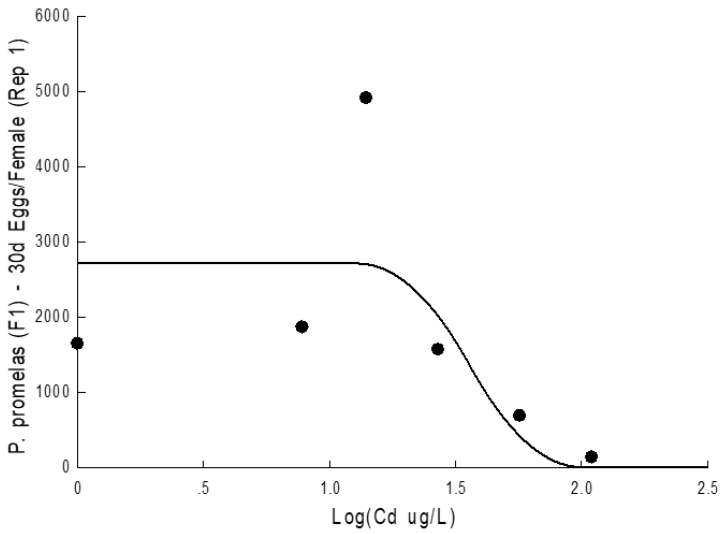


EC20:EC5 = 1.319

	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	1.1	1.1023	0.018162	1.0623	1.1422
Slope	2.6	2.6294	0.39099	1.7688	3.49
Y-intercept	82	83.184	2.5623	77.544	88.823
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	12.655	11.542	13.875	0.018162	1.1023
20	**9.1724**	7.8625	10.701	0.030408	0.96249
10	7.7989	6.2074	9.7986	0.045038	0.89204
5	**6.9538**	5.1042	9.4735	0.061015	0.84222
0	5.2717	3.4325	8.0966	0.084666	0.72195

Notes: Not core data.

Pickering and Gast 1972	
Species: *Pimephales promelas*	
Test Endpoint: LC Reproduction	
C-R Curve Label: Cd-Chronic-47	
Test: chronic test 2 (fry) - 30 d	
Cd, (µg/L)	**# of eggs per female - rep 1**
1.0	1645
7.8	1864
14	4916
27	1566
57	686
110	133

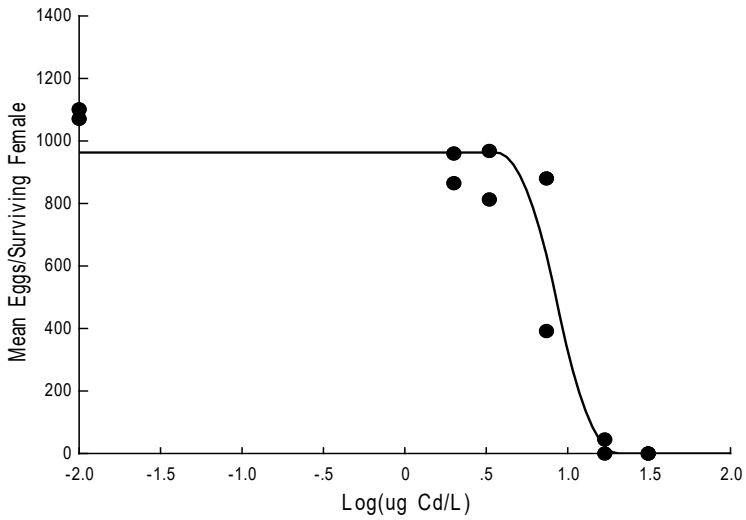


	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	1.5	1.5565	0.30325	0.59142	2.5216
Slope	2.2	2.2461	4.0729	-10.716	15.208
Y-intercept	2800	2712.6	931.32	-251.25	5676.5
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	36.016	3.9032	332.34	0.30325	1.5565
20	**24.709**	0.95597	638.67	0.44381	1.3929
10	20.436	0.2458	1699	0.60325	1.3104
5	**17.868**	0.042657	7484.2	0.82392	1.2521
0	12.92	8.4342E-12	1.9793E+13	3.8289	1.1113

EC20:EC5 = 1.383

Notes: Unacceptable noise at low level effects; large SE for X50 and slope.

Carlson et al. 1982	
Species: *Jordanella floridae*	
Test Endpoint: LC Reproduction	
C-R Curve Label: Cd-Chronic-49	
Test: 0.004 mg/L taconite tailings	
Cd, (µg/L)	**Mean # eggs/Surviving female (adjusted)**
0	1101
0	1071
2.0	960
2.0	865
3.3	813
3.3	968
7.4	392
7.4	880
16.9	45
16.9	0
31.2	-
31.2	-



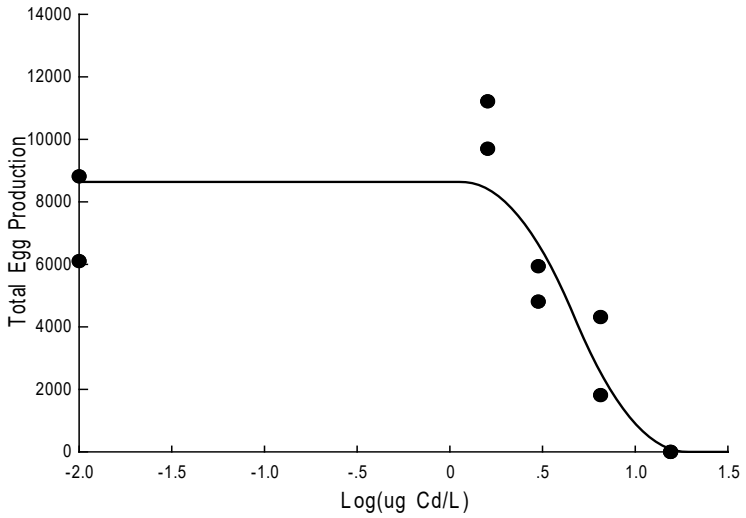
EC20:EC5 = 1.313

	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.9	0.93497	0.053248	0.81451	1.0554
Slope	2.5	2.6759	1.4008	-0.49289	5.8448
Y-intercept	1086	963	58.203	831.34	1094.7

p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	8.6093	6.524	11.361	0.053248	0.93497
20	**6.275**	3.8889	10.125	0.091855	0.79762
10	5.3505	6.437E-07	44471000	3.0589	0.72839
5	**4.7802**	1.3356	17.109	0.2448	0.67944
0	3.6414	1.8307	7.2431	0.13202	0.56127

Notes: Poor model fit; large SE for slope.

Carlson et al. 1982	
Species: *Jordanella floridae*	
Test Endpoint: LC Reproduction	
C-R Curve Label: Cd-Chronic-50	
Test: 0.08 mg/L taconite tailings	
Cd, (µg/L)	**Total egg production**
0	8817
0	6106
1.6	11216
1.6	9699
3.0	4810
3.0	5941
6.5	1820
6.5	4314
15.5	0
15.5	0
29.9	-
29.9	-

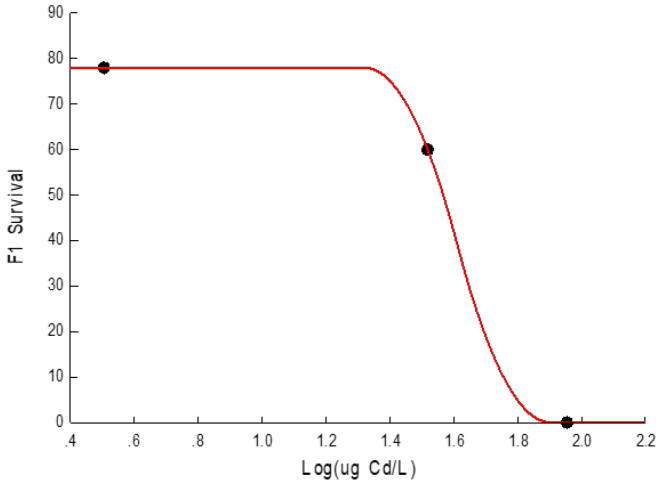


EC20:EC5 = 1.554

	Initial Guess	Final Est.	Standard Error	95% LCL	95% UCL
Log X50	0.65	0.67149	0.10809	0.41591	0.92707
Slope	1.6	1.6514	0.83649	-0.32661	3.6294
Y-intercept	8959.5	8634.7	1155.5	5902.3	11367
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	4.6934	2.6056	8.4541	0.10809	0.67149
20	**2.8114**	1.0547	7.4939	0.18006	0.44892
10	2.1714	0.60344	7.8138	0.23518	0.33675
5	**1.809**	0.42892	7.6292	0.26433	0.25743
0	1.164	0.23096	5.8659	0.29704	0.065935

Notes: Unacceptable noise at low level effects; large SE for slope.

Eaton 1974	
Species: *Lepomis macrochirus*	
Test Endpoint: Survival	
C-R Curve Label: Cd-Chronic-51	
Test: F-1 Generation	
Cd, (µg/L)	**F1 Survival**
3.2	78
33	60
90	0
239	-
757	-
2140	-



	Initial Guess	Final Est.	Standard Error	95% LCL	95% HCL
Log X50	1.6	1.6118			
Slope	3	3.4358			
Y-intercept	78	78			
p	**Xp**	**95% LCL**	**95% UCL**	**LogXp S.E.**	**LogXp**
50	40.911				1.6118
20	**31.979**				1.5049
10	28.245				1.4509
5	**25.871**				1.4128
0	20.931				1.3208

EC20:EC5 = 1.236

Notes: TRAP flagged for IP (No unique solution).

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

September 4, 2018

Mr. Troy Andersen
U.S. Fish and Wildlife Service
Virginia Field Office
6669 Short Lane
Gloucester, Virginia 23061

Dear Mr. Andersen:

This letter is to request the Fish and Wildlife Service's (FWS) concurrence under Section 7 of the Endangered Species Act that EPA's approval of Virginia's adoption of statewide amendments to the aquatic life water quality criteria for cadmium and ammonia under Section 303(c)(3) of the Clean Water Act (CWA) are not likely to adversely affect listed species in Virginia.

On September 18, 2017, the Virginia Department of Environmental Quality (VADEQ) announced for public review and comment proposed amendments to its cadmium and ammonia criteria. The comment period ended December 8, 2017. Virginia is expected to respond to public comments and publish the revised cadmium and ammonia criteria under Virginia's Water Quality Standards Title 9 VACS 25-260 Water Quality Standards Regulations, and submit to EPA within the coming months.

The enclosed Biological Evaluation documents EPA's analysis of the possible effects of our approval of the statewide cadmium and ammonia aquatic life water quality criteria on listed species and designated critical habitats under the FWS jurisdictions. EPA concludes that the actions EPA intends to take are not likely to adversely affect threatened and endangered species and designated critical habitats. We ask that FWS provide a letter indicating your concurrence with our findings within thirty (30) days of receipt of this letter. If you have any questions, please contact me at (215) 814-5717, or Cheryl Atkinson at (215) 814-3392.

Sincerely,

Evelyn S. MacKnight

Evelyn S. MacKnight, Associate Director
Water Protection Division

Enclosure

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

OCT 11 2018

Ms. Janet Mizzi
Field Supervisor
U.S. Fish and Wildlife Service
Asheville Ecological Services Field Office
160 Zillicoa Street
Asheville, North Carolina 28801

Subject: Transmittal of the Endangered Species Act Section 7(a) Biological Evaluation for the EPA's Clean Water Act, Section 303(c) Approval Action for the Eastern Band of Cherokee Indians Water Quality Standards

Dear Ms. Mizzi:

The U.S. Environmental Protection Agency is obligated under Section 7(a)(2) of the Endangered Species Act (ESA), 16 U.S.C. § 1536(a)(2) to ensure that any action it approves is not likely to jeopardize the continued existence of any threatened or endangered species or result in the destruction or adverse modification of critical habitat. The Federal action being evaluated is the potential EPA approval of the Eastern Band of Cherokee Indians (EBCI) Water Quality Standards: Administrative Rules (Rules) as related to the protection of aquatic life. The Rules became effective as Tribal law on August 16, 2018, following the August 15, 2018, public meeting and are to be submitted to Mr. Onis "Trey" Glenn, Regional Administrator of the EPA's Region 4 Office on November 8, 2018, during his visit to Cherokee, North Carolina. The EPA requests that the Fish and Wildlife Service (Service) review the enclosed biological evaluation (BE) for the EPA's approval of the aquatic life WQS provisions, pursuant to section 303(c) of the Clean Water Act (CWA), 33 U.S.C. § 1313(c).

The aquatic life provisions and the effects determinations for threatened and endangered species in EBCI lands are described in the enclosed BE. The EPA is submitting this request under the informal consultation provision of the ESA regulations at 50 CFR Part 402.13, and has made determinations of "no effect" or "may effect, but not likely to adversely affect" for all aquatic and aquatic dependent species and their designated critical habitats in EBCI lands as detailed in the enclosed BE. The EPA has reviewed the adopted Rules and anticipates their approval pursuant to the time frame outlined in the CWA section 303(c).

The Memorandum of Agreement signed by the Service and the EPA regarding enhanced coordination under the CWA and ESA, provision V.B.6., requests that the EPA notify the Service in writing when making a "may effect, not likely to adversely affect" determination. Additionally, the Service will respond in writing within 30 days of receipt of such determination, unless extended by mutual agreement. The response will state whether the Service concurs or does not concur. If the Service does not concur, it will provide a written explanation that includes the species and/or critical habitat of concern, the perceived adverse effects, supporting information and a basic rationale. 66 Fed. Reg. 11,202-11,210 (Feb. 22, 2001).

We would like to express our appreciation to Mr. Bryan Tompkins and other staff in your office for the time they have taken and effort they have provided in helping to develop and complete this evaluation. Please contact Ms. Lydia Mayo at (404) 562-9247 or mayo.lydia@epa.gov should you have questions regarding the enclosed BE.

Sincerely,

for
Tony Able, Acting Chief
Water Quality Planning Branch

Enclosure

cc: Mr. Bryan Tompkins, FWS, Asheville Ecological Services Field Office

BIOLOGICAL EVALUATION OF EASTERN BAND OF CHEROKEE INDIANS WATER QUALITY STANDARDS ADMINISTRATIVE RULES

FOR THE U.S. FISH AND WILDLIFE SERVICE

Prepared by:

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION 4
61 FORSYTH STREET, SW
ATLANTA, GEORGIA 30303

October 2018

EPA-HQ-2019-004830 001069

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Overview

This Biological Evaluation (BE) was prepared to determine, under section 7(a)(2) of the Endangered Species Act (ESA), whether effects may occur to threatened and endangered species and/or designated critical habitat (CH) from the EPA's potential approval of aquatic life water quality standards as related to the protection of aquatic life uses and criteria for the protection of these uses as adopted by the Eastern Band of Cherokee Indians (EBCI, Tribe or Cherokee).

On January 26, 2015, the EPA approved the EBCI to administer a Water Quality Standards (WQS) program under Clean Water Act (CWA) section 303(c). The EPA determined that the Tribe is eligible to be treated in a manner similar to a state (TAS) for purposes of setting WQS and issuing water quality certifications under the CWA. The Tribe became the 49th Tribe to receive TAS for these programs nationally since 1991. The Tribe has now adopted, in the Cherokee Code, WQS for tribal waters. The Tribe anticipates that it will submit the WQS to the U.S. Environmental Protection Agency on November 8, 2018, for review under section 303(c) of the CWA. The Eastern Band of Cherokee Indians WQS: Administrative Rules can be found in Appendix A.

In addition to the EPA's review under section 303(c) of the CWA, section 7(a)(2) of the ESA requires federal agencies, in consultation with the Fish and Wildlife Service (FWS) and/or the National Marine Fisheries Service (NMFS), to ensure that their actions are not likely to jeopardize the continued existence of federally listed species or result in the destruction or adverse modification of designated critical habitat of such species. This BE provides you with the EPA's analysis of the potential effects on threatened and endangered species and designated critical habitat by the EPA's potential approval of the Tribe's water quality standards as related to aquatic life uses and criteria.

Description of Federal Action

Section 303 of the CWA, 33 U.S.C. § 1313, requires states and authorized tribes to establish WQS and to submit any new or revised standards to the EPA for review and approval or disapproval. Tribal WQS are not effective for CWA purposes until approved by the EPA. 40 CFR Part 131.21(c).

Summary of the BE Findings

There are no federally listed endangered or threatened aquatic species that exist within Tribal waters. This BE assesses three listed aquatic dependent mammals and one listed aquatic dependent plant species that may exist on Tribal lands. The aquatic dependent species are the Gray bat (*Myotis grisescens*), Indiana bat (*Myotis sodalis*), Northern Long-Eared Bat (*Myotis septentrionalis*), and Virginia spiraea (*Spiraea virginiana*). This BE addresses one listed aquatic species, the Appalachian elktoe (*Alasmidonta raveneliana*). This species exists in the Tuckasegee River and does not exist in Tribal waters or in downstream adjacent waters. **All other species listed in Appendix B either do not exist in Tribal waters (or in downstream adjacent waters) or are not aquatic dependent species.**

Although suitable habitat may exist for these aquatic dependent federally listed species on Tribal lands, there is a general absence of records of the areas where these species have been documented, therefore the potential effects of Tribal WQS whether beneficial or otherwise are uncertain. Effects would be due to exposure to pollutants resulting from the application of Tribal water quality standards as related to

aquatic life uses and criteria, and are considered insignificant for the species due to limited exposure or contact with water for any life stage as well as limited exposure through diet (prey species) and drinking water. In addition, the percentage of Tribal waters that the species are exposed to that may contribute effects to the listed species are small in scale and would not be estimated as significant contributors that could cause harm or detrimental affects to the species. These insignificant effects are considered undetectable, not measurable, or sufficiently minor that they cannot be meaningfully evaluated and therefore, are not expected to rise to a level that would produce an adverse effect or even a beneficial effect that could be measured. For the plant species, the effects are determined to be associated more with the physical limitations of the plant's habitat and not the plant's actual exposure to the aquatic environment. **Therefore, effects to the four aquatic dependent species are considered "may affect, but not likely to adversely affect" (NLAA).**

The aquatic federally listed species that occurs in the mainstem of the Tuckasegee River, North Carolina is the Appalachian elktoe. No portion of the Tuckasegee River is a Tribal waterbody. The Appalachian elktoe exists approximately 2.5 miles downstream of the EBCI Tribal boundary within the mainstem of the Tuckasegee River. The Tuckasegee River mainstem is not considered an adjacent downstream water, and therefore, the species is not being considered for consultation purposes. The Appalachian elktoe is exposed to water quality in its CH that is governed by North Carolina WQS. The Tribe is required to meet the North Carolina WQS at the Tribal/State boundary in the Oconaluftee River about 2.5 miles upstream of the confluence of the Tuckasegee and Oconaluftee Rivers. Just as State waters are required to meet Tribal WQS when entering Tribal waters, Tribal waters are required to meet State WQS when entering State waters. **Therefore, because the State WQS will be met at the state line, effects to the Appalachian elktoe (*Alasmidonta raveneliana*) are considered "No Effect".** All findings are outlined in more detail below.

History of ESA Consultation on Clean Water Act Activities

Section 7(a)(2) of the ESA requires the EPA, in consultation with the FWS and/or the NMFS, to ensure that any action authorized by the agency is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of designated CH for such species. As provided in the Memorandum of Agreement between the EPA, the FWS, and the NMFS regarding enhanced coordination of CWA and ESA obligations, the EPA uses a BE to analyze whether a new or revised water quality standard may affect federally listed species or designated CH. The BE was prepared to determine whether the EPA's potential approval of the Eastern Band of Cherokee Indian's WQS may affect federally listed endangered or threatened species or the designated CH of such species. If the EPA determines that approval may affect listed species or CH but is not likely to adversely affect listed species or habitat, then formal consultation with the FWS is not required if the FWS concurs on the "may affect, not likely to adversely affect" finding.

Early coordination between the EPA and the FWS began on January 20, 2015. The EPA and the Tribe met with staff of the Asheville Ecological Field Office of the FWS to begin discussions regarding the consultation process. By letter dated February 10, 2015, the EPA asked the FWS Asheville Field Office for a list of threatened and endangered aquatic and aquatic dependent species that may be found on Tribal lands. On March 5, 2015, the FWS provided the EPA with Endangered and Threatened Species Lists for Haywood, Jackson, Swain, Graham and Cherokee Counties, North Carolina. The sicklefin redhorse was identified as a candidate species in the March 5, 2015 letter. However, after a detailed

Candidate Conservation Agreement (CCA) for the sicklefin redhorse (Moxostoma sp.) was signed in February 2016, this species was removed from the candidate list in October of 2016. **The species list is unchanged as of November 2018**. The complete list of species is outlined in Appendix B. If any species (aquatic or aquatic dependent) is listed in Tribal waters or land in the future, the species will be reevaluated through re-initiation of consultation per 50 CFR Part 402.16.

Overview of Water Quality Standards

The CWA provides the statutory basis for the WQS program and defines broad water quality goals. In short, a WQS defines the water quality goals for a waterbody by designating the use or uses of the water, by setting criteria necessary to protect the uses, and by preventing or limiting degradation of water quality through antidegradation provisions. Sections 101 and 303 of the CWA set the national goals and objectives to achieve a level of water quality that provides for the protection and propagation of aquatic life, protection of human health and all other beneficial uses. In addition to protecting these uses, the WQS rules are intended to restore and maintain the chemical, physical and biological quality of the nation's waters. Section 303(c) of the CWA requires that states and authorized tribes adopt WQS and that the EPA review and approve these standards.

Description of EBCI's Water Quality Standards

The EBCI Division of Agriculture and Natural Resources announced to the public in early June 2018 that the public hearing for review of The Eastern Band of Cherokee Indians WQS: Administrative Rules was to be held on August 15, 2018. The hearing took place on August 15, 2018 as planned, and the rules became effective as Tribal law on August 16, 2018. The WQS Rules are to be submitted in person to Mr. Onis "Trey" Glenn, Regional Administrator of the EPA's Region 4 Office on November 8, 2018, during his visit to meet with the Tribe. The EPA will then reviewed the effective WQS Rules in accordance with section 303(c) of the CWA. The Federal action being evaluated in this BE is the potential approval of the rules under section 7 of the ESA that relate to the protection of aquatic life uses and criteria as set forth in the Tribal WQS. A complete copy of the WQS Rules is enclosed as Appendix A. The EPA is requesting early concurrence which is dependent upon the WQS Rules remaining unchanged. If the WQS rules were to be revised, any FWS concurrence would be negated until the revised WQS Rules went though a future public hearing process, were approved by the Tribe as effective, were certified by Tribal counsel and were resubmitted to the EPA for review.

Description of the Geographic Area That May Be Affected by the Action

Located near the Great Smoky Mountains National Park in western North Carolina, the Tribe has approximately 300 miles of various types of waterbodies. The Tribe is known for their trout fishery, species diversity, clear mountain streams, and scenic views.

The Tribal WQS, including those related to aquatic life uses and criteria that are subject to consultation, will apply to all Tribal waters including those within the Oconaluftee River, Cheoah River and Hiwasee River watersheds and sub-watersheds. These waters share borders with several entities including the following: the state of North Carolina, Great Smoky Mountain National Park, and Nantahala National Forest. The action area for this evaluation includes all waters within the EBCI lands. These areas are outlined in Appendix C, entitled "Maps and Watersheds of the Eastern Band of Cherokee Indians". The

maps included in Appendix C are as follows: Qualla boundary north map, Qualla boundary south map, 3200 Acre map, Snowbird map and Cherokee County map. In addition, each Tribal map is shown with its associated sub-watershed map or maps(s). The Qualla north map lands are located primarily in the Raven Fork Sub-watershed within the larger Oconaluftee River watershed. The Qualla south maps lands are made up of a smaller portion of the Oconaluftee River watershed and the Soco Creek watersheds. The 3200 Acre map lands are located in the Tuckasegee River watershed south and east of Bryson City, NC. The Snowbird map lands are located in the Cheoah River watershed. The Cherokee County map lands are located in the Hiwassee River watershed.

The Eastern Band of Cherokee Indians Reservation, Qualla Boundary portion, is located south of Great Smoky Mountains National Park in North Carolina. The Qualla boundary portion of the reservation lies in eastern Swain County and northern Jackson County. Many smaller portions of Tribal lands are scattered to the southwest in Graham and Cherokee Counties. The total land area of the Eastern Band of Cherokee Indians is approximately 60,000[1] acres. The Tribal lands are held in trust by the federal government supervised by the U.S. Bureau of Indian Affairs. The Tribe obtained a corporate charter from the state of North Carolina in 1870, in order that the Cherokee could obtain land holdings. The enrolled members of the Cherokee Nation live largely within this boundary. Today the Tribal economy is dependent on various outdoor tourism activities such as fishing, hunting and other outdoor recreational activities that rely upon high quality natural environments of the Tribe which include exceptional water quality. The Tribal economy includes minimal commercial developments for tourism activities and gaming enterprises.[2] The Tribal trout fishery is comprised of several hatchery facilities that promote the tourism economy through various fishing opportunities. The Tribe also participates in the enhancement of native fish through the growing and stocking of traditionally valued sicklefin and sucker fish species. The Tribal reservation is a recreation and tourism attraction for many in Western North Carolina and draws visitors from throughout the United States and the world.[3]

Summary of the Species of Interest for ESA Consulation

The species listed in the table below were considered for analysis in this BE. The analysis of these aquatic species and the aquatic dependent species is outlined in detail in the "Analysis of Actions' Potential to Affect Endangered and Threatened Species" section below.

Group	Animal Species/Listing Name	Status	Lead Office	Designated CH	Counties	Aquatic	Aquatic Dependent
Mussels	Appalachian elktoe (*Alasmidonta raveneliana*)	Endangered	Asheville Ecological Services Field Office	Yes	Jackson, Swain, Graham, Haywood	X	
Mammals	Northern Long-Eared Bat (*Myotis septentrionalis*)	Threatened	Minnesota-Wisconsin Ecological Services Field Office	No	Jackson, Swain, Graham, Haywood, Cherokee		X

[1] http://cherokeepreservation.org
[2] http://cherokee-hmd.com/our-community.html
[3] Legacy Plan Eastern Band of Cherokee Integrated Resource Management Plan

Group	Animal Species/Listing Name	Status	Lead Office	Designated CH	Counties	Aquatic	Aquatic Dependent
	Indiana bat (*Myotis sodalis*)	Endangered	Indiana Ecological Services Field Office	No	Swain, Graham, Haywood, Cherokee		X
	Gray bat (*Myotis grisescens*)	Endangered	Missouri Ecological Services Field Office	No	Swain, Haywood		X
Flowering Plants	Virginia spiraea (*Spiraea virginiana*)	Threatened	Virginia Ecological Services Field Office	No	Swain, Graham		X

According to FWS guidance regarding ESA consultation, in order for the EPA to determine that a proposed action is a "may affect, but not likely to adversely affect (NLAA)" action for threatened and endangered species or designated CH, all of the effects of the action must be expected to be discountable, insignificant, or beneficial. Discountable effects are those extremely unlikely to occur. Insignificant effects relate to the size or extent of the impact and include those effects that are undetectable, not measurable, or cannot be evaluated and as such should never reach the scale where taking of a species occurs. Beneficial effects have favorable effects to the species and habitat without any adverse effects.

Description of Tribal Water Quality Within the Geographic Area

The waters around the Tribal lands in the five western North Carolina counties make up an important part of the identity of the Cherokee people.[4] The streams and rivers have been recognized for their natural beauty, biological richness, and pristine water quality. The Tribal lands and waters historically and currently provide important food and medicinal resources, recreational activities, and livelihoods for the Cherokee. The area provides outdoor recreational opportunities for fishing, ceremonial uses, rafting etc. for Tribal members and tourists. The many miles of unspoiled scenic beauty of these waters and watersheds enrich the lives and livelihoods of the Cherokee as well as those who visit this area. The streams are important for ceremonial and spiritual festivals held by the Cherokee. The Cherokee population and related residential and commercial activities of Tribal members on limited Tribal lands has increased in recent years.

Protection of water quality and aquatic species and habitats from activities such as forestry, agriculture, new hydro-electric projects, and any other economic developments is of extreme importance to the Tribe. The Cherokee have valued and protected the quality of their waters and the biological diversity of their streams for generations. The Cherokee emphasize the need for balance between economic progress through infrastructure and development and the continued preservation of cultural and natural resources, both of which are important to the Cherokee.[5] The adoption of WQS is seen as a vitally important step to the Cherokee in protecting Tribal waters now and in the future.

[4] Cantrell, Mark A. 2005. The Fishes Gathered in Cherokee Country. Report prepared for the Eastern Band of Cherokee Indians. U.S. Fish & Wildlife Service, Asheville, North Carolina.

[5] Legacy Plan Eastern Band of Cherokee Integrated Resource Management Plan

Effects of the Action

A. Overview

The ESA section 7 implementing regulations at 50 CFR Part 402.02 define "effects of an action" as:

> The direct and indirect effects of an action on the species or critical habitat together with the effects of other activities interrelated or interdependent with that action, that will be added to the environmental baseline. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process. Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur.

B. Direct Effects

Currently, there are no WQS in effect for Tribal waters. The Tribal WQS being evaluated in this consultation will provide protection through the adoption of aquatic life criteria and a Tribal antidegradation policy for all waters within Tribal lands. The Tribal WQS include narrative and numeric criteria, and are considered equal to or in certain instances more stringent than that which is required by the CWA. (Appendix A provides a copy of the Eastern Band of Cherokee Indians Water Quality Standards: Administrative Rules.) The Tribal WQS are important for the protection of Tribal high quality waters. For the following reasons, the EPA does not believe the Tribal WQS will cause immediate direct effects to listed species: 1) there are no aquatic species that exist within Tribal waters, and 2) the approval of Tribal WQS will not immediately change the environmental baseline of water quality in Tribal waters. The approval of the Tribal WQS will likely result in the maintenance of water quality that meets aquatic life and high quality water designated uses which will be applied through the Tribal WQS as they are implemented in the future.

C. Indirect Effects

Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur. The potential approval of Tribal WQS may have indirect effects. Examples of CWA programs that may lead to indirect effects include the implementation of WQS in the Tribal permits and the implementation of non-point source management plans. The EPA is not assessing the adequacy of these programs to attain standards and the EPA's action discussed in this BE does not address approval of these various programs. The WQS are intended to establish the basis for permits, non-point source controls and water quality assessment. and overall will protect uses and meet WQS.

Description of Critical Habitat

There are no CH on Tribal Lands. The CH for the Appalachian elktoe exists approximately 2.5 miles downstream of the EBCI Tribal boundary within the mainstem of the Tuckasegee River, and therefore is not considered an adjacent downstream water for consultation purposes. The CH for the Appalachian

elktoe is in the Tuckasegee River include approximately 25.8 miles of the mainstem upstream of Highway 19 bridge crossing just east of Bryson City, NC to just below the town of Cullowhee, NC. [50 CFR Part 17 (FR/Vol. 67, No. 188/Friday, September 27, 2002 Designation of Critical Habitat for the Appalachian Elktoe Final Rule]. There is no CH designated for the Virginia spiraea, Gray bat, Indiana bat, and Northern Long-Eared Bat species.

Please refer to Appendix D for the individual species accounts.

Analysis of Actions' Potential to Affect Endangered and Threatened Species

Appalachian elktoe

The Appalachian elktoe is an aquatic species that occurs in the mainstem of the Tuckasegee River. The portion of the Tuckasegee River designated as CH includes approximately 25.8 miles of the mainstem of the Tuckasegee River upstream of Highway 19 Tuckasegee River bridge crossing just east of Bryson City, NC to just below the town of Cullowhee, NC. No portion of the Tuckasegee River is a Tribal waterbody. **Through a joint analysis, the EPA and the FWS established that there are no aquatic species within Tribal waters.**

Virginia spiraea

The Virginia spiraea is an aquatic dependent species and has a very restricted habitat in fast moving streams banks and within stream beds which usually consist of braided channels where sediments and stream substrate are deposited due to natural high and low flow conditions. These physical conditions are necessary for the species to exist. Other conditions that limit this species include lack of seed germination and colonization, competition from other species, human disturbance, and dams that prevent natural seasonal flooding and low flow conditions.

There are no records showing exact areas of the existence of this species or designation of CH on Tribal lands and/or in Tribal waters. General information was obtained from the FWS website at https://www.fws.gov/endangered/ for these species. Suitable habitat may exist on Tribal lands in Swain and/or Graham Counties, therefore, this species is being addressed in this BE. Due to the absence of records and limited Tribal lands in the two counties where this species may exist, the potential effects of Tribal WQS whether beneficial or otherwise are being estimated for these species. In total, Tribal acreage in the Oconaluftee River drainage area in Swain County is about 0.078% and Tribal acreage in the Cheoah River drainage area in Graham County is about 0.013%. The combined total Tribal acreage for both counties is 0.091% and the total Tribal stream miles is estimated at 126. The acreage information was taken from the Cherokee Legacy Plan. This information including habitat percentages per county and stream miles can be found in Appendix D Species accounts. The maps in Appendix C show the Tribal waters within the river watersheds and subwatersheds.

Analysis: Impacts, either beneficial or otherwise, associated with this plant species would be due to protections provided mainly by narrative and numeric Tribal WQS. The effects are determined to be associated more with the physical limitations of the plant's habitat and not the plant's exposure to the aquatic environment.

Northern Long-Eared, Indiana and Gray Bats

It was determined that the Northern Long-Eared Bat (*Myotis septentrionalis*) may exist in Jackson, Swain, Graham, Haywood, and Cherokee Counties. It was determined that the Indiana bat (*Myotis sodalis*) may exist in Swain, Graham, Haywood, and Cherokee Counties. It was determined that the Gray bat (*Myotis grisescens*) may exist in Swain and Haywood Counties.

There are no official records showing exact areas of the existence of this species or designated CH on Tribal lands. General information was obtained for these species from the FWS website at https://www.fws.gov/endangered/. However, it is presumed that suitable habitat may exist on Tribal lands in certain areas of the five counties, therefore, these species are being addressed in this BE. Due to the absence of records and limited Tribal lands in the five counties where these species may exist, the potential effects of Tribal WQS whether beneficial or otherwise are being estimated for these species. In total, Tribal acreage in the counties which may contain bat habitat is 0.362%. The acreage information was taken from the Cherokee Legacy Plan. The information including habitat percentages per county and stream miles can be found in Appendix D Species accounts. In addition, the maps in Appendix C show the Tribal waters within the river watersheds and subwatersheds.

All three bats are invertivores feeding upon flying insects including mosquitoes, mayflies, moths, and beetles. They are opportunistic feeders with the diet varying depending on local resources and habitat. They feed along rivers, farm ponds, lake shorelines, in forests, crowns of trees in floodplains and in upland forests. The aquatic life standards that apply to all Tribal waters should maintain the existing aquatic invertebrate populations including those with flying, adult life stages likely to be fed upon. The composition and abundance of these emerging insects should be protected by the aquatic life standards. The bats could get their drinking water from the open water associated with the Tribal land rivers, streams, and reservoirs. They could also obtain their food from areas including flying insects emerging from these waters. The wide-ranging foraging habits of these bats makes determining if the flying insects emerging from Tribal streams could contribute to a body burden that would adversely affect these bats impossible. The aquatic life standards should be adequate to keep from this from being the case. Since the Tribal lands represent an insignificant percentage of their potential range the approval of the Tribal, then the aquatic life standards should not likely adversely affect these bats.

Analysis: Impacts, either beneficial or otherwise, associated with these areas would be due to protections provided by Tribal WQS. Exposure to pollutants resulting from the application of Tribal WQS is considered extremely unlikely for all bat species due to a limited exposure or contact with water for any life stage of the species and limited exposure through diet, drinking water and/or consumption of prey species. The portions of Tribal waters that could be considered to contribute insignificant effects to the listed species are considered small in size or scale and would not be considered a significant contribution that could harm or affect the species. These effects are considered undetectable, not measurable, or so minor that they cannot be meaningfully evaluated. These types of insignificant effects are not expected to rise to a level that would produce an adverse effect or even a beneficial effect that could be measured.

Determinations

Appalachian elktoe (*Alasmidonta raveneliana*)

Based on the above analysis, the EPA determines that the effect of the Tribal WQS on the Appalachian elktoe and its CH is "No Effect".

Virginia spiraea (*Spiraea virginiana*)

Based on the above analysis, the EPA determines that the effect of the Tribal WQS on the Virginia spiraea and its CH is NLAA insignificant.

Gray bat (*Myotis grisescens*)
Indiana bat (*Myotis sodalis*)
Northern Long-Eared Bat (*Myotis septentrionalis*)

Based on the above analysis, the EPA determines that the effect of the Tribal WQS on the three bat species is NLAA insignificant.

All other species listed in Appendix B including the rock gnome lichen, Carolina northern flying squirrel, bog (Muhlenberg) turtle, cumberland bean (pearlymussel), littlewing pearlymussel, spotfin chub, Spruce-fir moss spider, Small whorled pogonia, Swamp pink and noonday snail, either do not exist in Tribal waters (or in downstream adjacent waters) or are not aquatic dependent species.

Appendices

Appendix A

Eastern Band of Cherokee Indians Water Quality Standards: Administrative Rules

Appendix B

Listed Species by County in Eastern Band of Cherokee Indians Tribal Land

Jackson County			
Group	**Animal Species/Listing Name**	**Status**	**Lead Office**
Arachnids	Spruce-fir moss spider (*Microhexura montivaga*)	Endangered	Asheville Ecological Services Field Office
Mussels	Appalachian elktoe (*Alasmidonta raveneliana*)	Endangered	Asheville Ecological Services Field Office
Flowering Plants	Small whorled pogonia (*Isotria medeoloides*)	Threatened	New England Ecological Services Field Office
	Swamp pink (*Helonias bullata*)	Threatened	New Jersey Ecological Services Field Office
Lichens	Rock gnome lichen (*Gymnoderma lineare*)	Endangered	Asheville Ecological Services Field Office
Mammals	Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*)	Endangered	Asheville Ecological Services Field Office
	Northern Long-Eared Bat (*Myotis septentrionalis*)	Threatened	Minnesota-Wisconsin Ecological Services Field Office

Swain County			
Group	**Name**	**Status**	**Lead Office**
Arachnids	Spruce-fir moss spider (*Microhexura montivaga*)	Endangered	Asheville Ecological Services Field Office
Mussels	Littlewing pearlymussel (*Pegias fabula*)	Endangered	Kentucky Ecological Services Field Office
	Appalachian elktoe (*Alasmidonta raveneliana*)	Endangered	Asheville Ecological Services Field Office
Fishes	Spotfin Chub (*Erimonax monachus*)	Threatened	Asheville Ecological Services Field Office
Flowering Plants	Virginia spiraea (*Spiraea virginiana*)	Threatened	Virginia Ecological Services Field Office
Lichens	Rock gnome lichen (*Gymnoderma lineare*)	Endangered	Asheville Ecological Services Field Office
Mammals	Indiana bat (*Myotis sodalis*)	Endangered	Indiana Ecological Services Field Office
	Gray bat (*Myotis grisescens*)	Endangered	Missouri Ecological Services Field Office
	Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*)	Endangered	Asheville Ecological Services Field Office
	Northern Long-Eared Bat (*Myotis septentrionalis*)	Threatened	Minnesota-Wisconsin Ecological Services Field Office
Snails	noonday snail (*Mesodon clarki nantahala*)	Threatened	Asheville Ecological Services Field Office

Graham County			
Group	**Name**	**Status**	**Lead Office**
Mussels	Appalachian elktoe (*Alasmidonta raveneliana*)	Endangered	Asheville Ecological Services Field Office
Fishes	Spotfin Chub (*Erimonax monachus*)	Threatened	Asheville Ecological Services Field Office

Graham County			
Group	**Name**	**Status**	**Lead Office**
Flowering Plants	Virginia spiraea (*Spiraea virginiana*)	Threatened	Virginia Ecological Services Field Office
Lichens	Rock gnome lichen (*Gymnoderma lineare*)	Endangered	Asheville Ecological Services Field Office
Mammals	Indiana bat (*Myotis sodalis*)	Endangered	Indiana Ecological Services Field Office
	Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*)	Endangered	Asheville Ecological Services Field Office
	Northern Long-Eared Bat (*Myotis septentrionalis*)	Threatened	Minnesota-Wisconsin Ecological Services Field Office
Reptiles	bog turtle (*Clemmys muhlenbergii*)	Similarity of Appearance (Threatened)	Office of the Regional Director

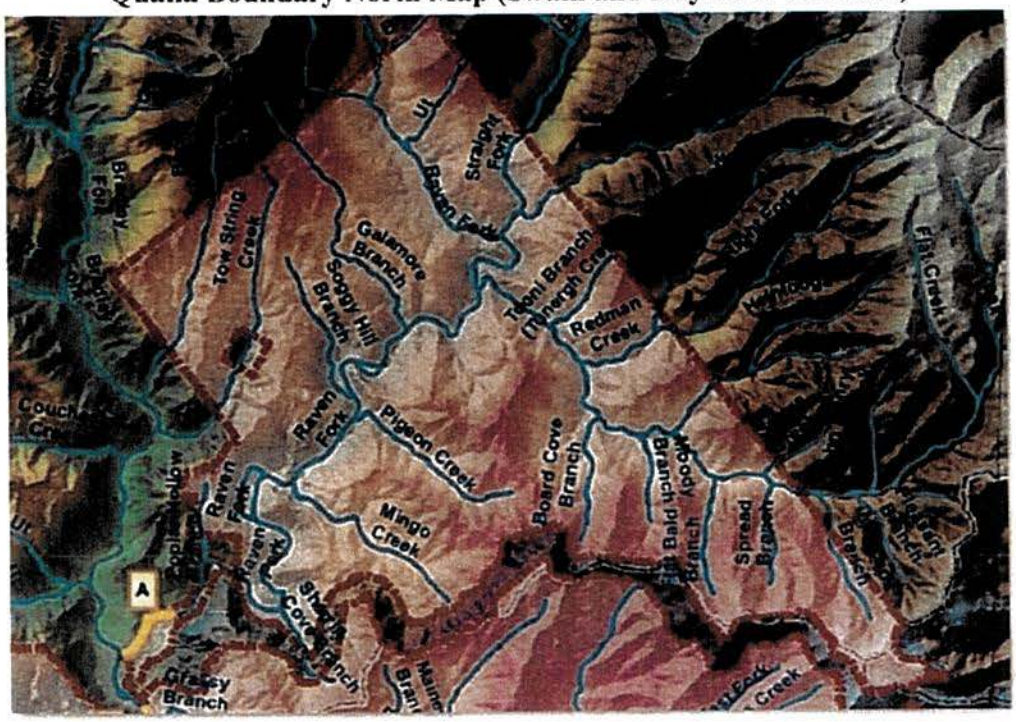
Haywood County			
Group	**Name**	**Status**	**Lead Office**
Arachnids	Spruce-fir moss spider (*Microhexura montivaga*)	Endangered	Asheville Ecological Services Field Office
Mussels	Appalachian elktoe (*Alasmidonta raveneliana*)	Endangered	Asheville Ecological Services Field Office
Flowering Plants	Spreading avens (*Geum radiatum*)	Endangered	Asheville Ecological Services Field Office
	Small whorled pogonia (*Isotria medeoloides*)	Threatened	New England Ecological Services Field Office
Lichens	Rock gnome lichen (*Gymnoderma lineare*)	Endangered	Asheville Ecological Services Field Office
Mammals	Indiana bat (*Myotis sodalis*)	Endangered	Indiana Ecological Services Field Office
	Gray bat (*Myotis grisescens*)	Endangered	Missouri Ecological Services Field Office
	Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*)	Endangered	Asheville Ecological Services Field Office
	Northern Long-Eared Bat (*Myotis septentrionalis*)	Threatened	Minnesota-Wisconsin Ecological Services Field Office

Cherokee County			
Group	**Name**	**Status**	**Lead Office**
Mussels	Cumberland bean (pearlymussel) (*Villosa trabalis*)	Endangered	Kentucky Ecological Services Field Office
Flowering Plants	Small whorled pogonia (*Isotria medeoloides*)	Threatened	New England Ecological Services Field Office
	White fringeless orchid (*Platanthera integrilabia*)	Threatened	Tennessee Ecological Services Field Office
Mammals	Indiana bat (*Myotis sodalis*)	Endangered	Indiana Ecological Services Field Office
	Northern Long-Eared Bat (*Myotis septentrionalis*)	Threatened	Minnesota-Wisconsin Ecological Services Field Office
Reptiles	bog turtle (*Clemmys muhlenbergii*)	Similarity of Appearance (Threatened)	Office of the Regional Director

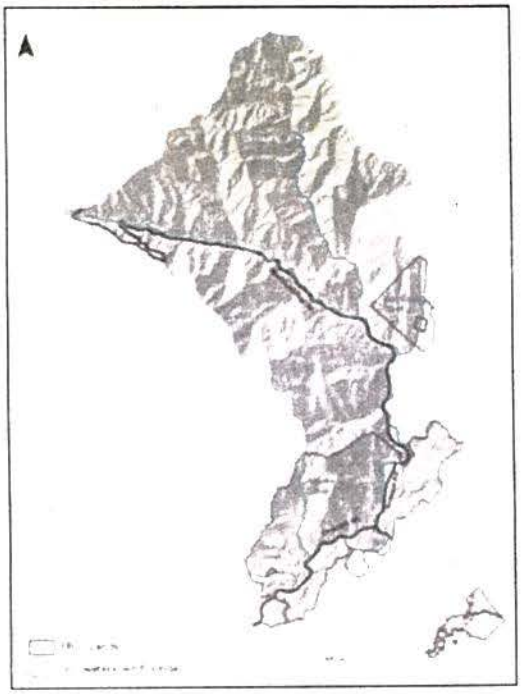
Appendix C

Maps and Watersheds of the Eastern Band of Cherokee Indians

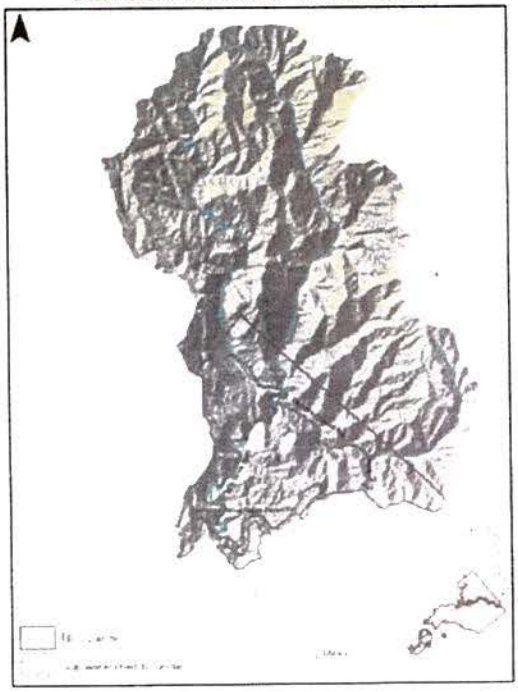
Qualla Boundary North Map (Swain and Haywood Counties)



Oconaluftee River Sub-watershed

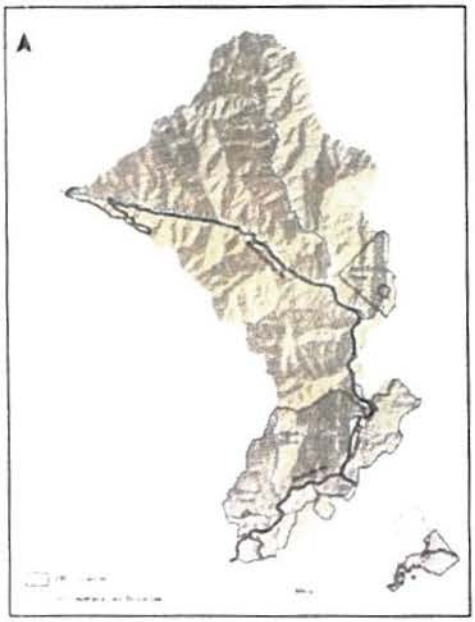


Raven Fork Sub-Watershed

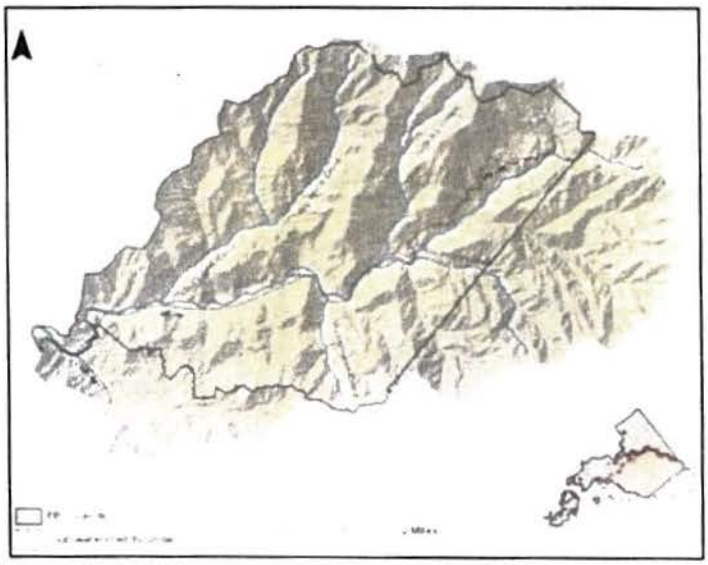


Qualla Boundary South Map (Jackson County)

Oconaluftee River Sub-watershed

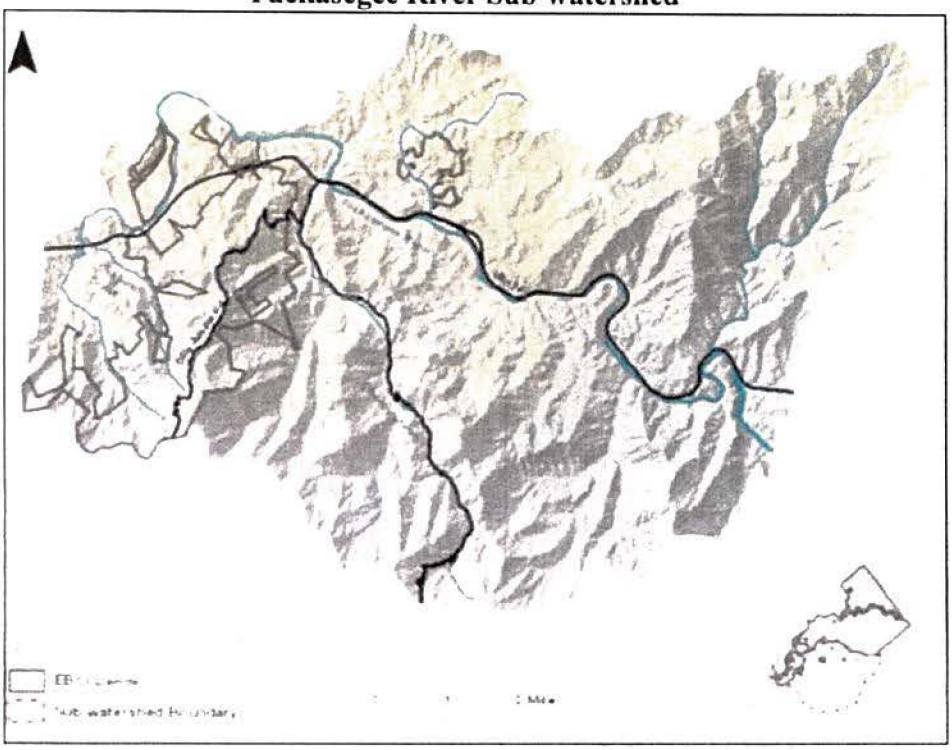


Soco Creek Sub-watershed

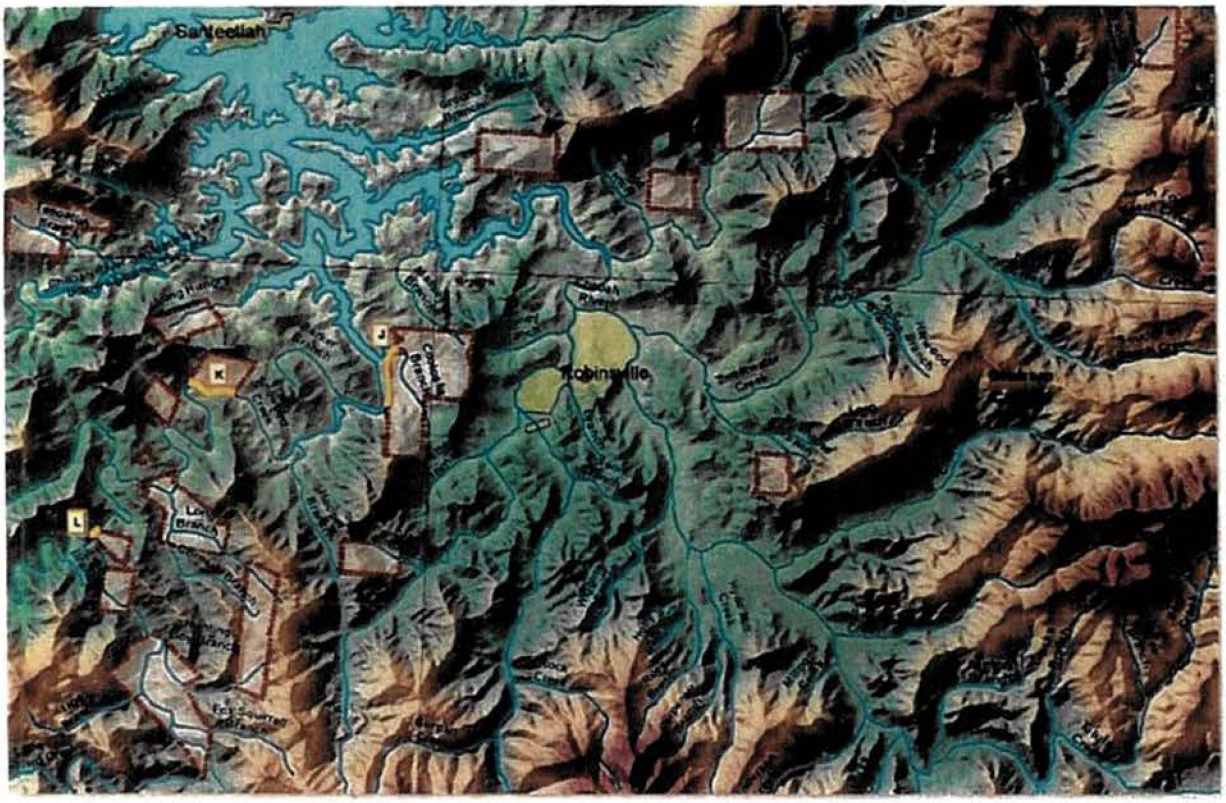


3200 Acre Map (Jackson County)

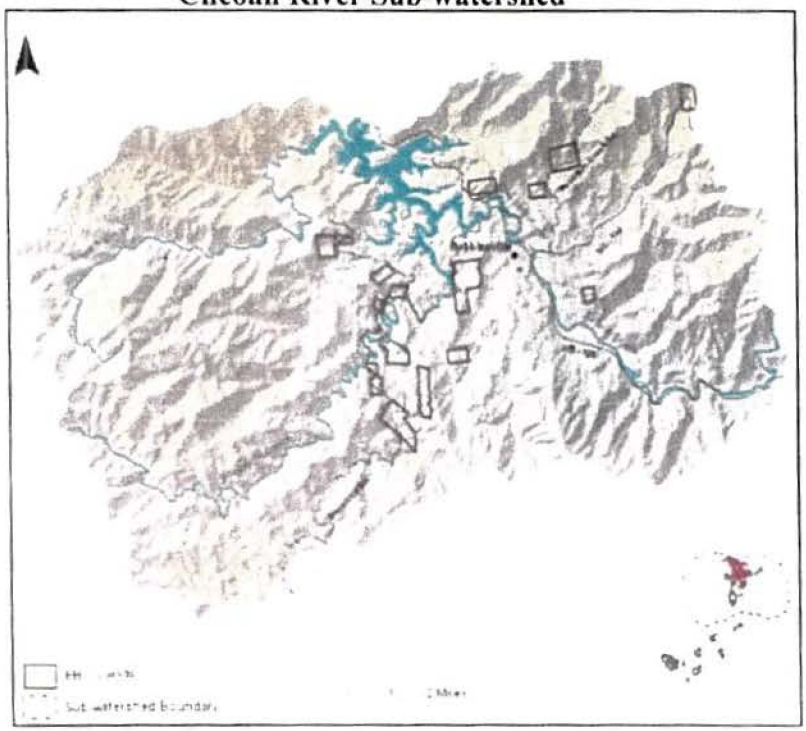
Tuckasegee River Sub-watershed



Snowbird Map (Graham County)

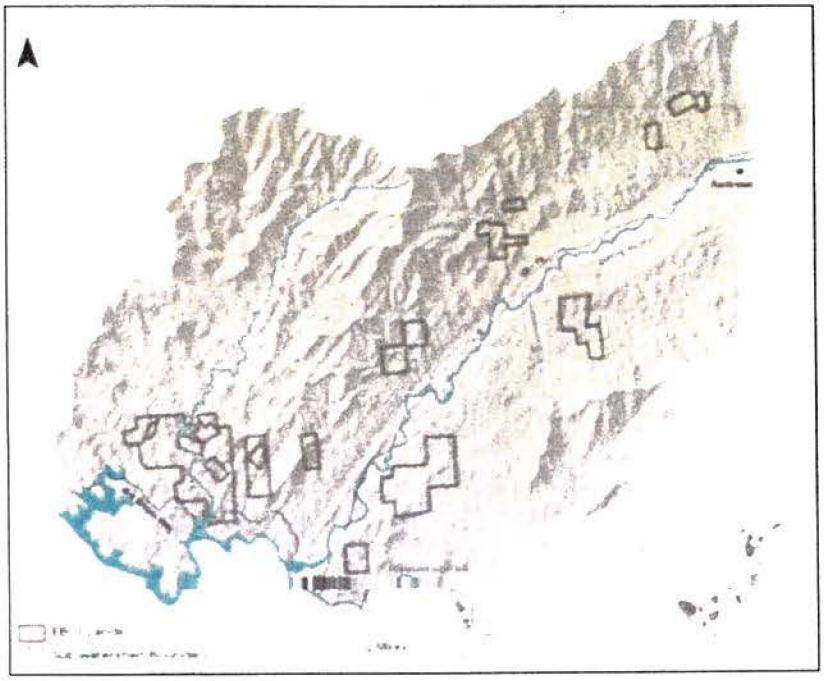


Cheoah River Sub-watershed

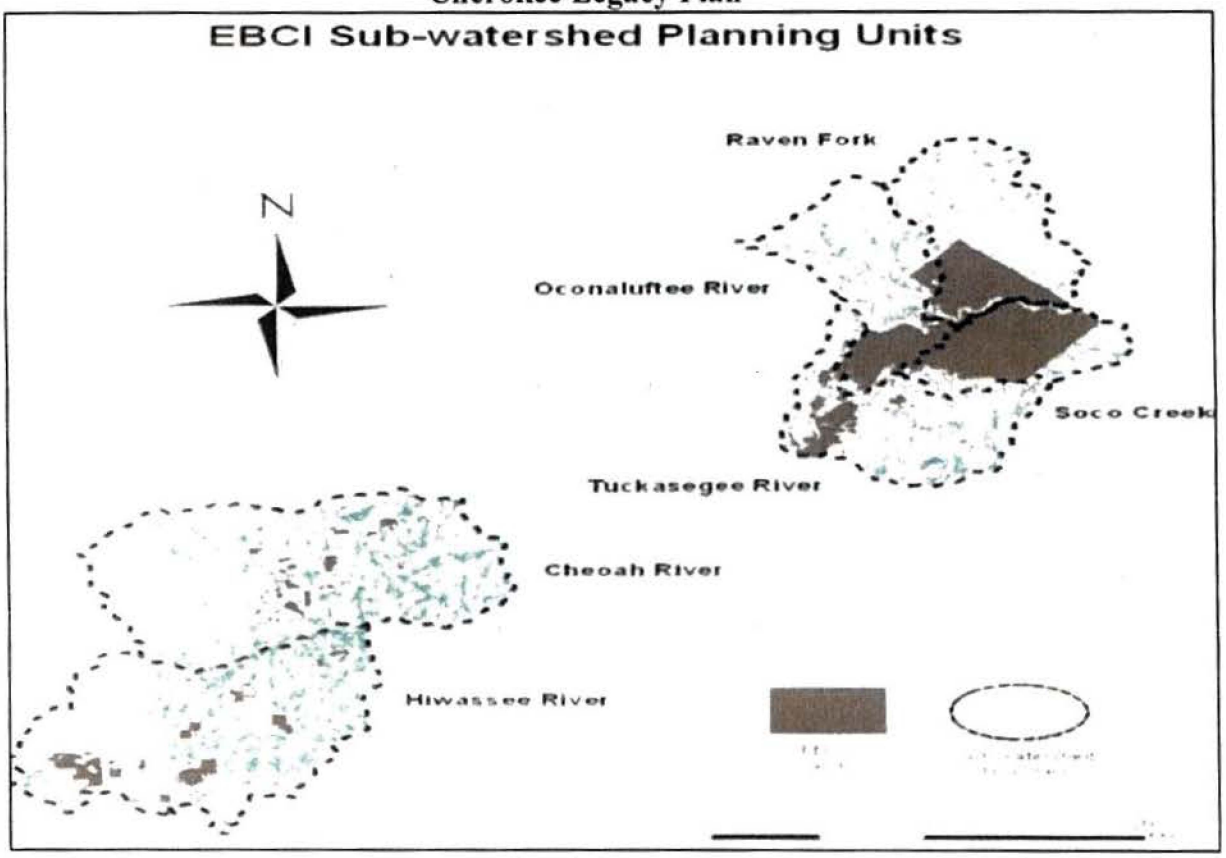


Cherokee County Map (Cherokee County)

Hiwasee River Sub-watershed



Cherokee Legacy Plan



Appendix D

Species accounts

1) *Alasmidonta raveneliane* (Appalachian elktoe)

The status of the Appalachian elktoe is endangered. The species was listed as endangered on November 23, 1994. CH areas for the Appalachian elktoe were designated on September 27, 2002.

Description: The Appalachian elktoe has a thin, kidney-shaped shell, extending to about 10 centimeters (4 inches). Juveniles generally have a yellowish-brown outer shell surface, while the outer shell of the adults is usually dark brown to greenish-black in color. Although rays are prominent on some shells, particularly in the posterior portion of the shell, many individuals have only obscure greenish rays. The shell nacre (inside shell surface) is shiny, often white to bluish-white, changing to a salmon, pinkish, or brownish color in the central and beak cavity portions of the shell; some specimens may be marked with irregular brownish blotches. The reproductive cycle of the species is similar to other native mussels. Males release sperm into the water, and the eggs are fertilized when the sperm are taken in by the females through their siphons during feeding and respiration. Females retain the fertilized eggs in their gills until the larvae (glochidia) are fully developed. The glochidia are released into the water and must attach to the gills or fins of the appropriate fish species. They remain attached to their fish host for several weeks, drawing nourishment from the fish while they develop into juvenile mussels. They do not hurt their fish host. The juvenile mussels then detach from the fish host and drop to the bottom of the stream where they continue to develop, provided they land in a suitable place with good water conditions. The dependence on a certain species of fish increases the mussels' vulnerability to habitat disturbances. If the fish host is lost due to habitat loss or other issues, the mussels can't reproduce and will eventually die out.

Habitat and Range: The species has been reported from relatively shallow, medium-sized creeks and rivers with cool, clean, well-oxygenated, moderate to fast-flowing water. The species is most often found in riffles, runs, and shallow flowing pools with stable, relatively silt-free, coarse sand and gravel substrate associated with cobble, boulders, and/or bedrock. Stability of the substrate appears to be critical to the Appalachian elktoe, and the species is seldom found in stream reaches with accumulations of silt or shifting sand, gravel, or cobble. Individuals that have been encountered in these areas are believed to have been scoured out of upstream areas during periods of heavy rain, and have not been found on subsequent surveys. The Appalachian elktoe is known only from the mountain streams of western North Carolina and eastern Tennessee. Although the complete historical range of the Appalachian elktoe is unknown, available information indicates that the species once lived in the majority of the rivers and larger creeks of the upper Tennessee River system in North Carolina. In Tennessee, the species is known only from its present range in the main stem of the Nolichucky River.

Currently, the Appalachian elktoe has a very fragmented distribution. The species survives in scattered pockets of suitable habitat in portions of the Little Tennessee River system, Pigeon River system, Mills River, and Little River in North Carolina, and the Nolichucky River systems in North Carolina and Tennessee. In the Little Tennessee River system in North Carolina, populations survive in the reach of the main stem of the Little Tennessee River, between the city of Franklin and Fontana Reservoir, in Swain and Macon Counties; and in scattered reaches of the main stem of the Tuckasegee River in

Jackson and Swain Counties from below Cullowhee, NC downstream to Bryson City, NC. The species occurs in the Cheoah River, from the Santeetlah Dam, downstream to its confluence with the Little Tennessee River in Graham County.

In the Pigeon River system in North Carolina, a limited population of the Appalachian elktoe occurs in small scattered sites in the West Fork Pigeon River and in the main stem of the Pigeon River, above Canton, in Haywood County. The species has been recorded from the Mills River (upper French Broad River system) in Henderson County; and, the Little River (upper French Broad River system) population of the species, in Transylvania County, North Carolina, is restricted to small scattered pockets of suitable habitat downstream of Cascade Lake. In the Nolichucky River system, the Appalachian elktoe survives in a few scattered areas of suitable habitat in the Toe River, Yancey and Mitchell Counties, North Carolina; Cane River, Yancey County, North Carolina; and the main stem of the Nolichucky River, Yancey and Mitchell Counties, North Carolina, extending downstream to the vicinity of Erwin in Unicoi County, Tennessee. It has also been found in the North Toe River, Yancey and Mitchell Counties, North Carolina, below the confluence of Crabtree Creek, and in the South Toe River, Yancey County, North Carolina. The majority of the surviving occurrences of the Appalachian elktoe appear to be small to extremely small and restricted to scattered pockets of suitable habitat.

Tribal Habitat: This species does not exist in any waters or streams within Tribal lands. The mainstem of the Tuckasegee River in Jackson and Swain Counties is designated CH for the Appalachian elktoe and is protected through the application of the North Carolina WQS.

Threats: Poor water quality and habitat conditions have led to the decline and loss of populations of the Appalachian elktoe and threaten the remaining populations. Studies have shown that freshwater mussels, especially in their early life stages, are extremely sensitive to many of the pollutants (chlorine, ammonia, heavy metals, etc.) commonly found in municipal and industrial wastewater releases. Impoundments (dams), channelization projects, and in-stream dredging operations directly eliminate habitat. These activities also alter the quality and stability of remaining stream reaches by affecting the water flow, temperature, and chemistry. Agriculture (both crop and livestock) and forestry operations, roads, residential areas, golf courses, and other construction activities that do not adequately control soil erosion and water run-off contribute excessive amounts of silt, pesticides, fertilizers, heavy metals, and other pollutants that suffocate and poison freshwater mussels. The alteration of floodplains or the removal of forested stream buffers can be especially detrimental. Flood plains and forested stream buffers help maintain water quality and stream stability by absorbing, filtering, and slowly releasing rainwater. This also helps recharge groundwater levels and maintain flows during dry months.

References:

LeGrand, Jr., H.E., J.T. Finnegan, S.E. McRae, S.P. Hall. 2010. Natural Heritage Program List of the Rare Animal Species of North Carolina. N.C. Natural Heritage Program, Raleigh, NC.
U.S. Fish and Wildlife Service. 1996. Appalachian Elktoe Recovery Plan. Atlanta, GA. 32 pp.

Citations:

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http://www.fws.gov/southeast/5yearReviews/5yearreviews/AppalachianElktoe20090305.pdf
http://ecos.fws.gov/crithab/
http://ecos.fws.gov/docs/federal_register/fr3975.pdf

http://www.fws.gov/raleigh/species/es_appalachian_elktoe.html
http://ecos.fws.gov/speciesProfile/profile/speciesProfile?spcode=F00L

2) *Spiraea virginiana* (Virginia spiraea)

The status of the Virginia spiraea is threatened. The species was listed as on June 15, 1990. 55 FR 24241 24247. There are no CH areas designated for the species.

Description: Virginia spiraea is a perennial shrub with many branches. It grows 3 to 10 feet tall. Its alternate leaves are single-tooth serrated; 1 to 6 inches long and 1 to 2 inches wide; occasionally curved; and have a narrow, moderately tapered base. The leaves are also darker green above than below. This plant produces flowers that are yellowish green to pale white, with stamens twice the length of the sepal. It blooms from late May to late July, but flower production is sparse and does not begin until after the first year of establishment. Virginia spiraea has a clonal root system that can fragment and produce more plants. This form of vegetative reproduction is more common than flower pollination and seed dispersal in this species.

Habitat and Range: Virginia spiraea occurs along rivers and streams and relies on periodic disturbances, such as high-velocity scouring floods, which eliminate competition from trees and other woody vegetation. However, if the frequency and intensity of these floods is too great, the plant may become dislodged and wash downstream into less suitable habitat. Virginia spiraea is a Southern Appalachian species, with isolated populations found in the mountain regions of Georgia, North Carolina, Tennessee, Kentucky, Virginia, Ohio, and West Virginia.

Tribal Habitat: The counties where this species may occur include Graham and Swain. The Cherokee Tribal lands in the Oconaluftee drainage area include approximately 63.4 square miles which represents about 34% of the Oconaluftee drainage area (p 14). According to the Legacy Plan, the total Tribal acreage includes 11,263 for Raven Fork (48 stream miles) and 11,043 for Oconaluftee River (50 stream miles) mainly within Swain County. In addition, within the Tuckasegee River drainage area of Tribal acrease is estimated at 4,107 acres (12 stream miles) mainly within Swain County. Tribal acreage in the Cheoah River drainage area of Graham County is estimated at approximately 2,404 out of the 186,880 (16 stream miles).

County	County Acres	Tribal Watershed Acres			Percentage of Tribal Acreage per County
Swain County[6]	337,920	11,263 Raven Fork	11,043 Oconaluftee	4,107 Tuckasegee	0.078%
Graham County[7]	186,880	2,404 Cheoah			0.013%

County	Tribal Watershed Stream miles[8]		
Swain County[9]	48 Raven Fork	50 Oconaluftee	12 Tuckasegee
Graham County[10]	16 Cheoah		

[6] https://www.ncpedia.org/geography/swain
[7] https://www.ncpedia.org/geography/graham
[8] Cherokee Legacy Plan
[9] https://www.ncpedia.org/geography/swain
[10] https://www.ncpedia.org/geography/graham

Therefore, Tribal acreage in the Oconaluftee River drainage area makes up approximately 26,413 out of the 337,920 acres of Swain County or about 0.078% including about 110 stream miles. Tribal acreage in the Cheoah River drainage area makes up approximately 2,404 out of the 186,880 acres of Graham County or about 0.013% including about 16 stream miles. In total, Tribal acreage makes up approximately 0.091% of all counties considered to have habitat for this species. The maps in Appendix C show the Tribal waters within the river watersheds and subwatersheds. The stream miles were approximated using information from the Cherokee Legacy Plan.

Threats: Due to its specific habitat requirements, Virginia spiraea is vulnerable to alterations of stream-flow patterns. Impoundments, road construction, unmanaged recreational use of river corridors, industrial development, lack of watershed management, and uncontrolled development of river corridors have already threatened and exterminated several populations of this species. Another threat to Virginia spiraea is competition from exotic invasive plants. This species has a relative lack of or limited records indicating locations on Tribal lands in Graham, Swain and Jackson Counties.Potential effects (beneficial or otherwise) to this species are due to flow and/or physical conditions rather than water quality, conditions that limit this species such as lack of seed germination and colonization, competition from other species, human disturbance and dams that prevent natural seasonal flooding and low flow conditions.

References:
https://www.fws.gov/asheville/htmls/listed_species/Virginia_spiraea.html

3) Myotis septentrionalis (**Northern Long-Eared Bat**)

The status of the *Myotis septentrionalis* is threatened. The species was listed as on April 2, 2015 80 FR 17973 18033. There are no CH areas designated for the species.

Description: The northern long-eared bat is a medium-sized bat about 3 to 3.7 inches in length but with a wingspan of 9 to 10 inches. As its name suggests, this bat is distinguished by its long ears, particularly as compared to other bats in its genus, Myotis, which are actually bats noted for their small ears (Myotis means mouse-eared). The northern long-eared bat is found across much of the eastern and north central United States and all Canadian provinces from the Atlantic coast west to the southern Northwest Territories and eastern British Columbia. The species' range includes 37 states.

Habitat: During summer, northern long-eared bats roost singly or in colonies underneath bark, in cavities, or in crevices of both live and dead trees. Males and non-reproductive females may also roost in cooler places, like caves and mines. This bat seems opportunistic in selecting roosts, using tree species based on suitability to retain bark or provide cavities or crevices. It has also been found, rarely, roosting in structures like barns and sheds. Northern long-eared bats spend winter hibernating in caves and mines, called hibernacula. They typically use large caves or mines with large passages and entrances; constant temperatures; and high humidity with no air currents. Specific areas where they hibernate have very high humidity, so much so that droplets of water are often seen on their fur. Within hibernacula, surveyors find them in small crevices or cracks, often with only the nose and ears visible.

Diet:
Adult Food Habits: Invertivore
Immature Food Habits: Invertivore
This species evidently is an opportunistic insectivore (Kunz 1973); prey composition varies widely among sites and seasons; diet includes Lepidoptera, Coleoptera, Neuroptera, Diptera, Hymenoptera, Homoptera, and Hemiptera[11] (Whitaker 1972, LaVal and LaVal 1980, Griffith and Gates 1985, Dodd et al. 2012; see also Ammerman et al. 2012r for a review of other recent information). These bats capture flying insects and also glean prey from plants or the forest floor.

Tribal Habitat: The counties where this species may occur include Jackson, Swain, Graham, Haywood and Cherokee Counties. Please refer to the table below for Tribal acreage and stream miles within the five counties identified for this species.

County	County Acres	Tribal Watershed Acres			Percentage of Tribal Acreage per County
Jackson County[12]	316,160	19,006 Soco	*11,043 Oconaluftee**	*4,107 Tuckasegee**	0.060%
Swain County[13]	337,920	11,263 Raven Fork	11,043 Oconaluftee	4,107 Tuckasegee	0.078%
Graham County[14]	186,880	2,404 Cheoah			0.013%
Cherokee County[15]	291,200	6,115 Hiwassee			0.021%
Haywood County[16]	349,440	<1 Pigeon			0.000%

*these watersheds exist mainly in Swain County

County	Tribal Watershed Stream miles[17]		
Jackson County[18]	75 Soco	50 Oconaluftee	12 Tuckasegee
Swain County[19]	48 Raven Fork	50 Oconaluftee	12 Tuckasegee
Graham County[20]	16 Cheoah		
Cherokee County[21]	36 Hiwassee		
Haywood County[22]	<0.5 Wolf Laurel Branch		

In total, Tribal acreage makes up approximately 0.172% of all Counties considered to have habitat for this species. The maps in Appendix C show the Tribal waters within the river watersheds and subwatersheds. The stream miles were approximated using information from the Cherokee Legacy Plan.

Range:
The species historical range included Alabama, Arkansas, Connecticut, Delaware, District of Columbia, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Vermont, Virginia, West Virginia, Wisconsin, and Wyoming. See below for information about where the species is known or believed to occur.

[11] Whitaker 1972, LaVal and LaVal 1980, Griffith and Gates 1985, Dodd et al. 2012; see also Ammerman et al. 2012r for a review of other recent information
[12] https://www.jacksonnc.org/county-history.html
[13] https://www.ncpedia.org/geography/swain
[14] https://www.ncpedia.org/geography/graham
[15] https://www.census.gov/quickfacts/fact/table/cherokeecountynorthcarolina/POP060210
[16] http://www.haywoodnc.net/index.php?option=com_content&view=category&layout=blog&id=83&Itemid=106
[17] Cherokee Legacy Plan
[18] https://www.jacksonnc.org/county-history.html
[19] https://www.ncpedia.org/geography/swain
[20] https://www.ncpedia.org/geography/graham
[21] https://www.census.gov/quickfacts/fact/table/cherokeecountynorthcarolina/POP060210
[22] http://www.haywoodnc.net/index.php?option=com_content&view=category&layout=blog&id=83&Itemid=106

Threats: White-nose syndrome, a fungal disease known to affect bats, is currently the predominant threat to this bat, especially throughout the Northeast where the species has declined by up to 99 percent from pre-white-nose syndrome levels at many hibernation sites. Although the disease has not yet spread throughout the northern long-eared bat's entire range (white-nose syndrome is currently found in at least 25 of 37 states where the northern long-eared bat occurs), it continues to spread. Experts expect that where it spreads, it will have the same impact as seen in the Northeast. Highway construction, commercial development, surface mining, and wind facility construction permanently remove habitat and are activities prevalent in many areas of this bat's range. Forest management benefits northern long-eared bats by keeping areas forested rather than converted to other uses. But, depending on type and timing, forest management activities can cause mortality and temporarily remove or degrade roosting and foraging habitat.

References:
https://www.fws.gov/Midwest/endangered/mammals/nleb/index.html

4) ***Myotis sodalis*** **(Indiana Bat)**

The status of the *Myotis sodalis* is threatened. The species was listed as on March 11, 1967. There are no CH areas designated for the species.

Description: The scientific name of the Indiana bat is Myotis sodalis and it is an accurate description of the species. Myotis means "mouse ear" and refers to the relatively small, mouse-like ears of the bats in this group. Sodalis is the Latin word for "companion." The Indiana bat is a very social species; large numbers cluster together during hibernation. The species is called the Indiana bat because the first specimen described to science in 1928 was based on a specimen found in southern Indiana's Wyandotte Cave in 1904. The Indiana bat is quite small, weighing only one-quarter of an ounce (about the weight of three pennies). In flight, it has a wingspan of 9 to 11 inches. The fur is dark-brown to black. The Indiana bat is similar in appearance to many other related species. Biologists can distinguish it from similar species by comparing characteristics such as the structure of the foot and color variations in the fur.

Habitat: Indiana bats hibernate during winter in caves or, occasionally, in abandoned mines. For hibernation, they require cool, humid caves with stable temperatures, under 50° F but above freezing. Very few caves within the range of the species have these conditions. Hibernation is an adaptation for survival during the cold winter months when no insects are available for bats to eat. Bats must store energy in the form of fat before hibernating. During the six months of hibernation the stored fat is their only source of energy. If bats are disturbed or cave temperatures increase, more energy is needed and hibernating bats may starve. After hibernation, Indiana bats migrate to their summer habitat in wooded areas where they usually roost under loose tree bark on dead or dying trees. During summer, males roost alone or in small groups, while females roost in larger groups of up to 100 bats or more. Indiana bats also forage in or along the edges of forested areas.

Diet:
Adult Food Habits: Invertivore
Immature Food Habits: Invertivore

Flying insects are the typical prey items; diet reflects prey present in available foraging habitat. Forages along river and lake shorelines, in the crowns of trees in floodplains[23] and in upland forest[24]. In Illinois, generally foraged within about a mile of roost tree[25]. In Indiana, reproductively active females showed a preference for foraging in floodplain forests with closed canopies and impounded water such as farm ponds[26]. The foraging habitat for an Indiana colony included an airspace 2-30 m above a stream and a linear distance of 0.8 km; foraging density was 17-29 bats/ha; feeding rate on aerial insects was 8-17 capture attempts/minute[27].

Tribal Habitat: The counties where this species may occur include Jackson, Swain, Graham, Haywood and Cherokee Counties. Please refer to the table below for Tribal acreage and stream miles within the five counties identified for this species.

County	Acres	Tribal Watershed Acres			Percentage of Tribal Acreage per County
Swain County[28]	337,920	11,263 Raven Fork	11,043 Oconaluftee	4,107 Tuckasegee	0.078%
Graham County[29]	186,880	2,404 Cheoah			0.013%
Cherokee County[30]	291,200	6,115 Hiwassee			0.021%
Haywood County[31]	349,440	<1 Pigeon			0.000%

County	Tribal Watershed Stream miles[32]		
Swain County[33]	48 Raven Fork	50 Oconaluftee	12 Tuckasegee
Graham County[34]	16 Cheoah		
Cherokee County[35]	36 Hiwassee		
Haywood County[36]	<0.5 Wolf Laurel Branch		

In total, Tribal acreage makes up approximately 0.112% of all Counties considered to have habitat for this species. The maps in Appendix C show the Tribal waters within the river watersheds and subwatersheds. The stream miles were approximated using information from the Cherokee Legacy Plan.

Range: Indiana bats are found over most of the eastern half of the United States. Almost half of all Indiana bats (207,000 in 2005) hibernate in caves in southern Indiana. In 2005, other states which supported populations of over 40,000 included Missouri (65,000), Kentucky (62,000), Illinois (43,000) and New York (42,000). Other states within the current range of the Indiana bat include Alabama, Arkansas, Connecticut, Iowa, Maryland, Michigan, New Jersey, North Carolina, Ohio, Oklahoma, Pennsylvania, Tennessee, Vermont, Virginia, West Virginia. The 2005 population estimate is about 457,000 Indiana bats, half as many as when the species was listed as endangered in 1967.

[23] Humphrey et al. 1977
[24] Brack and LaVal 1985
[25] Garner and Gardner 1992
[26] Garner and Gardner 1992
[27] Humphrey et al. 1977
[28] https://www.ncpedia.org/geography/swain
[29] https://www.ncpedia.org/geography/graham
[30] https://www.census.gov/quickfacts/fact/table/cherokeecountynorthcarolina/POP060210
[31] http://www.haywoodnc.net/index.php?option=com_content&view=category&layout=blog&id=83&Itemid=106
[32] Cherokee Legacy Plan
[33] https://www.ncpedia.org/geography/swain
[34] https://www.ncpedia.org/geography/graham
[35] https://www.census.gov/quickfacts/fact/table/cherokeecountynorthcarolina/POP060210
[36] http://www.haywoodnc.net/index.php?option=com_content&view=category&layout=blog&id=83&Itemid=106

Threats: Indiana bats, because they hibernate in large numbers in only a few caves, are extremely vulnerable to disturbance. During hibernation, they cluster in groups of up to 500 per square foot. Since the largest hibernation caves support from 20,000 to 50,000 bats, it is easy to see how a large part of the total population can be affected by a single event. Episodes of large numbers of Indiana bat deaths have occurred due to human disturbance during hibernation. The commercialization of caves – allowing visitors to tour caves during hibernation – drives bats away. Changes in the structure of caves, such as blocking an entrance, can change the temperature in a cave. A change of even a few degrees can make a cave unsuitable for hibernating bats. Some caves are fitted with gates to keep people out, but improper gating that prevents access by bats or alters air flow, temperature, or humidity can also be harmful. Properly constructed gates are beneficial because they keep people from disturbing hibernating bats while maintaining temperature and other requirements and allowing access for bats. Indiana bats use trees as roosting and foraging sites during summer months. Loss and fragmentation of forested habitats can affect bat populations. Insect-eating bats may seem to have an unlimited food supply, but in local areas, insects may not be plentiful because of pesticide use. This can also affect the quality of the bats' food supply. Many scientists believe that population declines occurring today might be due, in part, to pesticides and environmental contaminants. Bats may be affected by eating contaminated insects, drinking contaminated water, or absorbing the chemicals while feeding in areas that have been recently treated.

References:
https://www.fws.gov/midwest/endangered/mammals/inba/inbafctsht.html

5) *Myotis grisescens* (Gray Bat)

The status of the Myotis grisescens is threatened. The species was listed as on April 28, 1976. There are no CH areas designated for the species.

Description: Gray bats are distinguished from other bats by the unicolored fur on their back. In addition, following their molt in July or August, gray bats have dark gray fur which often bleaches to a chestnut brown or russet. They weigh 7-16 grams. The bat's wing membrane connects to its ankle instead of at the toe, where it is connected in other species of Myotis.

Habitat: With rare exceptions, gray bats live in caves year-round. During the winter gray bats hibernate in deep, vertical caves. In the summer, they roost in caves which are scattered along rivers. These caves are in limestone karst areas of the southeastern United States. They do not use houses or barns.

Diet:
Adult Food Habits: Invertivore
Immature Food Habits: Invertivore
This species feeds mostly upon flying insects, including mayflies (Choroterpes spp., Stenocron spp.) and beetles[37]. Diet may vary with local resources and habitat.

Tribal Habitat: The counties where this species may occur include Jackson, Swain, Graham, Haywood and Cherokee Counties. Please refer to the table below for Tribal acreage and stream miles within the five counties identified for this species.

[37] Tuttle et al., Lacki et al. 1995

County	Acres	Tribal Watershed Acres			Percentage of Tribal Acreage per County
Swain County[38]	337,920	11,263 Raven Fork	11,043 Oconaluftee	4,107 Tuckasegee	0.078%
Haywood County[39]	349,440	<1 Pigeon			0.000%

County	Tribal Watershed Stream miles		
Swain County[40]	48 Raven Fork	50 Oconaluftee	12 Tuckasegee
Haywood County[41]	<0.5 Wolf Laurel Branch		

In total, Tribal acreage makes up approximately 0.078% of all Counties considered to have habitat for this species. The maps in Appendix C show the Tribal waters within the river watersheds and subwatersheds. The stream miles were approximated using information from the Cherokee Legacy Plan.

Range: The gray bat occupies a limited geographic range in limestone karst areas of the southeastern United States. They are mainly found in Alabama, northern Arkansas, Kentucky, Missouri, and Tennessee. A few can be found in northwestern Florida, western Georgia, southeastern Kansas, southern Indiana, southern and southwestern Illinois, northeastern Oklahoma, northeastern Mississippi, western Virginia, and possibly western North Carolina.

Threats: Habitat loss through the flooding of reservoirs, cave commercialization and improper gating of caves are listed as the main threats to this species.

References:
https://www.fws.gov/midwest/endangered/mammals/grbat_fc.html

[38] https://www.ncpedia.org/geography/swain
[39] http://www.haywoodnc.net/index.php?option=com_content&view=category&layout=blog&id=83&Itemid=106
[40] https://www.ncpedia.org/geography/swain
[41] http://www.haywoodnc.net/index.php?option=com_content&view=category&layout=blog&id=83&Itemid=106

15A NCAC 02B .0206 is amended as published in 28:24 NCR 3004-3032 as follows:

15A NCAC 02B .0206 FLOW DESIGN CRITERIA FOR EFFLUENT LIMITATIONS

(a) Water quality based effluent limitations ~~are~~ shall be developed to allow appropriate frequency and duration of deviations from water quality standards so that the designated uses of receiving waters are protected. There are water quality standards for a number of categories of pollutants and to protect a range of water uses. For this reason, the appropriate frequency and duration of deviations from water quality standards ~~is not~~ shall not be the same for all categories of standards. A flow design criterion ~~is~~ shall be used in the development of water quality based effluent limitations as a simplified means of estimating the acceptable frequency and duration of deviations. More complex modeling techniques ~~can~~ may also be used to set effluent limitations directly based on frequency and duration criteria published by the U.S. Environmental Protection Agency available free of charge ~~pursuant to Section 304(a) of the Federal Clean Water Act as amended.~~ at http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm are hereby incorporated by reference including any subsequent amendments. Use of more complex modeling techniques to set water quality based effluent limitations ~~will~~ shall be approved by the Commission or its designee on a case-by-case basis. Flow design criteria to calculate water quality based effluent limitations for categories of water quality standards ~~are listed as follows:~~ shall be the following:

(1) All standards except toxic substances and aesthetics ~~will~~ shall be protected using the minimum average flow for a period of seven consecutive days that has an average recurrence of once in ten years (7Q10 flow). Other governing flow ~~strategies~~ strategies, such as varying discharges with the receiving waters ability to assimilate ~~wastes~~wastes, may be designated by the Commission or its designee on a case-by-case basis if the discharger or permit applicant ~~provide~~ provides evidence ~~which~~ that establishes to the satisfaction of the Director that the alternative flow strategies will give equal or better protection for the water quality standards. ~~Better~~ "Better protection for the water quality ~~standards~~ standards" means that deviations from the standard would be expected less frequently than provided by using the 7Q10 flow.

(2) Toxic substance standards to protect aquatic life from chronic toxicity ~~will~~ shall be protected using the 7Q10 flow.

(3) Toxic substance standards to protect aquatic life from acute toxicity [~~will~~] shall be protected using the 1Q10 flow.

~~(3)~~(4) Toxic substance standards to protect human health ~~will be:~~ shall be the following:

(A) The 7Q10 flow for standards to protect human health through the consumption of water, ~~fish~~ fish, and shellfish from ~~noncarcinogens;~~ noncarcinogens; and

(B) The mean annual flow to protect human health from carcinogens through the consumption of water, ~~fish~~ fish, and shellfish unless site specific fish contamination concerns necessitate the use of an alternative design flow;

~~(4)~~(5) Aesthetic quality ~~will~~ shall be protected using the minimum average flow for a period of 30 consecutive days that has an average recurrence of once in two years (30Q2 flow).

(b) In cases where the stream flow is regulated, a minimum daily low flow may be used as a substitute for the 7Q10 ~~flow~~ flow, except in cases where there are acute toxicity concerns for aquatic life. In the cases where there are acute toxicity concerns, an alternative low ~~flow~~ flow, such as the instantaneous minimum ~~release~~ release, shall be approved by the Director ~~may be used~~ on a case-by-case ~~basis.~~basis so that the designated uses of receiving waters are protected.

(c) Flow design criteria ~~are~~ shall be used to develop water quality based effluent limitations and for the design of wastewater treatment facilities. Deviations from a specific water quality standard resulting from discharges ~~which~~ that are affirmatively demonstrated to be in compliance with water quality based effluent limitations for that standard ~~will~~ shall not be a violation pursuant to G.S. 143-215.6 when the actual flow is significantly less than the design flow.

(d) In cases where the 7Q10 flow of the receiving stream is estimated to be zero, water quality based effluent limitations ~~will~~ shall be assigned as follows:

(1) Where the 30Q2 flow is estimated to be greater than zero, effluent limitations for new or expanded (additional) discharges of oxygen consuming waste ~~will~~ shall be set at BOD_5= 5 mg/l, NH_3-N = 2 mg/l and DO = 6 mg/l, unless it is determined by the Director that these limitations will not protect water quality standards. Requirements for existing discharges ~~will~~ shall be determined on a case-by-case basis by the Director. More stringent limits ~~will~~ shall be applied in cases where violations of water quality standards are predicted to occur for a new or expanded discharge with the limits set pursuant to this Rule, or where existing limits are determined to be inadequate to protect water quality standards.

(2) If the 30Q2 and 7Q10 flows are both estimated to be zero, no new or expanded (additional) discharge of oxygen consuming waste ~~will~~ shall be allowed. Requirements for existing discharges to streams where the 30Q2 and 7Q10 flows are both estimated to be zero ~~will~~ shall be determined on a case-by-case basis.

(3) Other water quality standards ~~will~~shall be protected by requiring the discharge to meet the standards unless the Director determines that alternative limitations ~~are determined by the Director to~~ protect the classified water uses.

(e) Receiving water flow statistics ~~will~~ shall be estimated through consultation with the U.S. Geological Survey. Estimates for any given location may be based on actual flow data, modeling analyses, or other methods determined to be appropriate by the Commission or its designee.

History Note: *Authority G.S. 143-214.1; 143-215.3(a)(1);*
Eff. February 1, 1976;
Amended Eff. January 1, 2015; February 1, 1993; October 1, 1989; August 1, 1985; January 1, 1985.

15A NCAC 02B .0211 is amended with changes as published in 28:24 NCR 3004-3032 as follows:

15A NCAC 02B .0211 FRESH SURFACE WATER QUALITY STANDARDS FOR CLASS C WATERS

General. The water quality standards for all fresh surface waters ~~are~~ shall be the basic standards applicable to Class C waters. ~~See Rule .0208 of this Section for standards for toxic substances and temperature.~~ Water quality standards for temperature and numerical water quality standards for the protection of human health applicable to all fresh surface waters are in Rule .0208 of this Section. Additional and more stringent standards applicable to other specific freshwater classifications are specified in Rules .0212, .0214, .0215, .0216, ~~.0217,~~ .0218, .0219, .0223, .0224 and .0225 of this Section. Action Levels for purposes of National Pollutant Discharge Elimination System (NPDES) [~~NPDES~~] permitting are specified in Item (22) of this Rule.

(1) Best Usage of Waters: aquatic life propagation and maintenance of biological integrity (including fishing and fish), wildlife, secondary recreation, ~~agriculture~~ agriculture, and any other usage except for primary recreation or as a source of water supply for drinking, ~~culinary~~ culinary, or food processing purposes;

(2) Conditions Related to Best Usage: the waters shall be suitable for aquatic life propagation and maintenance of biological integrity, wildlife, secondary recreation, and agriculture. Sources of water pollution ~~which~~ that preclude any of these uses on either a short-term or long-term basis shall be considered to be violating a water quality standard;

~~(3) Quality standards applicable to all fresh surface waters:~~

(3) Chlorine, total residual: 17 ug/l;

(4)~~(a)~~ Chlorophyll a (corrected): not greater than 40 ug/l for lakes, reservoirs, and other waters subject to growths of macroscopic or microscopic vegetation not designated as trout waters, and not greater than 15 ug/l for lakes, reservoirs, and other waters subject to growths of macroscopic or microscopic vegetation designated as trout waters (not applicable to lakes or reservoirs less than 10 acres in surface area). The Commission or its designee may prohibit or limit any discharge of waste into surface waters ~~if, in the opinion of the Director,~~ if the surface waters experience or the discharge would result in growths of microscopic or macroscopic vegetation such that the standards established pursuant to this Rule would be violated or the intended best usage of the waters would be impaired;

(5) Cyanide, total: 5.0 ug/L;

(6)~~(b)~~ Dissolved oxygen: not less than 6.0 mg/l for trout waters; for non-trout waters, not less than a daily average of 5.0 mg/l with a minimum instantaneous value of not less than 4.0 mg/l; swamp waters, lake ~~coves~~ coves, or backwaters, and lake bottom waters may have lower values if caused by natural conditions;

(7) Fecal coliform: shall not exceed a geometric mean of 200/100ml (MF count) based upon at least five consecutive samples examined during any 30 day period, nor exceed 400/100ml in more than 20 percent of the samples examined during such period. Violations of the fecal coliform standard

are expected during rainfall events and, in some cases, this violation is expected to be caused by uncontrollable nonpoint source pollution. All coliform concentrations [~~are to~~]shall be analyzed using the membrane filter [~~technique~~] technique, unless high turbidity or other adverse conditions necessitate the tube dilution[~~method;~~] method. [~~in~~]In case of controversy over results, the MPN 5-tube dilution technique shall be used as the reference method;

(8)~~(c)~~ Floating solids, settleable solids, or sludge deposits: only such amounts attributable to sewage, industrial ~~wastes~~ wastes, or other wastes as shall not make the water unsafe or unsuitable for aquatic life and wildlife or impair the waters for any designated uses;

(9) Fluorides: 1.8 mg/l;

(10)~~(d)~~ Gases, total dissolved: not greater than 110 percent of saturation;

~~(e) Organisms of the coliform group: fecal coliforms shall not exceed a geometric mean of 200/100ml (MF count) based upon at least five consecutive samples examined during any 30 day period, nor exceed 400/100ml in more than 20 percent of the samples examined during such period. Violations of the fecal coliform standard are expected during rainfall events and, in some cases, this violation is expected to be caused by uncontrollable nonpoint source pollution. All coliform concentrations are to be analyzed using the membrane filter technique unless high turbidity or other adverse conditions necessitate the tube dilution method; in case of controversy over results, the MPN 5-tube dilution technique shall be used as the reference method;~~

(11) Metals:

(a) With the exception of mercury and selenium, freshwater aquatic life standards for metals shall be based upon measurement of the dissolved fraction of the metal. Mercury and [~~Selenium~~] selenium water quality standards [~~must~~] shall be based upon measurement of the total recoverable ~~metal.~~metal; [~~Alternative site-specific metals standards can be developed where studies are designed in accordance with the "Water Quality Standards Handbook: Second Edition" published by the US Environmental Protection Agency (EPA 823-B-94-005a) hereby incorporated by reference including any subsequent amendments;~~]

(b) Freshwater metals standards that are not hardness-dependent [~~are~~] shall be as follows:

(i) Arsenic, dissolved, acute: WER· 340 ug/l;

(ii) Arsenic, dissolved, chronic: WER· 150 ug/l;

(iii) Beryllium, dissolved, acute: WER· 65 ug/l;

(iv) Beryllium, dissolved, chronic: WER· 6.5 ug/l;

(v) Chromium VI, dissolved, acute: WER· 16 ug/l;

(vi) Chromium VI, dissolved, chronic: WER· 11 ug/l;

(vii) Mercury, total recoverable, chronic: 0.012 ug/l;

(viii) Selenium, total recoverable, chronic: 5 ug/l;

(ix) Silver, dissolved, chronic: WER· 0.06 ug/l;

With the exception of mercury and selenium, acute and chronic freshwater aquatic life standards for metals listed [~~above~~] in this Subparagraph apply to the dissolved form of the metal and apply as a function of the pollutant's water effect ratio (WER). A WER [~~is a factor that~~] expresses the difference between the measures of the toxicity of a substance in laboratory waters and the toxicity in site water. The WER [~~is~~]shall be assigned a value equal to one [~~(1)~~]unless any person demonstrates to the [~~Department's~~]Division's satisfaction in a permit proceeding that another value is [~~appropriately~~] developed in accordance with the "Water Quality Standards Handbook: Second Edition" published by the US Environmental Protection Agency (EPA-823-B-12-002), free of charge, at http://water.epa.gov/scitech/swguidance/standards/handbook/, hereby incorporated by reference including any subsequent amendments. Alternative site-specific standards [~~can~~] may also be developed when any person submits values that demonstrate to the Commissions' satisfaction that they were derived in accordance with the "Water Quality Standards Handbook: Second Edition, Recalculation Procedure or the Resident Species [~~Procedure".~~]Procedure", hereby incorporated by reference including subsequent amendments at http://water.epa.gov/scitech/swguidance/standards/handbook/.

This material is available free of charge.

Hardness-dependent freshwater metals standards are located in Sub-Item (c) and (d) and in Table A: Dissolved Freshwater Standards for Hardness-Dependent Metals;

(c) Hardness-dependent freshwater metals standards [~~are~~] shall be as follows:

(i) Hardness-dependent metals standards shall be derived using the equations specified in Table A: Dissolved Freshwater Standards for Hardness-Dependent Metals. If the actual instream hardness (expressed as $CaCO_3$ or Ca+Mg) is less than 25 milligrams/liter (mg/l), standards shall be calculated based upon 25 mg/l hardness. If the actual instream hardness is greater than 25 mg/l and less than 400 mg/l, standards [~~will~~] shall be calculated based upon the actual instream hardness. If the instream hardness is greater than 400 mg/l, the maximum applicable hardness shall be 400 mg/l;

(ii) Hardness-dependent metals [~~standards~~] in NPDES permitting: for NPDES permitting purposes, application of the equations in Table A: Dissolved Freshwater Standards for Hardness-Dependent Metals [~~requires~~] shall have hardness values (expressed as $CaCO_3$ or Ca+Mg) established using the median of instream hardness data collected within the local US Geological Survey (USGS) and Natural Resources Conservation Service (NRCS) 8-digit Hydrologic Unit (HU). The minimum applicable instream hardness shall be 25 mg/l and the maximum applicable instream hardness shall be 400 mg/l, even when the actual median instream hardness is less than 25 mg/l and greater than 400 mg/l;

(d) Alternatives:

Acute and chronic freshwater aquatic life standards for metals listed in Table A apply to the dissolved form of the metal and apply as a function of the pollutant's water effect ratio[~~(WER).~~](WER), which is set forth in Sub-Item (b). [~~A WER is a factor that expresses the difference between the measures of the toxicity of a substance in laboratory waters and the toxicity in site water. The WER is assigned a value equal to one (1) unless any person demonstrates to the Department's satisfaction in a permit proceeding that another value is appropriately developed in accordance with the "Water Quality Standards Handbook: Second Edition" published by the US Environmental Protection Agency (EPA-823-B-12-002) hereby incorporated by reference including any subsequent amendments.~~ Alternative site-specific standards [~~can~~] may also be developed as set forth in Sub-Item (b); [~~when any person submits values that demonstrate to the Commissions' satisfaction that they were derived in accordance with the "Water Quality Standards Handbook: Second Edition, Recalculation Procedure or the Resident Species Procedure";~~]

Table A: Dissolved Freshwater Standards for Hardness-Dependent Metals

Numeric standards[~~listed below are~~]calculated at 25 mg/l hardness are listed below for illustrative purposes. The Water Effects Ratio (WER) is equal to one [~~(1)~~] unless determined otherwise under [~~15A NCAC 02B .0211 (d).~~] Sub-Item (d) of this rule.

Metal	Equations for Hardness-Dependent Freshwater Metals (ug/l)	Standard at 25 mg/l hardness (ug/l)
Cadmium, Acute	WER· [{1.136672-[*ln* hardness](0.041838)} · *e*^{0.9151 [*ln* hardness]-3.1485}]	0.82
Cadmium, Acute, Trout waters	WER· [{1.136672-[*ln* hardness](0.041838)} · *e*^{0.9151[*ln* hardness]-3.6236}]	0.51
Cadmium, Chronic	WER· [1.101672-[*ln* hardness](0.041838)} · *e*^{0.7998[*ln* hardness]-4.4451}]	0.15
Chromium III, Acute	WER· [0.316 · *e*^{0.8190[*ln* hardness]+3.7256}]	180
Chromium III, Chronic	WER· [0.860 · *e*^{0.8190[*ln* hardness]+0.6848}]	24
Copper, Acute	WER· [0.960 · *e*^{0.9422[*ln* hardness]-1.700}] Or, Aquatic Life Ambient Freshwater Quality Criteria—Copper 2007 Revision	3.6 NA

	(EPA-822-R-07-001)	
Copper, Chronic	WER· [0.960 · *e*^{0.8545[*ln* hardness]-1.702}] Or, Aquatic Life Ambient Freshwater Quality Criteria—Copper 2007 Revision (EPA-822-R-07-001)	2.7 NA
Lead, Acute	WER· [{1.46203-[*ln* hardness](0.145712)} · *e*^{1.273[*ln* hardness]-1.460}]	14
Lead, Chronic	WER· [{1.46203-[*ln* hardness](0.145712)} · *e*^{1.273[*ln* hardness]-4.705}]	0.54
Nickel, Acute	WER· [0.998 · *e*^{0.8460[*ln* hardness]+2.255}]	140
Nickel, Chronic	WER· [0.997 · *e*^{0.8460[*ln* hardness]+0.0584}]	16
Silver, Acute	WER· [0.85 · *e*^{1.72[*ln* hardness]-6.59}]	0.30
Zinc, Acute	WER· [0.978 · *e*^{0.8473[*ln* hardness]+0.884}]	36
Zinc, Chronic	WER· [0.986 · *e*^{0.8473[*ln* hardness]+0.884}]	36

[~~(d)~~](e) Compliance with acute instream metals standards shall only be evaluated using an average of two or more samples collected within one hour. Compliance with chronic instream metals standards shall only be evaluated using averages of a minimum of four samples taken on consecutive days, or as a 96-hour average;

[~~(e) With the exception of mercury and selenium, demonstrated attainment of the applicable aquatic life use in a waterbody will take precedence over the application of the aquatic life criteria established for metals associated with these uses. An instream exceedence of the numeric criterion for metals shall not be considered to have caused an adverse impact to the instream aquatic community if biological monitoring has demonstrated attainment of biological integrity.~~]

(f) Metals criteria [~~will~~] shall be used for proactive environmental management. An instream exceedence of the numeric criterion for metals shall not be considered to have caused an adverse impact to the instream aquatic community without biological confirmation and a comparison of all available monitoring data and applicable water quality standards. This weight of evidence evaluation [~~will~~]shall take into account data quality and the overall confidence in how representative the sampling is of conditions in the waterbody segment before an assessment of aquatic life use attainment, or non-attainment, [~~is~~] shall be made by the Division. Recognizing the synergistic and antagonistic complexities of other water quality variables on the actual toxicity of metals, with the exception of mercury and selenium, biological monitoring will be used to validate, by direct measurement, whether or not the aquatic life use is supported;

~~(f)~~(12) Oils, deleterious substances, ~~colored~~ colored, or other wastes: only such amounts as shall not render the waters injurious to public health, secondary ~~recreation~~ recreation, or to aquatic life and

~~wildlife~~ wildlife, or adversely affect the palatability of fish, aesthetic ~~quality~~ quality, or impair the waters for any designated uses. For the purpose of implementing this Rule, oils, deleterious substances, ~~colored~~ colored, or other wastes shall include ~~but not be limited to~~ substances that cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines pursuant to 40 CFR 110.3(a)-(b) which are hereby incorporated by reference including any subsequent amendments and additions. This material is ~~available~~available, free of charge, at: http://www.ecfr.gov/; ~~for inspection at the Department of Environment and Natural Resources, Division of Water Quality,~~ [~~Water Resources,~~] ~~512 North Salisbury Street, Raleigh, North Carolina.~~[~~Carolina;~~] ~~Copies may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402-9325 at a cost of forty-five dollars ($45.00);D.C.;~~

(13) Pesticides:

(a) Aldrin: 0.002 ug/l;

(b) Chlordane: 0.004 ug/l;

(c) DDT: 0.001 ug/l;

(d) Demeton: 0.1 ug/l;

(e) Dieldrin: 0.002 ug/l;

(f) Endosulfan: 0.05 ug/l;

(g) Endrin: 0.002 ug/l;

(h) Guthion: 0.01 ug/l;

(i) Heptachlor: 0.004 ug/l;

(j) Lindane: 0.01 ug/l;

(k) Methoxychlor: 0.03 ug/l;

(l) Mirex: 0.001 ug/l;

(m) Parathion: 0.013 [~~ug/l;~~] ug/l; and

(n) Toxaphene: 0.0002 ug/l;

~~(g)~~(14) pH: shall be normal for the waters in the area, which ~~generally shall~~ range between 6.0 and 9.0 except that swamp waters may have a pH as low as 4.3 if it is the result of natural conditions;

~~(h)~~(15) Phenolic compounds: only such levels as shall not result in fish-flesh tainting or impairment of other best usage;

(16) Polychlorinated biphenyls (total of all PCBs and congeners identified): 0.001 ug/l;

~~(i)~~(17) Radioactive substances:

~~(i)~~(a) Combined radium-226 and radium-228: the ~~maximum~~ average annual activity level (based on at least one sample collected per quarter)~~four samples collected quarterly)~~ for combined radium-226 and radium-228 shall not exceed five picoCuries per liter;

~~(ii)~~(b) Alpha Emitters: the average annual gross alpha particle activity (including radium-226, but excluding radon and uranium) shall not exceed 15 picoCuries per liter;

~~(iii)~~(c) Beta Emitters: the ~~maximum~~ average annual activity level (based on at least one sample collected per quarter) ~~four samples, collected quarterly)~~ for strontium-90 shall not exceed eight picoCuries per liter; nor shall the average annual gross beta particle activity (excluding potassium-40 and other naturally occurring ~~radio-nuclides)~~radionuclides) exceed 50 picoCuries per liter; nor shall the ~~maximum~~ average annual activity level for tritium exceed 20,000 picoCuries per liter;

~~(j)~~(18) Temperature: not to exceed 2.8 degrees C (5.04 degrees F) above the natural water temperature, and in no case to exceed 29 degrees C (84.2 degrees F) for mountain and upper piedmont waters and 32 degrees C (89.6 degrees F) for lower piedmont and coastal plain Waters; the temperature for trout waters shall not be increased by more than 0.5 degrees C (0.9 degrees F) due to the discharge of heated liquids, but in no case to exceed 20 degrees C (68 degrees F);

(19) Toluene: 11 ug/l or 0.36 ug/l in trout classified waters;

(20) Trialkyltin compounds: 0.07 ug/l expressed as tributyltin;

~~(k)~~(21) Turbidity: the turbidity in the receiving water shall not exceed 50 Nephelometric Turbidity Units (NTU) in streams not designated as trout waters and 10 NTU in streams, ~~lakes~~ lakes, or reservoirs designated as trout waters; for lakes and reservoirs not designated as trout waters, the turbidity shall not exceed 25 NTU; if turbidity exceeds these levels due to natural background conditions, the existing turbidity level shall not be increased. Compliance with this turbidity standard can be met when land management activities employ Best Management Practices (BMPs) [as defined by Rule .0202 of this Section] recommended by the Designated Nonpoint Source Agency [as defined by Rule .0202 of this Section]. BMPs ~~must~~ shall be in full compliance with all specifications governing the proper design, installation, ~~operation~~ operation, and maintenance of such BMPs;

~~(l) Toxic substances: numerical water quality standards (maximum permissible levels) for the protection of human health applicable to all fresh surface waters are in Rule .0208 of this Section. Numerical water quality standards (maximum permissible levels) to protect aquatic life applicable to all fresh surface waters:~~

~~(i) Arsenic: 50 ug/l;~~

~~(ii) Beryllium: 6.5 ug/l;~~

~~(iii) Cadmium: 0.4 ug/l for trout waters and 2.0 ug/l for non-trout waters; attainment of these water quality standards in surface waters shall be based on measurement of total recoverable metals concentrations unless appropriate studies have been conducted to translate total recoverable metals to a toxic form. Studies used to determine the toxic form or translators must be designed according to the "Water Quality Standards Handbook Second Edition" published by the Environmental Protection Agency (EPA 823-B-94-005a) or "The Metals Translator: Guidance For Calculating a Total Recoverable Permit Limit From a Dissolved Criterion" published by the Environmental Protection Agency (EPA 823-B-96-007) which~~

~~are hereby incorporated by reference including any subsequent amendments. The Director shall consider conformance to EPA guidance as well as the presence of environmental conditions that limit the applicability of translators in approving the use of metal translators;~~

~~(iv) Chlorine, total residual: 17 ug/l;~~

~~(v) Chromium, total recoverable: 50 ug/l;~~

~~(vi) Cyanide, 5.0 ug/l, unless site specific criteria are developed based upon the aquatic life at the site utilizing The Recalculation Procedure in Appendix B of Appendix L in the Environmental Protection Agency's Water Quality Standards Handbook hereby incorporated by reference including any subsequent amendments;~~

~~(vii) Fluorides: 1.8 mg/l;~~

~~(viii) Lead, total recoverable: 25 ug/l, collection of data on sources, transport and fate of lead shall be required as part of the toxicity reduction evaluation for dischargers who are out of compliance with whole effluent toxicity testing requirements and the concentration of lead in the effluent is concomitantly determined to exceed an instream level of 3.1 ug/l from the discharge;~~

~~(ix) Mercury: 0.012 ug/l;~~

~~(x) Nickel: 88 ug/l, attainment of these water quality standards in surface waters shall be based on measurement of total recoverable metals concentrations unless appropriate studies have been conducted to translate total recoverable metals to a toxic form. Studies used to determine the toxic form or translators must be designed according to the "Water Quality Standards Handbook Second Edition" published by the Environmental Protection Agency (EPA 823-B-94-005a) or "The Metals Translator: Guidance For Calculating a Total Recoverable Permit Limit From a Dissolved Criterion" published by the Environmental Protection Agency (EPA 823-B-96-007) which are hereby incorporated by reference including any subsequent amendments. The Director shall consider conformance to EPA guidance as well as the presence of environmental conditions that limit the applicability of translators in approving the use of metal translators;~~

~~(xi) Pesticides:~~

~~(A) Aldrin: 0.002 ug/l;~~

~~(B) Chlordane: 0.004 ug/l;~~

~~(C) DDT: 0.001 ug/l;~~

~~(D) Demeton: 0.1 ug/l;~~

~~(E) Dieldrin: 0.002 ug/l;~~

~~(F) Endosulfan: 0.05 ug/l;~~

~~(G) Endrin: 0.002 ug/l;~~

~~(H) Guthion: 0.01 ug/l;~~

~~(I) Heptachlor: 0.004 ug/l;~~

~~(J) Lindane: 0.01 ug/l;~~

~~(K) Methoxychlor: 0.03 ug/l;~~

~~(L) Mirex: 0.001 ug/l;~~

~~(M) Parathion: 0.013 ug/l;~~

~~(N) Toxaphene: 0.0002 ug/l;~~

~~(xii) Polychlorinated biphenyls: (total of all PCBs and congeners identified) 0.001 ug/l;~~

~~(xiii) Selenium: 5 ug/l;~~

~~(xiv) Toluene: 11 ug/l or 0.36 ug/l in trout waters;~~

~~(xv) Trialkyltin compounds: 0.07 ug/l expressed as tributyltin;~~

~~(4)~~(22) Action Levels for Toxic ~~Substances:~~ Substances Applicable to NPDES Permits:

(a) ~~Copper: 7 ug/l;~~Copper, dissolved, chronic: 2.7 ug/l;

~~(b) Iron: 1.0 mg/l;~~

(c) ~~Silver:~~Silver, dissolved, chronic: 0.06 ug/l;

(d) ~~Zinc:~~Zinc, dissolved, chronic: ~~50 ug/l;~~36 [~~ug/l;~~] ug/l; and

(e) Chloride: 230 mg/l;

The hardness-dependent freshwater action levels for ~~Copper and Zinc,~~ copper and zinc, provided here for illustrative purposes, corresponds to a hardness of 25 mg/l. Copper and [~~Zinc~~] zinc action level values for other instream hardness values shall be calculated per the chronic equations specified in Item (11) of this Rule and in Table A: Dissolved Freshwater Standards for Hardness-Dependent Metals. If the ~~Action Levels~~ action levels for any of the substances listed in this ~~Subparagraph~~Item (which are generally not bioaccumulative and have variable toxicity to aquatic life because of chemical form, solubility, stream characteristics or associated waste characteristics) are determined by the waste load allocation to be exceeded in a receiving water by a discharge under the specified ~~low flow~~ 7Q10 criterion for toxic ~~substances (Rule .0206 in this Section),~~ substances, the discharger shall monitor the chemical or biological effects of the discharge; efforts shall be made by all dischargers to reduce or eliminate these substances from their effluents. Those substances for which ~~Action Levels~~ action levels are listed in this ~~Subparagraph~~Item shall be limited as appropriate in the NPDES permit ~~based on the Action Levels listed in this Subparagraph~~ if sufficient information (to be determined for metals by measurements of that portion of the dissolved instream concentration of the ~~Action Levels~~ action levels parameter attributable to a specific NPDES permitted discharge) exists to indicate that any of those substances may be a causative factor resulting in toxicity of the effluent. ~~NPDES permit limits~~

~~may be based on translation of the toxic form to total recoverable metals. Studies used to determine the toxic form or translators must be designed according to "Water Quality Standards Handbook Second Edition" published by the Environmental Protection Agency (EPA 823-B-94-005a) or "The Metals Translator: Guidance For Calculating a Total Recoverable Permit Limit From a Dissolved Criterion" published by the Environmental Protection Agency (EPA 823-B-96-007) which are hereby incorporated by reference including any subsequent amendments. The Director shall consider conformance to EPA guidance as well as the presence of environmental conditions that limit the applicability of translators in approving the use of metal translators.~~

~~For purposes other than consideration of NPDES permitting of point source discharges as described in this Subparagraph, the Action Levels in this Rule, as measured by an appropriate analytical technique, per 15A NCAC 02B .0103(a), shall be considered as numerical instream water quality standards.~~

History Note: *Authority G.S. 143-214.1; 143-215.3(a)(1);*
Eff. February 1, 1976;
Amended Eff. January 1, 2015; May 1, 2007; April 1, 2003; August 1, 2000; October 1, 1995; August 1, 1995; April 1, 1994; February 1, 1993.

15A NCAC 02B .0212 is amended with changes as published in 28:24 NCR 3004-3032 as follows:

15A NCAC 02B .0212 FRESH SURFACE WATER QUALITY STANDARDS FOR CLASS WS-I WATERS

The following water quality standards apply to surface waters within water supply watersheds ~~that are~~ classified as WS-I. Water quality standards applicable to Class C waters as described in Rule .0211 of this Section shall also apply to Class WS-I waters.

(1) The best usage of WS-I waters ~~are~~ shall be as follows: a source of water supply for drinking, culinary, or food-processing purposes for those users desiring maximum protection of their water supplies; waters located on land in public ownership; and any best usage specified for Class C waters;

(2) The conditions related to the best usage ~~are~~ shall be as follows: waters of this class are protected water supplies within essentially natural and undeveloped watersheds in public ownership with no permitted point source dischargers except those specified in Rule .0104 of this Subchapter; waters within this class ~~must~~ shall be relatively unimpacted by nonpoint sources of pollution; land use management programs are required to protect waters from nonpoint source pollution; the waters, following treatment required by the ~~Division of Environmental Health,~~Division, shall meet the Maximum Contaminant Level concentrations considered safe for drinking, culinary, and food-processing purposes ~~which~~ that are specified in the national drinking water regulations and in the North Carolina Rules Governing Public Water Supplies, 15A NCAC 18C .1500. Sources of water pollution ~~which~~ that preclude any of these uses on either a short-term or long-term basis shall be considered to be violating a water quality standard. The Class WS-I classification may be used to protect portions of Class WS-II, ~~WS-III~~ WS-III, and WS-IV water supplies. For reclassifications occurring after the July 1, 1992 statewide reclassification, the more protective classification requested by local governments shall be considered by the Commission when all local governments having jurisdiction in the affected area(s) have adopted a resolution and the appropriate ordinances to protect the watershed or the Commission acts to protect a watershed when one or more local governments has failed to adopt necessary protection measures;

(3) Quality standards applicable to Class WS-I Waters ~~are~~ shall be as follows:

(a) MBAS (Methylene-Blue Active Substances): not greater than 0.5 mg/l to protect the aesthetic qualities of water supplies and to prevent foaming;

(b) Nonpoint Source Pollution: none shall be allowed that would adversely impact the waters for use as a water supply or any other designated use;

(c) Organisms of coliform group: total coliforms not to exceed 50/100 ml (MF count) as a monthly geometric mean value in watersheds serving as unfiltered water supplies;

(d) Chlorinated phenolic compounds: not greater than 1.0 ug/l to protect water supplies from taste and odor problems from chlorinated phenols;

(e) Sewage, industrial wastes: none shall be allowed except those specified in ~~Subparagraph~~~~Item(2)~~ Item (2) of this ~~Paragraph~~Rule or Rule .0104 of this Subchapter;

(f) Solids, total dissolved: not greater than 500 mg/l;

(g) Total hardness: not greater than 100 mg/l as calcium ~~carbonate;~~carbonate ($CaCO_3$ or Ca + Mg);

(h) Toxic and other deleterious substances:

(i) Water quality standards (maximum permissible concentrations) to protect human health through water consumption and fish tissue consumption for non-carcinogens in Class WS-I waters:

(A) Barium: 1.0 mg/l;

(B) Chloride: 250 mg/l;

~~(C) Manganese: 200 ug/l;~~

~~(D)~~(C) Nickel: 25 ug/l;

~~(E)~~(D) Nitrate nitrogen: 10.0 mg/l;

~~(F)~~(E) 2,4-D: ~~100 ug/l;~~70 ug/l;

~~(G)~~(F) 2,4,5-TP (Silvex): 10 ~~ug/l;~~ ug/l; and

~~(H)~~(G) Sulfates: 250 mg/l;

(ii) Water quality standards (maximum permissible concentrations) to protect human health through water consumption and fish tissue consumption for carcinogens in Class WS-I waters:

(A) Aldrin: 0.05 ng/1;

(B) Arsenic: 10 ug/l;

(C) Benzene: 1.19 ug/1;

(D) Carbon tetrachloride: 0.254 ug/l;

(E) Chlordane: 0.8 ng/1;

(F) Chlorinated benzenes: 488 ug/l;

(G) DDT: 0.2 ng/1;

(H) Dieldrin: 0.05 ng/1;

(I) Dioxin: 0.000005 ng/l;

(J) Heptachlor: 0.08 ng/1;

(K) Hexachlorobutadiene: 0.44 ug/l;

(L) Polynuclear aromatic hydrocarbons (total of all PAHs): 2.8 ng/l;

(M) Tetrachloroethane (1,1,2,2): 0.17 ug/l;

(N) Tetrachloroethylene: 0.7 ug/l;

(O) Trichloroethylene: 2.5 ~~ug/l;~~ ug/l; and

(P) Vinyl Chloride: 0.025 ug/l.

History Note: *Authority G.S. 143-214.1; 143-215.3(a)(1);*
Eff. February 1, 1976;
Amended Eff. January 1, 2015; May 1, 2007; April 1, 2003; October 1, 1995; February 1, 1993; March 1, 1991; October 1, 1989.

15A NCAC 02B .0214 is amended with changes as published in 28:24 NCR 3004-3032 as follows:

15A NCAC 02B .0214 FRESH SURFACE WATER QUALITY STANDARDS FOR CLASS WS-II WATERS

The following water quality standards apply to surface waters within water supply watersheds ~~that are~~ classified as WS-II. Water quality standards applicable to Class C waters as described in Rule .0211 of this Section shall also apply to Class WS-II waters.

(1) The best usage of WS-II waters ~~are~~ shall be as follows: a source of water supply for drinking, culinary, or food-processing purposes for those users desiring maximum protection for their water supplies where a WS-I classification is not feasible and any best usage specified for Class C waters;

(2) The conditions related to the best usage ~~are~~ shall be as follows: waters of this class are protected as water supplies ~~which~~ that are in predominantly undeveloped watersheds and meet average watershed development density levels as specified in Sub-Items (3)(b)(i)(A), (3)(b)(i)(B), (3)(b)(ii)(A) and (3)(b)(ii)(B) of this Rule; discharges ~~which~~ that qualify for a General Permit pursuant to 15A NCAC 2H .0127, trout farm discharges, recycle (closed loop) systems that only discharge in response to 10-year storm events and other stormwater discharges ~~are~~ shall be allowed in the entire watershed; new domestic and industrial discharges of treated wastewater ~~are not~~ shall not be allowed in the entire watershed; the waters, following treatment required by the ~~Division of Environmental Health,~~Division, shall meet the Maximum Contaminant Level concentrations considered safe for drinking, culinary, and food-processing purposes ~~which~~ that are specified in the national drinking water regulations and in the North Carolina Rules Governing Public Water Supplies, 15A NCAC 18C .1500. Sources of water pollution ~~which~~ that preclude any of these uses on either a short-term or long-term basis shall be considered to be violating a water quality standard. The Class WS-II classification may be used to protect portions of Class WS-III and WS-IV water supplies. For reclassifications of these portions of Class WS-III and WS-IV water supplies occurring after the July 1, 1992 statewide reclassification, the more protective classification requested by local governments shall be considered by the Commission when all local governments having jurisdiction in the affected area(s) have adopted a resolution and the appropriate ordinances to protect the watershed or the Commission acts to protect a watershed when one or more local governments has failed to adopt necessary protection measures;

(3) Quality standards applicable to Class WS-II Waters ~~are~~ shall be as follows:

(a) Sewage, industrial wastes, non-process industrial wastes, or other wastes: none shall be allowed except for those specified in either Item (2) of this Rule and Rule .0104 of this Subchapter; none shall be allowed that have an adverse effect on human health or that are not ~~effectively~~ treated to the satisfaction of the Commission and in accordance with the requirements of the ~~Division of Environmental Health, North Carolina Department of~~

~~Environment and Natural Resources.~~Division. Any discharger ~~may~~ shall be required upon request by the Commission to disclose all chemical constituents present or potentially present in their wastes and chemicals ~~which~~ that could be spilled or be present in runoff from their facility ~~which~~ that may have an adverse impact on downstream water quality. These facilities may be required to have spill and treatment failure control plans as well as perform special monitoring for toxic substances;

(b) Nonpoint Source and Stormwater Pollution: none that would adversely impact the waters for use as a water supply or any other designated use;

(i) Nonpoint Source and Stormwater Pollution Control Criteria for Entire Watershed:

(A) Low Density Option: development density ~~must~~shall be limited to either no more than one dwelling unit per acre of single family detached residential development (or 40,000 square foot lot excluding roadway ~~right of way)~~ right-of-way), or 12 percent built-upon area for all other residential and non-residential development in the watershed outside of the critical area; stormwater runoff from the development shall be transported by vegetated conveyances to the maximum extent practicable;

(B) High Density Option: if new development exceeds the low density option requirements as stated in Sub-Item (3)(b)(i)(A) of this Rule, then engineered stormwater controls ~~must~~ shall be used to control runoff from the first inch of rainfall; new residential and non-residential development shall not exceed 30 percent built-upon area;

(C) Land within the watershed shall be deemed compliant with the density requirements if the following condition is met: the density of all existing development at the time of reclassification does not exceed the density requirement when densities are averaged throughout the entire watershed area at the time of classification;

(D) Cluster development ~~is~~ shall be allowed on a project-by-project basis as follows:

(I) overall density of the project meets associated density or stormwater control requirements of this Rule;

(II) buffers meet the minimum statewide water supply watershed protection requirements;

(III) built-upon areas ~~are~~ shall be designed and located to minimize stormwater runoff impact to the receiving waters, minimize concentrated stormwater flow, maximize the use of

sheet flow through vegetated areas, and maximize the flow length through vegetated areas;

(IV) areas of concentrated development ~~are~~ shall be located in upland areas and away, to the maximum extent practicable, from surface waters and drainageways;

(V) remainder of tract to remain in vegetated or natural state;

(VI) area in the vegetated or natural state may be conveyed to a property owners association, a local government for preservation as a park or greenway, a conservation organization, or placed in a permanent conservation or farmland preservation easement;

(VII) a maintenance agreement for the vegetated or natural area shall be filed with the Register of Deeds; and

(VIII) cluster development that meets the applicable low density option requirements shall transport stormwater runoff from the development by vegetated conveyances to the maximum extent practicable;

(E) A maximum of 10 percent of each jurisdiction's portion of the watershed outside of the critical area as delineated on July 1, 1993 may be developed with new development projects and expansions of existing development of up to 70 percent built-upon surface area (the "10/70 option") in addition to the new development approved in compliance with the appropriate requirements of Sub-Item (3)(b)(i)(A) or Sub-Item (3)(b)(i)(B) of this Rule. For expansions to existing development, the existing built-upon surface area ~~is not~~shall not be counted toward the allowed 70 percent built-upon surface area. A local government having jurisdiction within the watershed may transfer, in whole or in part, its right to the ~~10 percent/70 percent~~ 10/70 option land area to another local government within the watershed upon submittal of a joint resolution and review by the Commission. When the water supply watershed is composed of public lands, such as National Forest land, local governments may count the public land acreage within the watershed outside of the critical area in calculating the acreage allowed under this provision. For local governments that do not choose to use the high density option in that WS-II watershed, each project ~~must,~~ shall, to the maximum extent practicable, minimize built-upon surface area, direct stormwater runoff away from surface ~~waters~~waters, and

incorporate best management ~~practices~~practices, as defined in Rule .0202 of this Section, to minimize water quality impacts. If the local government selects the high density development option within that WS-II watershed, then engineered stormwater controls ~~must~~ shall be employed for the new development;

(F) If local governments choose the high density development option ~~which~~that requires stormwater controls, then they shall assume ultimate responsibility for operation and maintenance of the required controls as outlined in Rule .0104 of this Subchapter;

(G) ~~Minimum~~ A minimum 100 foot vegetative buffer ~~is~~ shall be required for all new development activities that exceed the low density option requirements as specified in Sub-Items (3)(b)(i)(A) and Sub-Item (3)(b)(ii)(A) of this Rule, otherwise a minimum 30 foot vegetative buffer for development activities ~~is~~ shall be required along all perennial waters indicated on the most recent versions of U.S.G.S. 1:24,000 (7.5 minute) scale topographic maps or as determined by local government studies. Nothing in this Rule shall stand as a bar to artificial streambank or shoreline stabilization;

(H) No new development ~~is~~ shall be allowed in the buffer; water dependent structures, or other structures such as flag poles, ~~signs~~ signs, and security lights, which result in only de minimus increases in impervious area and public projects such as road crossings and greenways may be allowed where no practicable alternative exists. These activities shall minimize built-upon ~~surface area, direct runoff away from the surface waters and maximize the utilization of BMPs;~~surface area and avoid channelizing stormwater;

(I) No National Pollutant Discharge Elimination System(NPDES) ~~NPDES~~ permits shall be issued for landfills that discharge treated leachate;

(ii) Critical Area Nonpoint Source and Stormwater Pollution Control Criteria:

(A) Low Density Option: new development ~~is~~ shall be limited to either no more than one dwelling unit of single family detached residential development per two acres (or 80,000 square foot lot excluding roadway ~~right-of-way)~~right-of-way), or six percent built-upon area for all other residential and non-residential development; stormwater runoff from the development shall be transported by vegetated conveyances to the maximum extent practicable;

(B) High Density Option: if new development density exceeds the low density requirements specified in Sub-Item (3)(b)(ii)(A) of this Rule, then engineered stormwater controls ~~must~~ shall be used to control runoff from the first inch of rainfall; new residential and non-residential development density ~~not to~~ shall not exceed 24 percent built-upon area;

(C) No new permitted sites for land application of residuals or petroleum contaminated soils ~~are~~ shall be allowed;

(D) No new landfills ~~are~~ shall be allowed;

(c) MBAS (Methylene-Blue Active Substances): not greater than 0.5 mg/l to protect the aesthetic qualities of water supplies and to prevent foaming;

(d) Odor producing substances contained in sewage or other wastes: only such amounts, whether alone or in combination with other substances or wastes, as shall not cause taste and odor difficulties in water supplies ~~which~~that cannot be corrected by treatment, impair the palatability of fish, or have a deleterious effect upon any best usage established for waters of this class;

(e) Chlorinated phenolic compounds: not greater than 1.0 ug/l to protect water supplies from taste and odor problems from chlorinated phenols;

(f) Total hardness: not greater than 100 mg/l as calcium ~~carbonate;~~carbonate ($CaCO_3$ or Ca + Mg);

(g) Total dissolved solids: not greater than 500 mg/l;

(h) Toxic and other deleterious substances:

(i) Water quality standards (maximum permissible concentrations) to protect human health through water consumption and fish tissue consumption for non-carcinogens in Class WS-II waters:

(A) Barium: 1.0 mg/l;

(B) Chloride: 250 mg/l;

~~(C) Manganese: 200 ug/l;~~

~~(D)~~(C) Nickel: 25 ug/l;

~~(E)~~(D) Nitrate nitrogen: 10 mg/l;

~~(F)~~(E) 2,4-D: ~~100 ug/l;~~70 ug/l;

~~(G)~~(F) 2,4,5-TP (Silvex): 10 ~~ug/l;~~ ug/l; and

~~(H)~~(G) Sulfates: 250 mg/l;

(ii) Water quality standards (maximum permissible concentrations) to protect human health through water consumption and fish tissue consumption for carcinogens in Class WS-II waters:

(A) Aldrin: 0.05 ng/l;

(B) Arsenic: 10 ug/l;

(C) Benzene: 1.19 ug/l;

(D) Carbon tetrachloride: 0.254 ug/l;

(E) Chlordane: 0.8 ng/l;

(F) Chlorinated benzenes: 488 ug/l;

(G) DDT: 0.2 ng/l;

(H) Dieldrin: 0.05 ng/l;

(I) Dioxin: 0.000005 ng/l;

(J) Heptachlor: 0.08 ng/l;

(K) Hexachlorobutadiene: 0.44 ug/l;

(L) Polynuclear aromatic hydrocarbons (total of all PAHs): 2.8 ng/l;

(M) Tetrachloroethane (1,1,2,2): 0.17 ug/l;

(N) Tetrachloroethylene: 0.7 ug/l;

(O) Trichloroethylene: 2.5 ~~ug/l;~~ ug/l; and

(P) Vinyl Chloride: 0.025 ug/l.

History Note: *Authority G.S. 143-214.1; 143-215.3(a)(1);*
Eff. May 10, 1979;
Amended Eff. January 1, 2015; May 1, 2007; April 1, 2003; January 1, 1996; October 1, 1995.

15A NCAC 02B .0215 is amended with changes as published in 28:24 NCR 3004-3032 as follows:

15A NCAC 02B .0215 FRESH SURFACE WATER QUALITY STANDARDS FOR CLASS WS-III WATERS

The following water quality standards apply to surface waters within water supply ~~waters~~ watersheds ~~that are~~ classified as WS-III. Water quality standards applicable to Class C waters as described in Rule .0211 of this Section shall also apply to Class WS-III waters.

(1) The best usage of WS-III waters ~~are~~ shall be as follows: a source of water supply for drinking, culinary, or food-processing purposes for those users where a more protective WS-I or WS-II classification is not feasible and any other best usage specified for Class C waters;

(2) The conditions related to the best usage ~~are~~ shall be as follows: waters of this class are protected as water supplies ~~which~~ that are ~~generally~~ in low to moderately developed watersheds and meet average watershed development density levels as specified in Sub-Items (3)(b)(i)(A), (3)(b)(i)(B), (3)(b)(ii)(A) and (3)(b)(ii)(B) of this Rule; discharges that qualify for a General Permit pursuant to 15A NCAC 2H .0127, trout farm discharges, recycle (closed loop) systems that only discharge in response to 10-year storm events, and other stormwater discharges ~~are~~ shall be allowed in the entire watershed; treated domestic wastewater discharges ~~are~~ shall be allowed in the entire watershed but no new domestic wastewater discharges ~~are~~ shall be allowed in the critical area; no new industrial wastewater discharges except non-process industrial discharges ~~are~~ shall be allowed in the entire watershed; the waters, following treatment required by the ~~Division of Environmental Health,~~Division, shall meet the Maximum Contaminant Level concentrations considered safe for drinking, culinary, or food-processing purposes ~~which~~ that are specified in the national drinking water regulations and in the North Carolina Rules Governing Public Water Supplies, 15A NCAC 18C .1500. Sources of water pollution ~~which~~ that preclude any of these uses on either a short-term or long-term basis shall be considered to be violating a water quality standard. The Class WS-III classification may be used to protect portions of Class WS-IV water supplies. For reclassifications of these portions of WS-IV water supplies occurring after the July 1, 1992 statewide reclassification, the more protective classification requested by local governments shall be considered by the Commission when all local governments having jurisdiction in the affected area(s) have adopted a resolution and the appropriate ordinances to protect the watershed or the Commission acts to protect a watershed when one or more local governments has failed to adopt necessary protection measures;

(3) Quality standards applicable to Class WS-III Waters ~~are~~ shall be as follows:

(a) Sewage, industrial wastes, non-process industrial wastes, or other wastes: none shall be allowed except for those specified in Item (2) of this Rule and Rule .0104 of this Subchapter; none shall be allowed that have an adverse effect on human health or that are not ~~effectively~~ treated to the satisfaction of the Commission and in accordance with the

requirements of the ~~Division of Environmental Health, North Carolina Department of Environment and Natural Resources.~~Division. Any discharger may be required by the Commission to disclose all chemical constituents present or potentially present in their wastes and chemicals ~~which~~ that could be spilled or be present in runoff from their facility ~~which~~ that may have an adverse impact on downstream water quality. These facilities may be required to have spill and treatment failure control plans as well as perform special monitoring for toxic substances;

(b) Nonpoint Source and Stormwater Pollution: none that would adversely impact the waters for use as water supply or any other designated use;

(i) Nonpoint Source and Stormwater Pollution Control Criteria For Entire Watershed:

(A) Low Density Option: development density ~~must~~ shall be limited to either no more than two dwelling units of single family detached residential development per acre (or 20,000 square foot lot excluding roadway ~~right-of-way)~~ right-of-way), or 24 percent built-upon area for all other residential and non-residential development in watershed outside of the critical area; stormwater runoff from the development shall be transported by vegetated conveyances to the maximum extent practicable;

(B) High Density Option: if new development density exceeds the low density option requirements specified in Sub-Item (3)(b)(i)(A) of this Rule then development ~~must~~ shall control runoff from the first inch of rainfall; new residential and non-residential development shall not exceed 50 percent built-upon area;

(C) Land within the watershed shall be deemed compliant with the density requirements if the following condition is met: the density of all existing development at the time of reclassification does not exceed the density requirement when densities are averaged throughout the entire watershed area;

(D) Cluster development ~~is~~ shall be allowed on a project-by-project basis as follows:

(I) overall density of the project meets associated density or stormwater control requirements of this Rule;

(II) buffers meet the minimum statewide water supply watershed protection requirements;

(III) built-upon areas ~~are~~ shall be designed and located to minimize stormwater runoff impact to the receiving waters, minimize

concentrated stormwater flow, maximize the use of sheet flow through vegetated areas, and maximize the flow length through vegetated areas;

(IV) areas of concentrated development ~~are~~ shall be located in upland areas and away, to the maximum extent practicable, from surface waters and drainageways;

(V) remainder of tract to remain in vegetated or natural state;

(VI) area in the vegetated or natural state may be conveyed to a property owners association, a local government for preservation as a park or greenway, a conservation ~~organization~~ organization, or placed in a permanent conservation or farmland preservation easement;

(VII) a maintenance agreement for the vegetated or natural area shall be filed with the Register of Deeds; and

(VIII) cluster development that meets the applicable low density option requirements shall transport stormwater runoff from the development by vegetated conveyances to the maximum extent practicable;

(E) A maximum of 10 percent of each jurisdiction's portion of the watershed outside of the critical area as delineated on July 1, 1993 may be developed with new development projects and expansions of existing development of up to 70 percent built-upon surface area (the "10/70 option") in addition to the new development approved in compliance with the appropriate requirements of Sub-Item (3)(b)(i)(A) or Sub-Item (3)(b)(i)(B) of this Rule. For expansions to existing development, the existing built-upon surface area ~~is not~~shall not be counted toward the allowed 70 percent built-upon surface area. A local government having jurisdiction within the watershed may transfer, in whole or in part, its right to the ~~10 percent/70 percent~~10/70 option land area to another local government within the watershed upon submittal of a joint resolution and review by the Commission. When the water supply watershed is composed of public lands, such as National Forest land, local governments may count the public land acreage within the watershed outside of the critical area in figuring the acreage allowed under this provision. For local governments that do not choose to use the high density option in that WS-III watershed, each project ~~must,~~ shall, to the maximum extent practicable, minimize built-upon surface

area, direct stormwater runoff away from surface waters, and incorporate best management ~~practices~~ practices, as defined in Rule .0202 of this Section, to minimize water quality impacts. If the local government selects the high density development option within that WS-III watershed, then engineered stormwater controls ~~must~~ shall be employed for the new development;

(F) If local governments choose the high density development option ~~which~~ that requires engineered stormwater controls, then they shall assume ultimate responsibility for operation and maintenance of the required controls as outlined in Rule .0104 of this Subchapter;

(G) ~~Minimum~~ A minimum 100 foot vegetative buffer ~~is~~ shall be required for all new development activities that exceed the low density requirements as specified in Sub-Item (3)(b)(i)(A) and Sub-Item (3)(b)(ii)(A) of this Rule, otherwise a minimum 30 foot vegetative buffer for development ~~is~~ shall be required along all perennial waters indicated on the most recent versions of U.S.G.S. 1:24,000 (7.5 minute) scale topographic maps or as determined by local government studies. Nothing in this Rule shall stand as a bar to artificial streambank or shoreline stabilization;

(H) No new development ~~is~~ shall be allowed in the buffer; water dependent structures, or other structures such as flag poles, ~~signs~~ signs, and security lights, which result in only de minimus increases in impervious area and public projects such as road crossings and greenways may be allowed where no practicable alternative exists. These activities shall minimize built-upon ~~surface area, direct runoff away from surface waters and maximize the utilization of BMPs;~~ surface area and avoid channelizing stormwater;

(I) No National Pollutant Discharge Elimination System (NPDES) ~~NPDES~~ permits shall be issued for landfills that discharge treated leachate;

(ii) Critical Area Nonpoint Source and Stormwater Pollution Control Criteria:

(A) Low Density Option: new development shall be limited to either no more than one dwelling unit of single family detached residential development per acre (or 40,000 square foot lot excluding roadway ~~right-of-way)~~ right-of-way), or 12 percent built-upon area for all other residential and non-residential development; stormwater runoff from the development shall be transported by vegetated conveyances to the maximum extent practicable;

(B) High Density Option: if new development exceeds the low density requirements specified in Sub-Item (3)(b)(ii)(A) of this Rule, then engineered stormwater controls ~~must~~ shall be used to control runoff from the first inch of rainfall; development shall not exceed 30 percent built-upon area;

(C) No new permitted sites for land application of residuals or petroleum contaminated soils ~~are~~ shall be allowed;

(D) No new landfills ~~are~~ shall be allowed;

(c) MBAS (Methylene-Blue Active Substances): not greater than 0.5 mg/l to protect the aesthetic qualities of water supplies and to prevent foaming;

(d) Odor producing substances contained in sewage, industrial wastes, or other wastes: only such amounts, whether alone or in combination with other substances or wastes, as shall not cause taste and odor difficulties in water supplies ~~which~~ that cannot be corrected by treatment, impair the palatability of fish, or have a deleterious effect upon any best usage established for waters of this class;

(e) Chlorinated phenolic compounds: not greater than 1.0 ug/l to protect water supplies from taste and odor problems from chlorinated phenols;

(f) Total hardness: not greater than 100 mg/l as calcium ~~carbonate;~~carbonate ($CaCO_3$ or Ca + Mg);

(g) Total dissolved solids: not greater than 500 mg/l;

(h) Toxic and other deleterious substances:

(i) Water quality standards (maximum permissible concentrations) to protect human health through water consumption and fish tissue consumption for non-carcinogens in Class WS-III waters:

(A) Barium: 1.0 mg/l;

(B) Chloride: 250 mg/l;

~~(C) Manganese: 200 ug/l;~~

~~(D)~~(C) Nickel: 25 ug/l;

~~(E)~~(D) Nitrate nitrogen: 10 mg/l;

~~(F)~~(E) 2,4-D: ~~100 ug/l;~~70 ug/l;

~~(G)~~(F) 2,4,5-TP (Silvex): 10 ~~ug/l;~~ ug/l; and

~~(H)~~(G) Sulfates: 250 mg/l;

(ii) Water quality standards (maximum permissible concentrations) to protect human health through water consumption and fish tissue consumption for carcinogens in Class WS-III waters:

(A) Aldrin: 0.05 ng/l;

(B) Arsenic: 10 ug/l;

(C) Benzene: 1.19 ug/l;

(D) Carbon tetrachloride: 0.254 ug/l;

(E) Chlordane: 0.8 ng/l;

(F) Chlorinated benzenes: 488 ug/l;

(G) DDT: 0.2 ng/l;

(H) Dieldrin: 0.05 ng/l;

(I) Dioxin: 0.000005 ng/l;

(J) Heptachlor: 0.08 ng/l;

(K) Hexachlorobutadiene: 0.44 ug/l;

(L) Polynuclear aromatic hydrocarbons (total of all PAHs): 2.8 ng/l;

(M) Tetrachloroethane (1,1,2,2): 0.17 ug/l;

(N) Tetrachloroethylene: 0.7 ug/l;

(O) Trichloroethylene: 2.5 ~~ug/l;~~ ug/l; and

(P) Vinyl Chloride: 0.025 ug/l.

History Note: *Authority G.S. 143-214.1; 143-215.3(a)(1);*
Eff. September 9, 1979;
Amended Eff. January 1, 2015; May 1, 2007; April 1, 2003; January 1, 1996; October 1, 1995; October 1, 1989.

15A NCAC 02B .0216 is amended with changes as published in 28:24 NCR 3004-3032 as follows:

15A NCAC 02B .0216 FRESH SURFACE WATER QUALITY STANDARDS FOR WS-IV WATERS

The following water quality standards apply to surface waters within water supply ~~waters that are~~ watersheds classified as WS-IV. Water quality standards applicable to Class C waters as described in Rule .0211 of this Section shall also apply to Class WS-IV waters.

(1) The best usage of WS-IV waters ~~are~~ shall be as follows: a source of water supply for drinking, culinary, or food-processing purposes for those users where a more protective WS-I, WS-II or WS-III classification is not feasible and any other best usage specified for Class C waters;

(2) The conditions related to the best usage ~~are~~ shall be as follows: waters of this class are protected as water supplies ~~which~~ that are ~~generally~~ in moderately to highly developed watersheds or protected areas and meet average watershed development density levels as specified in Sub-Items (3)(b)(i)(A), (3)(b)(i)(B), (3)(b)(ii)(A) and (3)(b)(ii)(B) of this Rule; discharges ~~which~~ that qualify for a General Permit pursuant to 15A NCAC 02H .0127, trout farm discharges, recycle (closed loop) systems that only discharge in response to 10-year storm events, other stormwater ~~discharges~~ discharges, and domestic wastewater discharges shall be allowed in the protected and critical areas; treated industrial wastewater discharges ~~are~~ shall be allowed in the protected and critical areas; however, new industrial wastewater discharges in the critical area shall be required to meet the provisions of 15A NCAC 02B .0224(1)(b)(iv), (v) and (vii), and 15A NCAC 02B .0203; new industrial connections and expansions to existing municipal discharges with a pretreatment program pursuant to 15A NCAC 02H .0904 ~~are~~ shall be allowed; the waters, following treatment required by the ~~Division of Environmental Health,~~Division, shall meet the Maximum Contaminant Level concentrations considered safe for drinking, culinary, or food-processing purposes ~~which~~ that are specified in the national drinking water regulations and in the North Carolina Rules Governing Public Water Supplies, 15A NCAC 18C .1500. Sources of water pollution ~~which~~ that preclude any of these uses on either a short-term or long-term basis shall be considered to be violating a water quality standard. The Class WS-II or WS-III classifications may be used to protect portions of Class WS-IV water supplies. For reclassifications of these portions of WS-IV water supplies occurring after the July 1, 1992 statewide reclassification, the more protective classification requested by local governments shall be considered by the Commission when all local governments having jurisdiction in the affected area(s) have adopted a resolution and the appropriate ordinances to protect the watershed or the Commission acts to protect a watershed when one or more local governments has failed to adopt necessary protection measures;

(3) Quality standards applicable to Class WS-IV Waters ~~are~~ shall be as follows:

(a) Sewage, industrial wastes, non-process industrial wastes, or other wastes: none shall be allowed except for those specified in Item (2) of this Rule and Rule .0104 of this

Subchapter and none shall be allowed that ~~shall~~ have an adverse effect on human health or that are not ~~effectively~~ treated to the satisfaction of the Commission and in accordance with the requirements of the ~~Division of Environmental Health, North Carolina Department of Environment and Natural Resources.~~Division. Any ~~discharges~~dischargers or industrial users subject to pretreatment standards may be required by the Commission to disclose all chemical constituents present or potentially present in their wastes and chemicals ~~which~~ that could be spilled or be present in runoff from their facility which may have an adverse impact on downstream water supplies. These facilities may be required to have spill and treatment failure control plans as well as perform special monitoring for toxic substances;

(b) Nonpoint Source and Stormwater Pollution: none shall be allowed that would adversely impact the waters for use as water supply or any other designated use.

(i) Nonpoint Source and Stormwater Pollution Control Criteria For Entire Watershed or Protected Area:

(A) Low Density Option: development activities ~~which~~ that require a Sedimentation/Erosion Control Plan in accordance with 15A NCAC 4 established by the North Carolina Sedimentation Control Commission or approved local government programs as delegated by the Sedimentation Control Commission shall be limited to no more than either: two dwelling units of single family detached development per acre (or 20,000 square foot lot excluding roadway ~~right of way)~~ right-of-way), or 24 percent built-upon on area for all other residential and non-residential development; or three dwelling units per ~~acre~~ acre, or 36 percent built-upon area for projects without curb and gutter street systems in the protected area outside of the critical area; stormwater runoff from the development shall be transported by vegetated conveyances to the maximum extent practicable;

(B) High Density Option: if new development activities ~~which~~ that require a Sedimentation/Erosion Control Plan exceed the low density requirements of Sub-Item (3)(b)(i)(A) of this ~~Rule~~ Rule, then development shall control the runoff from the first inch of rainfall; new residential and non-residential development shall not exceed 70 percent built-upon area;

(C) Land within the critical and protected area shall be deemed compliant with the density requirements if the following condition is met: the density of all existing development at the time of reclassification does

not exceed the density requirement when densities are averaged throughout the entire area;

(D) Cluster development shall be allowed on a project-by-project basis as follows:

(I) overall density of the project meets associated density or stormwater control requirements of this Rule;

(II) buffers meet the minimum statewide water supply watershed protection requirements;

(III) built-upon areas ~~are~~ shall be designed and located to minimize stormwater runoff impact to the receiving waters, minimize concentrated stormwater flow, maximize the use of sheet flow through vegetated areas, and maximize the flow length through vegetated areas;

(IV) areas of concentrated development ~~are~~ shall be located in upland areas and away, to the maximum extent practicable, from surface waters and drainageways;

(V) remainder of tract to remain in vegetated or natural state;

(VI) area in the vegetated or natural state may be conveyed to a property owners association, a local government for preservation as a park or greenway, a conservation organization, or placed in a permanent conservation or farmland preservation easement;

(VII) a maintenance agreement for the vegetated or natural area shall be filed with the Register of Deeds; and

(VIII) cluster development that meets the applicable low density option requirements shall transport stormwater runoff from the development by vegetated conveyances to the maximum extent practicable;

(E) If local governments choose the high density development option ~~which~~ that requires engineered stormwater controls, then they shall assume ~~ultimate~~ responsibility for operation and maintenance of the required controls as outlined in Rule .0104 of this Subchapter;

(F) ~~Minimum~~A minimum 100 foot vegetative buffer ~~is~~ shall be required for all new development activities that exceed the low density option requirements as specified in Sub-Item (3)(b)(i)(A) or Sub-Item (3)(b)(ii)(A) of this Rule, otherwise a minimum 30 foot vegetative buffer for development shall be required along all perennial waters

indicated on the most recent versions of U.S.G.S. 1:24,000 (7.5 minute) scale topographic maps or as determined by local government studies;

(G) No new development shall be allowed in the buffer; water dependent structures, or other structures, such as flag poles, ~~signs~~ signs, and security lights, which result in only de minimus increases in impervious area and public projects such as road crossings and greenways may be allowed where no practicable alternative exists. These activities shall minimize built-upon ~~surface area, divert runoff away from surface waters and maximize the utilization of BMPs;~~ surface area and avoid channelizing stormwater;

(H) For local governments that do not use the high density option, a maximum of 10 percent of each jurisdiction's portion of the watershed outside of the critical area as delineated on July 1, 1995 may be developed with new development projects and expansions to existing development of up to 70 percent built-upon surface area (the "10/70 option") in addition to the new development approved in compliance with the appropriate requirements of Sub-Item (3)(b)(i)(A) of this Rule. For expansions to existing development, the existing built-upon surface area shall not be counted toward the allowed 70 percent built-upon surface area. A local government having jurisdiction within the watershed may transfer, in whole or in part, its right to the ~~10 percent/70 percent~~ 10/70 option land area to another local government within the watershed upon submittal of a joint resolution for review by the Commission. When the designated water supply watershed area is composed of public land, such as National Forest land, local governments may count the public land acreage within the designated watershed area outside of the critical area in figuring the acreage allowed under this provision. Each project shall, to the maximum extent practicable, minimize built-upon surface area, direct stormwater runoff away from surface waters and incorporate best management ~~practices~~ practices, as defined in Rule .0202 of this Section, to minimize water quality impacts;

(ii) Critical Area Nonpoint Source and Stormwater Pollution Control Criteria:

(A) Low Density Option: new development activities ~~which~~ that require a Sedimentation/Erosion Control Plan in accordance with 15A NCAC 4 established by the North Carolina Sedimentation Control Commission or approved local government programs as delegated by the

Sedimentation Control Commission shall be limited to no more than two dwelling units of single family detached development per acre (or 20,000 square foot lot excluding roadway ~~right-of-way)~~ right-of-way), or 24 percent built-upon area for all other residential and non-residential development; stormwater runoff from the development shall be transported by vegetated conveyances to the maximum extent practicable;

(B) High Density Option: if new development density exceeds the low density requirements specified in Sub-Item (3)(b)(ii)(A) of this Rule, engineered stormwater controls shall be used to control runoff from the first inch of rainfall; new residential and non-residential development shall not exceed 50 percent built-upon area;

(C) No new permitted sites for land application of residuals or petroleum contaminated soils shall be allowed;

(D) No new landfills shall be allowed;

(c) MBAS (Methylene-Blue Active Substances): not greater than 0.5 mg/l to protect the aesthetic qualities of water supplies and to prevent foaming;

(d) Odor producing substances contained in sewage, industrial wastes, or other wastes: only such amounts, whether alone or in combination with other substances or waste, as will not cause taste and odor difficulties in water supplies ~~which~~ that ~~can not~~ cannot be corrected by treatment, impair the palatability of fish, or have a deleterious effect upon any best usage established for waters of this class;

(e) Chlorinated phenolic compounds: not greater than 1.0 ug/l to protect water supplies from taste and odor problems due to chlorinated phenols shall be allowed. Specific phenolic compounds may be given a different limit if it is demonstrated not to cause taste and odor problems and not to be detrimental to other best usage;

(f) Total hardness shall not exceed 100 mg/l as calcium ~~carbonate;~~carbonate ($CaCO_3$ or Ca + Mg);

(g) Total dissolved solids shall not exceed 500 mg/l;

(h) Toxic and other deleterious substances:

(i) Water quality standards (maximum permissible concentrations) to protect human health through water consumption and fish tissue consumption for non-carcinogens in Class WS-IV waters:

(A) Barium: 1.0 mg/l;

(B) Chloride: 250 mg/l;

~~(C) Manganese: 200 ug/l;~~

~~(D)~~(C) Nickel: 25 ug/l;

~~(E)~~(D) Nitrate nitrogen: 10.0 mg/l;

~~(F)~~(E) 2,4-D: ~~100 ug/l;~~ 70 ug/l;

~~(G)~~(F) 2,4,5-TP (Silvex): 10 ~~ug/l;~~ ug/l; and

~~(H)~~(G) Sulfates: 250 mg/l;

(ii) Water quality standards (maximum permissible concentrations) to protect human health through water consumption and fish tissue consumption for carcinogens in Class WS-IV waters:

(A) Aldrin: 0.05 ng/l;

(B) Arsenic: 10 ug/l;

(C) Benzene: 1.19 ug/l;

(D) Carbon tetrachloride: 0.254 ug/l;

(E) Chlordane: 0.8 ng/l;

(F) Chlorinated benzenes: 488 ug/l;

(G) DDT: 0.2 ng/l;

(H) Dieldrin: 0.05 ng/l;

(I) Dioxin: 0.000005 ng/l;

(J) Heptachlor: 0.08 ng/l;

(K) Hexachlorobutadiene: 0.44 ug/l;

(L) Polynuclear aromatic hydrocarbons (total of all PAHs): 2.8 ng/l;

(M) Tetrachloroethane (1,1,2,2): 0.17 ug/l;

(N) Tetrachloroethylene: 0.7 ug/l;

(O) Trichloroethylene: 2.5 ug/l; and

(P) Vinyl Chloride: 0.025 ug/l.

History Note: *Authority G.S. 143-214.1; 143-215.3(a)(1);*
Eff. February 1, 1986;
Amended Eff. January 1, 2015; May 1, 2007; April 1, 2003; June 1, 1996; October 1, 1995; August 1, 1995; June 1, 1994.

15A NCAC 02B .0218 is amended with changes as published in 28:24 NCR 3004-3032 as follows:

15A NCAC 02B .0218 FRESH SURFACE WATER QUALITY STANDARDS FOR CLASS WS-V WATERS

The following water quality standards apply to surface waters within water supply ~~waters~~ watersheds ~~that are~~ classified as WS-V. Water quality standards applicable to Class C waters as described in Rule .0211 of this Section shall also apply to Class WS-V waters.

(1) The best usage of WS-V waters ~~are~~ shall be as follows: waters that are protected as water supplies ~~which~~ that are ~~generally~~ upstream and draining to Class WS-IV waters; or waters previously used for drinking water supply purposes; or waters used by industry to supply their employees, but not municipalities or counties, with a raw drinking water supply source, although this type of use ~~is not~~ shall not be restricted to WS-V classification; and all Class C uses. The Commission may consider a more protective classification for the water supply if a resolution requesting a more protective classification is submitted from all local governments having land use jurisdiction within the affected watershed;

(2) The conditions related to the best usage ~~are~~ shall be as follows: waters of this class are protected water supplies; the waters, following treatment required by the ~~Division of Environmental Health,~~Division, shall meet the Maximum Contaminant Level concentrations considered safe for drinking, culinary, or food-processing purposes ~~which~~ that are specified in the national drinking water regulations and in the North Carolina Rules Governing Public Water Supplies, 15A NCAC 18C .1500; no categorical restrictions on watershed development or wastewater discharges ~~are~~ shall be required, however, the Commission or its designee may apply management requirements for the protection of waters downstream of receiving waters (15A NCAC 02B .0203). Sources of water pollution ~~which~~ that preclude any of these uses on either a short-term or long-term basis shall be considered to be violating a water quality standard;

(3) Quality standards applicable to Class WS-V Waters ~~are~~ shall be as follows:

(a) Sewage, industrial wastes, non-process industrial wastes, or other wastes: none shall be allowed that have an adverse effect on human health or that are not ~~effectively~~ treated to the satisfaction of the Commission and in accordance with the requirements of the ~~Division of Environmental Health, North Carolina Department of Environment and Natural Resources.~~Division. Any discharges or industrial users subject to pretreatment standards ~~may~~ shall be required by the Commission to disclose all chemical constituents present or potentially present in their wastes and chemicals ~~which~~ that could be spilled or be present in runoff from their facility which may have an adverse impact on downstream water supplies. These facilities may be required to have spill and treatment failure control plans as well as perform special monitoring for toxic substances;

(b) MBAS (Methylene-Blue Active Substances): not greater than 0.5 mg/l to protect the aesthetic qualities of water supplies and to prevent foaming;

(c) Nonpoint Source and Stormwater Pollution: none that would adversely impact the waters for use as water supply or any other designated use;

(d) Odor producing substances contained in sewage, industrial wastes, or other wastes: only such amounts, whether alone or in combination with other substances or waste, as will not cause taste and odor difficulties in water supplies ~~which~~ that ~~can not~~ cannot be corrected by treatment, impair the palatability of fish, or have a deleterious effect upon any best usage established for waters of this class;

(e) Chlorinated phenolic compounds: not greater than 1.0 ug/l to protect water supplies from taste and odor problems due to chlorinated phenols; specific phenolic compounds may be given a different limit if it is demonstrated not to cause taste and odor problems and not to be detrimental to other best usage;

(f) Total hardness: not greater than 100 mg/l as calcium ~~carbonate;~~carbonate ($CaCO_3$ or Ca + Mg);

(g) Total dissolved solids: not greater than 500 mg/l;

(h) Toxic and other deleterious substances:

(i) Water quality standards (maximum permissible concentrations) to protect human health through water consumption and fish tissue consumption for non-carcinogens in Class WS-V waters:

(A) Barium: 1.0 mg/l;

(B) Chloride: 250 mg/l;

~~(C) Manganese: 200 ug/l;~~

~~(D)~~(C) Nickel: 25 ug/l;

~~(E)~~(D) Nitrate nitrogen: 10.0 mg/l;

~~(F)~~(E) 2,4-D: ~~100 ug/l;~~70 ug/l;

~~(G)~~(F) 2,4,5-TP (Silvex): 10 ~~ug/l;~~ ug/l; and

~~(H)~~(G) Sulfates: 250 mg/l.

(ii) Water quality standards (maximum permissible concentrations) to protect human health through water consumption and fish tissue consumption for carcinogens in Class WS-V waters:

(A) Aldrin: 0.05 ng/l;

(B) Arsenic: 10 ug/l;

(C) Benzene: 1.19 ug/l;

(D) Carbon tetrachloride: 0.254 ug/l;

(E) Chlordane: 0.8 ng/l;

(F) Chlorinated benzenes: 488 ug/l;

(G) DDT: 0.2 ng/l;

(H) Dieldrin: 0.05 ng/l;

(I) Dioxin: 0.000005 ng/l;

(J) Heptachlor: 0.08 ng/l;

(K) Hexachlorobutadiene: 0.44 ug/l;

(L) Polynuclear aromatic hydrocarbons (total of all PAHs): 2.8 ng/l;

(M) Tetrachloroethane (1,1,2,2): 0.17 ug/l;

(N) Tetrachloroethylene: 0.7 ug/l;

(O) Trichloroethylene: 2.5 ~~ug/l;~~ ug/l; and

(P) Vinyl Chloride: 0.025 ug/l.

History Note: *Authority G.S. 143-214.1; 143-215.3(a)(1);*
Eff. October 1, 1989;
Amended Eff. January 1, 2015; May 1, 2007; April 1, 2003; October 1, 1995.

15A NCAC 02B .0220 is amended with changes as published in 28:24 NCR 3004-3032 as follows:

15A NCAC 02B .0220 TIDAL SALT WATER QUALITY STANDARDS FOR CLASS SC WATERS

General. The water quality standards for all tidal salt waters ~~are~~ shall be the basic standards applicable to Class SC waters. Additional and more stringent standards applicable to other specific tidal salt water classifications are specified in Rules .0221 and .0222 of this Section. Action Levels, for purposes of National Pollutant Discharge Elimination System (NPDES)[~~NPDES~~] permitting, are specified in Item (20) of this Rule.

(1) Best Usage of Waters: any usage except primary recreation or shellfishing for market purposes; usages include aquatic life propagation and maintenance of biological integrity (including fishing, fish and functioning ~~PNAs),~~ Primary Nursery Areas (PNAs)), wildlife, and secondary recreation;

(2) Conditions Related to Best Usage: the waters shall be suitable for aquatic life propagation and maintenance of biological integrity, wildlife, and secondary recreation. Any source of water pollution ~~which~~ that precludes any of these uses, including their functioning as PNAs, on either a short-term or a long-term basis shall be considered to be violating a water quality standard;

~~(3) Quality standards applicable to all tidal salt waters:~~

~~(a)~~(3) Chlorophyll a (corrected): not greater than 40 ug/l in sounds, estuaries, and other waters subject to growths of macroscopic or microscopic vegetation. The Commission or its designee may prohibit or limit any discharge of waste into surface waters if, in the opinion of the Director, the surface waters experience or the discharge would result in growths of microscopic or macroscopic vegetation such that the standards established pursuant to this Rule would be violated or the intended best usage of the waters would be impaired;

(4) Cyanide: 1 ug/l;

~~(b)~~(5) Dissolved oxygen: not less than 5.0 mg/l, except that swamp waters, poorly flushed tidally influenced streams or embayments, or estuarine bottom waters may have lower values if caused by natural conditions;

(6) Enterococcus, including *Enterococcus faecalis*, *Enterococcus faecium*, *Enterococcus avium* and *Enterococcus gallinarium*: not to exceed a geometric mean of 35 enterococci per 100 ml based upon a minimum of five samples within any consecutive 30 days. [~~In accordance with 33 U.S.C. 1313 (Federal Water Pollution Control Act) for~~]For purposes of beach monitoring and notification, "Coastal Recreational Waters Monitoring, Evaluation and Notification" regulations (15A NCAC 18A .3400), available free of charge at: http://www.ncoah.com/ , are hereby incorporated by reference including any subsequent amendments;

~~(c)~~(7) Floating solids, settleable solids, or sludge deposits: only such amounts attributable to sewage, industrial ~~wastes~~ wastes, or other wastes, as shall not make the waters unsafe or unsuitable for aquatic life and wildlife, or impair the waters for any designated uses;

~~(d)~~(8) Gases, total dissolved: not greater than 110 percent of saturation;

~~(e) Enterococcus, including *Enterococcus faecalis*, *Enterococcus faecium*, *Enterococcus avium* and *Enterococcus gallinarium*: not to exceed a geometric mean of 35 enterococci per 100 ml based upon a minimum of five samples within any consecutive 30 days. In accordance with 33 U.S.C. 1313 (Federal Water Pollution Control Act) for purposes of beach monitoring and notification, "Coastal Recreational Waters Monitoring, Evaluation and Notification" regulations (15A NCAC 18A .3400) are hereby incorporated by reference including any subsequent amendments;~~

(9) Metals:

(a) With the exception of mercury and selenium, tidal salt water quality standards for metals shall be based upon measurement of the dissolved fraction of the metals. Mercury and [~~Selenium~~] selenium [~~must~~] shall be based upon measurement of the total recoverable [~~metal.~~] metal; [~~Alternative site-specific standards can be developed where studies are designed according to the "Water Quality Standards Handbook: Second Edition" published by the US Environmental Protection Agency (EPA 823-B-94-005a) hereby incorporated by reference, including any subsequent amendments;~~]

(b) Compliance with acute instream metals standards shall only be evaluated using an average of two or more samples collected within one hour. Compliance with chronic instream metals standards shall only be evaluated using averages of a minimum of four samples taken on consecutive days, or as a 96-hour average;

[~~(c) With the exception of mercury and selenium, demonstrated attainment of the applicable aquatic life use in a waterbody will take precedence over the application of the aquatic life criteria established for metals associated with these uses. An instream exceedence of the numeric criterion for metals shall not be considered to have caused an adverse impact to the instream aquatic community if biological monitoring has demonstrated attainment of biological integrity;~~]

(c) Metals criteria [~~will~~]shall be used for proactive environmental management. An instream exceedence of the numeric criterion for metals shall not be considered to have caused an adverse impact to the aquatic community without biological confirmation and a comparison of all available monitoring data and applicable water quality standards. This weight of evidence evaluation [~~will~~]shall take into account data quality and the overall confidence in how representative the sampling is of conditions in the waterbody segment before an assessment of aquatic life use attainment, or non-attainment, is made by the Division. Recognizing the synergistic and antagonistic complexities of other water quality variables on the actual toxicity of metals, with the exception of mercury and selenium, biological monitoring [~~will~~]shall be used to validate, by direct measurement, whether or not the aquatic life use is supported.

(d) Acute and chronic tidal salt water quality metals standards are as follows:

(i) Arsenic, acute: WER· 69 ug/l;

(ii) Arsenic, chronic: WER· 36 ug/l;

(iii) Cadmium, acute: WER· 40 ug/l;

(iv) Cadmium, chronic: WER· 8.8 ug/l;

(v) Chromium VI, acute: WER· 1100 ug/l;

(vi) Chromium VI, chronic: WER· 50 ug/l;

(vii) Copper, acute: WER· 4.8 ug/l;

(viii) Copper, chronic: WER· 3.1 ug/l;

(ix) Lead, acute: WER· 210 ug/l;

(x) Lead, chronic: WER· 8.1 ug/l;

(xi) Mercury, total recoverable, chronic: 0.025 ug/l;

(xii) Nickel, acute: WER· 74 ug/l;

(xiii) Nickel, chronic: WER· 8.2 ug/l;

(xiv) Selenium, total recoverable, chronic: 71 ug/l;

(xv) Silver, acute: WER· 1.9 ug/l;

(xvi) Silver, chronic: WER· 0.1 ug/l;

(xvii) Zinc, acute: WER· 90 [ug/l;]ug/l; and

(xviii) Zinc, chronic: WER· 81 ug/l;

With the exception of mercury and selenium, acute and chronic tidal saltwater quality aquatic life standards for metals listed above apply to the dissolved form of the metal and apply as a function of the pollutant's water effect ratio (WER). A WER [~~is a factor that~~] expresses the difference between the measures of the toxicity of a substance in laboratory waters and the toxicity in site water. The WER [~~is~~]shall be assigned a value equal to one [~~(1)~~] unless any person demonstrates to the [~~Department's~~]Division's satisfaction in a permit proceeding that another value is [~~appropriately~~] developed in accordance with the "Water Quality Standards Handbook: Second Edition" published by the US Environmental Protection Agency (EPA-823-B-12-002), free of charge, at http://water.epa.gov/scitech/swguidance/standards/handbook/, hereby incorporated by reference including any subsequent amendments. Alternative site-specific standards [~~can~~] may also be developed when any person submits values that demonstrate to the Commissions' satisfaction that they were derived in accordance with the "Water Quality Standards Handbook: Second Edition, Recalculation Procedure or the Resident Species [~~Procedure".~~]Procedure", hereby incorporated by reference including subsequent amendments at http://water.epa.gov/scitech/swguidance/standards/handbook/.

This material is available free of charge;

~~(f)~~(10) Oils, deleterious substances, ~~colored~~ colored, or other wastes: only such amounts as shall not render the waters injurious to public health, secondary ~~recreation~~ recreation, ~~or~~ aquatic ~~life~~ life, and wildlife or adversely affect the palatability of fish,

aesthetic ~~quality~~ quality, or impair the waters for any designated uses. For the purpose of implementing this Rule, oils, deleterious substances, ~~colored~~ colored, or other wastes shall include ~~but not be limited to~~ substances that cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines pursuant to 40 CFR 110.3;

(11) Pesticides:

(a) Aldrin: 0.003 ug/l;

(b) Chlordane: 0.004 ug/l;

(c) DDT: 0.001 ug/l;

(d) Demeton: 0.1 ug/l;

(e) Dieldrin: 0.002 ug/l;

(f) Endosulfan: 0.009 ug/l;

(g) Endrin: 0.002 ug/l;

(h) Guthion: 0.01 ug/l;

(i) Heptachlor: 0.004 ug/l;

(j) Lindane: 0.004 ug/l;

(k) Methoxychlor: 0.03 ug/l;

(l) Mirex: 0.001 ug/l;

(m) Parathion: 0.178 [ug/l;]ug/l; and

(n) Toxaphene: 0.0002 ug/l;

~~(g)~~(12) pH: shall be normal for the waters in the area, which ~~generally shall~~ range between 6.8 and ~~8.5~~ 8.5, except that swamp waters may have a pH as low as 4.3 if it is the result of natural conditions;

~~(h)~~(13) Phenolic compounds: only such levels as shall not result in fish-flesh tainting or impairment of other best usage;

(14) Polychlorinated biphenyls: (total of all PCBs and congeners identified) 0.001 ug/l;

~~(i)~~(15) Radioactive substances:

~~(i)~~(a) Combined radium-226 and radium-228: The ~~maximum~~ average annual activity level (based on at least one sample collected per quarter)~~four samples collected quarterly)~~ for combined radium-226, and radium-228 shall not exceed five picoCuries per liter;

~~(ii)~~(b) Alpha Emitters. The average annual gross alpha particle activity (including radium-226, but excluding radon and uranium) shall not exceed 15 picoCuries per liter;

~~(iii)~~(c) Beta Emitters. The ~~maximum~~ average annual activity level (based on at least one sample collected per quarter)~~four samples collected quarterly)~~ for strontium-90 shall not exceed eight picoCuries per liter; nor shall the average annual gross beta particle activity (excluding potassium-40 and other naturally occurring ~~radio nuclides)~~ radionuclides exceed 50 picoCuries per liter; nor shall the ~~maximum~~ average annual activity level for tritium exceed 20,000 picoCuries per liter;

~~(j)~~(16) Salinity: changes in salinity due to hydrological modifications shall not result in removal of the functions of a PNA. Projects that are determined by the Director to result in modifications of salinity such that functions of a PNA are impaired ~~will~~ shall be required to employ water management practices to mitigate salinity impacts;

~~(k)~~(17) Temperature: shall not be increased above the natural water temperature by more than 0.8 degrees C (1.44 degrees F) during the months of June, July, and August nor more than 2.2 degrees C (3.96 degrees F) during other months and in no cases to exceed 32 degrees C (89.6 degrees F) due to the discharge of heated liquids;

(18) Trialkyltin compounds: 0.007 ug/l expressed as tributyltin;

~~(l)~~(19) Turbidity: the turbidity in the receiving water shall not exceed 25 Nephelometric Turbidity Units (NTU); ~~NTU;~~ if turbidity exceeds this level due to natural background conditions, the existing turbidity level shall not be increased. Compliance with this turbidity standard can be met when land management activities employ Best Management Practices (BMPs) [as defined by Rule .0202 of this Section] recommended by the Designated Nonpoint Source Agency (as defined by Rule .0202 of this Section). BMPs ~~must~~ shall be in full compliance with all specifications governing the proper design, installation, ~~operation~~ operation, and maintenance of such BMPs;

~~(m) Toxic substances: numerical water quality standards (maximum permissible levels) to protect aquatic life applicable to all tidal saltwaters:~~

~~(i) Arsenic, total recoverable: 50 ug/l;~~

~~(ii) Cadmium: 5.0 ug/l; attainment of these water quality standards in surface waters shall be based on measurement of total recoverable metals concentrations unless appropriate studies have been conducted to translate total recoverable metals to a toxic form. Studies used to determine the toxic form or translators must be designed according to the "Water Quality Standards Handbook Second Edition" published by the Environmental Protection Agency (EPA 823 B 94-005a) or "The Metals Translator: Guidance For Calculating a Total Recoverable Permit Limit From a Dissolved Criterion" published by the Environmental Protection Agency (EPA 823 B 96 007) which are hereby incorporated by reference including any subsequent amendments. The Director shall consider conformance to EPA guidance as well as the presence of environmental conditions that limit the applicability of translators in approving the use of metal translators;~~

~~(iii) Chromium, total: 20 ug/l;~~

~~(iv) Cyanide: 1.0 ug/l;~~

~~(v) Mercury: 0.025 ug/l;~~

~~(vi) Lead, total recoverable: 25 ug/l; collection of data on sources, transport and fate of lead shall be required as part of the toxicity reduction evaluation for~~

~~dischargers that are out of compliance with whole effluent toxicity testing requirements and the concentration of lead in the effluent is concomitantly determined to exceed an instream level of 3.1 ug/l from the discharge;~~

~~(vii) Nickel: 8.3 ug/l; attainment of these water quality standards in surface waters shall be based on measurement of total recoverable metals concentrations unless appropriate studies have been conducted to translate total recoverable metals to a toxic form. Studies used to determine the toxic form or translators must be designed according to the "Water Quality Standards Handbook Second Edition" published by the Environmental Protection Agency (EPA 823-B-94-005a) or "The Metals Translator: Guidance For Calculating a Total Recoverable Permit Limit From a Dissolved Criterion" published by the Environmental Protection Agency (EPA 823-B-96-007) which are hereby incorporated by reference including any subsequent amendments. The Director shall consider conformance to EPA guidance as well as the presence of environmental conditions that limit the applicability of translators in approving the use of metal translators;~~

~~(viii) Pesticides:~~

~~(A) Aldrin: 0.003 ug/l;~~

~~(B) Chlordane: 0.004 ug/l;~~

~~(C) DDT: 0.001 ug/l;~~

~~(D) Demeton: 0.1 ug/l;~~

~~(E) Dieldrin: 0.002 ug/l;~~

~~(F) Endosulfan: 0.009 ug/l;~~

~~(G) Endrin: 0.002 ug/l;~~

~~(H) Guthion: 0.01 ug/l;~~

~~(I) Heptachlor: 0.004 ug/l;~~

~~(J) Lindane: 0.004 ug/l;~~

~~(K) Methoxychlor: 0.03 ug/l;~~

~~(L) Mirex: 0.001 ug/l;~~

~~(M) Parathion: 0.178 ug/l;~~

~~(N) Toxaphene: 0.0002 ug/l;~~

~~(ix) Polychlorinated biphenyls: (total of all PCBs and congeners identified) 0.001 ug/l;~~

~~(x) Selenium: 71 ug/l;~~

~~(xi) Trialkyltin compounds: 0.007 ug/l expressed as tributyltin.~~

~~(4)~~(20) Action Levels for Toxic ~~Substances:~~Substances Applicable to NPDES Permits:

(a) ~~Copper:~~Copper, dissolved, chronic: ~~3 ug/l;~~3.1 ug/l;

(b) ~~Silver:~~Silver, dissolved, chronic: 0.1 ug/l;

(c) ~~Zinc:~~Zinc, dissolved, chronic: ~~86 ug/l;~~81 ug/l

If the [~~chronic~~] ~~Action Levels~~ action levels for any of the substances listed in this ~~Subparagraph~~Item (which are generally not bioaccumulative and have variable toxicity to aquatic life because of chemical form, solubility, stream ~~characteristics~~ characteristics, or associated waste characteristics) ~~are~~ shall be determined by the waste load allocation to be exceeded in a receiving water by a discharge under the ~~specified low~~7Q10 flow criterion for toxic ~~substances (Rule .0206 in this Section),~~substances, the discharger shall ~~be required to~~ monitor the chemical or biological effects of the discharge; efforts shall be made by all dischargers to reduce or eliminate these substances from their effluents. Those substances for which ~~Action Levels~~ action levels are listed in this ~~Subparagraph~~Item ~~may~~shall be limited as appropriate in the NPDES permit if sufficient information (to be determined for metals by measurements of that portion of the dissolved instream concentration of the ~~Action Level~~ action level parameter attributable to a specific NPDES permitted discharge) exists to indicate that any of those substances may be a causative factor resulting in toxicity of the effluent. ~~NPDES permit limits may be based on translation of the toxic form to total recoverable metals. Studies used to determine the toxic form or translators must be designed according to: "Water Quality Standards Handbook Second Edition" published by the Environmental Protection Agency (EPA 823-B-94-005a) or "The Metals Translator: Guidance For Calculating a Total Recoverable Permit Limit From a Dissolved Criterion" published by the Environmental Protection Agency (EPA 823-B-96-007) which are hereby incorporated by reference including any subsequent amendments. The Director shall consider conformance to EPA guidance as well as the presence of environmental conditions that limit the applicability of translators in approving the use of metal translators.~~

History Note: *Authority G.S. 143-214.1; 143-215.3(a)(1);*
Eff. October 1, 1995;
Amended Eff. January 1, 2015; May 1, 2007; August 1, 2000.

Attachment B

Summary of North Carolina's Adopted Pollutants Compared to Previous ESA section 7 Determinations by the NMFS and FWS Regarding Similar Concentrations of Pollutants in Other EPA Actions

Pollutant Details (Left Column) /Info. Source (Top Row)	**NC µg/L criterion at 25 hardness**	***NC µg/L criterion equivalent at 50***	***NC µg/L criterion equivalent at 100***	**OR WQS**		**ID WQS (2000)**	**ID cadmium and low end hardness cap of 10**	**CTR BO µg/L range for "salmonids and stickleback"**
Hardness (or labeled non HD if not hardness dependent)	25	50	100	100		100	100	50
Which Services BO?	n/a			FWS[1]	NMFS[2]	NMFS[3]	NMFS[4], FWS[5]	NMFS and FWS[6]
Note: In the North Carolina specific columns, three hardness levels are noted with the corresponding, equivalent NC water quality criterion for ease in comparison to non-North Carolina findings from historical BOs completed elsewhere in the country for these same parameters. A general statement regarding NC's equivalent criterion comparability to the adverse/positive findings is provided (as underlined text) in one or more of the hardness columns indicated for a parameter.				• Green cell shading, indicates positive findings of the Services [(e.g. anything other than likely to adversely affect (LTAA)], with the associated criterion that was consulted on provided as the listed numeric value. • Orange shading indicates RPA provided which would result in conversion to a positive finding. • Yellow shading indicates some intensity of effect noted, but no RPA identified (and therefore not highly adverse).				

[1] In a July 30, 2012 Biological and Conference Opinion, US FWS concurred with many of EPA's may affect, not likely to adversely affect (NLTAA) determinations. Where LTAA determinations were made for a subset of species (bull trout, Oregon chub, shortnose sucker, Lost River sucker, or vernal pool fairy shrimp) the level of anticipated take was not likely to result in jeopardy or result in destruction or adverse modification of critical habitat or proposed critical habitat for any of these species. In addition to those species already considered may affect, NLTAA or no effect (NE) for fresh water, the marine criteria for all but one of the LTAA species subset (bull trout) were considered to have no effect because the species reside in fresh water only.

[2] In the August 14, 2012 Biological Opinion, NMFS found the action (fresh water criteria for toxics) was likely to jeopardize several species/populations of salmon and steelhead, green sturgeon, eulachon, and killer whales as well as result in destruction or adverse modification of designated critical habitats for the same species (less the LCR coho salmon and killer whale). However, NMFS developed an RPA, which, if implemented, will change the action such that NMFS would conclude no jeopardy or destruction or adverse modification of critical habitat. The action was determined to be may affect, NLTAA for sea lions, whales, turtles (and the critical habitat of the sea lion and certain whale and turtle species).

[3] In the May 7, 2014 Biological Opinion and letters of concurrences, NMFS found adverse modification and jeopardy for hardness floor, chronic arsenic, and copper. NMFS found no jeopardy or adverse modification of critical habitat for chromium III, chromium VI, lead, nickel, silver, zinc.

[4] Based upon the information considered in its review, NMFS concurred on January 31, 2011 with the USEPA finding that the subject action for cadmium is may affect, NLTAA designated critical habitat for Snake River spring/summer Chinook salmon, Snake River fall Chinook salmon, Snake River sockeye salmon, and Snake River Basin steelhead.

[5] In a March 7, 2011 letter, FWS indicates agreement with EPA's NE and may affect, NLTAA determinations for various species with regard to Idaho's acute and chronic cadmium criteria.

[6] The Services provided a BO on March 24, 2000 regarding the conclusions of the consultation pertaining to the California Toxics Rule (CTR). While 126 priority pollutants are addressed within the CTR, the Services focused on the numeric criteria for selenium, mercury, pentachlorophenol, cadmium and formula based criteria for metals on a dissolved basis as the most problematic for listed species and critical habitat.

Pollutant Details (Left Column) /Info. Source (Top Row)	NC µg/L criterion at 25 hardness	*NC µg/L criterion equivalent at 50*	*NC µg/L criterion equivalent at 100*	OR WQS		ID WQS (2000)	ID cadmium and low end hardness cap of 10	CTR BO µg/L range for "salmonids and stickleback"
Hardness (or labeled non HD if not hardness dependent)	25	50	100	100		100	100	50
Which Services BO?	n/a			FWS[1]	NMFS[2]	NMFS[3]	NMFS[4], FWS[5]	NMFS and FWS[6]
				• To provide more context for the shading, footnotes provide additional general detail on the specific BO being discussed, with parameter specific information from the BOs contained in separate rows following each parameter in the table.				
Arsenic (acute)	340 (non HD) 340 is less than positive BO finding			n/a	n/a	360	n/a	n/a
Arsenic (chronic)	150 (non HD) 150 is less than adverse BO finding			n/a	n/a	190	n/a	n/a

Arsenic Discussion: If only direct water exposures were considered, arsenic would be of minimal concern to listed salmonids at typical ambient concentrations or at the criteria concentrations under review. The risk of harm from short-term water-only exposures to arsenic concentrations at the acute criterion is unlikely enough to be considered a minor risk for short-term exposures….The chronic criterion appears to avoid chronic adverse effects to the adult and juvenile salmonid life stages from water-only exposures; however, arsenic concentrations below the chronic criterion have been reported to cause mortality in salmonid embryos. The chronic arsenic criterion is far higher than concentrations of arsenic sufficient to bio-accumulate in invertebrates to concentrations that cause harm to the salmonids that feed on them. Bioaccumulation of arsenic in prey organisms to concentrations that could be harmful to salmonids has occurred in streams at exposures less than 10 µg/L. As such, adverse effects can occur at the chronic criterion, through reduced growth of juveniles via food web transfer. However, the BO from NMFS indicates an interim protection for arsenic is available through use of the human health criterion, which is 10 µg/L. Because it is more stringent than the chronic criterion of 150 µg/L, the criterion for the protection of human health is the controlling criterion for permitting actions. (See Idaho Triennial BO from NMFS)

EPA's Conclusion for Arsenic: While North Carolina's acute and chronic criteria are both below the criteria considered in the Idaho BO, which were found to be a mix of positive and adverse findings, the information in the BO indicated that even at lower values, the concern outlined in the BO was specific to sensitive life stages and other non-water exposure routes, principally from diet. The BO outlined the opportunity for an improved finding through use of another applicable criterion for arsenic in Idaho's state regulations, the 10 µg/L value. In North Carolina's case, the arsenic criterion of 10 µg/L would also be applicable to all waters in the action area. Because it is more stringent than the chronic criterion of 150 µg/L, the criterion for the protection of human health would be the controlling criterion for permitting actions. Therefore, the EPA expects that the same rationale would apply for North Carolina as was used in the Idaho BO to avoid jeopardy, through the use of the human health criterion in the interim. In order to determine whether bioaccumulation in the prey species is also a concern in the North Carolina fish species at concentrations at or near 10 µg/L, additional biological monitoring could be required by the US FWS in North Carolina, but at this time the EPA is unable to say whether such actions are necessary in North Carolina as they were in Idaho. Without additional information to compare the salmonid embryo information to more locally relevant species, the EPA has determined the use of the human health criterion is sufficient to support the Agency's determination relative to the revised acute and chronic arsenic criteria, that the revisions are may affect, NLAA-insignificant for North Carolina's acute and chronic arsenic criteria due to the fact that the exposure was limited to a small subset of a different sensitive species (salmonids), at a single life stage (embryos), and was otherwise lessened through use of the alternative criterion (the human health based value).

Pollutant Details (Left Column) /Info. Source (Top Row)	NC µg/L criterion at 25 hardness	*NC µg/L criterion equivalent at 50*	*NC µg/L criterion equivalent at 100*	OR WQS		ID WQS (2000)	ID cadmium and low end hardness cap of 10	CTR BO µg/L range for "salmonids and stickleback"
Hardness (or labeled non HD if not hardness dependent)	25	50	100	100		100	100	50
Which Services BO?	n/a			FWS[1]	NMFS[2]	NMFS[3]	NMFS[4], FWS[5]	NMFS and FWS[6]
Beryllium (acute)	65 (non HD)			n/a	n/a	n/a	n/a	n/a
Beryllium (chronic)	6.5 (non HD)			n/a	n/a	n/a	n/a	n/a

Beryllium Discussion: Beryllium was not included in any of the BOs considered in the review of North Carolina's revisions.

EPA's Conclusion for Beryllium: Only the acute criterion is being revised as part of North Carolina's Triennial Review since the chronic criterion was previously approved by the EPA and not considered a revision at this time. Therefore, the EPA's analysis for consultation purposes is only on the acute criterion of 65 µg/L. In 1980, the EPA concluded that an acute freshwater criterion could not be calculated due to a limited toxicity data base (EPA 440 5-80-024). Therefore, the EPA does not have an acute water quality recommendation for beryllium. The 1980 EPA report did note that acute toxicity could occur at concentrations as low as 130 ug/l. For the revision at hand, North Carolina utilized the acute data from the 1980 report and derived its acute freshwater criterion in a manner that is consistent with the EPA's 1985 Guidelines for Deriving Numerical National Water Quality Criteria for the Protection Of Aquatic Organisms and Their Uses (PB85-227049, EPA 1985). As a result, the state adopted a value which represents half of the lowest acute toxicity concentration identified in the 1980 report as its new acute criterion. Without any further information, the EPA concludes the information available at this time supports a may affect, NLAA-insignificant determination.

Pollutant Details (Left Column) /Info. Source (Top Row)	NC µg/L criterion at 25 hardness	*NC µg/L criterion equivalent at 50*	*NC µg/L criterion equivalent at 100*	OR WQS		ID WQS (2000)	ID cadmium and low end hardness cap of 10	CTR BO µg/L range for "salmonids and stickleback"
Hardness (or labeled non HD if not hardness dependent)	25	50	100	100		100	100	50
Which Services BO?	n/a			FWS[1]	NMFS[2]	NMFS[3]	NMFS[4], FWS[5]	NMFS and FWS[6]
Cadmium (acute in non-trout waters)	0.82	1.50	2.74 2.74 is greater than two positive BO findings and greater than adverse NMFS OR BO	2.00	2.00	*See 1.3 in next column as that BO focuses on the revised cadmium for Idaho.*	1.3	n/a
Cadmium (acute in trout waters)	0.51	0.93	1.70 1.70 is in the range of two positive acute BO findings and less than one adverse acute BO	n/a	n/a	n/a	n/a	n/a
Cadmium (chronic)	0.15	0.25 0.25 is less than CTR finding but greater than recommended alternative	0.42 0.42 is within range of two positive BO findings, 0.42 is greater than other finding	0.25	0.25	*See 0.6 in next column as that BO focuses on the revised cadmium for Idaho.*	0.6	1.4

Cadmium Discussion: The FWS BO conclusion found that the levels of 2.0 and 0.25 for cadmium was not likely to rise to the level of take, in instances where species were determined to be LTAA, and for other species it was determined to be may affect, NLAA from the beginning of the analysis. (See Oregon BO from FWS)

The BO concluded the freshwater acute criterion of 2.0 and chronic criterion of 0.25, although no RPA was identified for the chronic value, "are likely to reduce appreciably the likelihood of both the survival and recovery (S/R)" and "likely to reduce appreciably the conservation value (CV) of their critical habitat" multiple species of salmon and steelhead, green sturgeon, eulachon, and Southern Resident killer whales. The RPA indicates that an alternative acute cadmium criterion should be developed by state or EPA and that EPA should disapprove acute criterion of 2.0. The chronic criterion is not addressed in the RPA section. (See Oregon BO from NMFS)

The letter from FWS indicates agreement with EPA's No Effect and may affect, NLAA determinations for various species with regard to Idaho's acute and chronic cadmium criteria of 1.3 and 0.6. The may affect, NLAA covered two snails, *lanx, Physa*, white sturgeon, and bull trout (plus critical habitat of both fish species). The may affect, NLAA conclusion was based on insignificant exposure levels to cadmium based on data presented. (See Idaho cadmium BO from FWS)

The NMFS concurred with may affect, NLAA for acute and chronic of 1.3 and 0.6 for for 3 salmon and 1 steelhead species/populations. The may affect, NLAA was based on the best available information reviewed in the attached technical memorandum and consistent implementation of the "conservative measures" described in the BE and NMFS determined the subject action would have only insignificant effects on the listed species. (See Idaho cadmium BO from NMFS)

While 126 priority pollutants are addressed within the CTR, the Services focused on the numeric criteria for selenium, mercury, pentachlorophenol, cadmium and formula based criteria for metals on a dissolved basis as the most problematic for listed species and designated critical habitat. It appears the chronic criterion being analyzed in the CTR was 1.4 µg/L. As outlined in the BO, based on the evaluations using the chronic N value and looking at several ACR methods, it appears that a chronic criterion for cadmium that would be protective of salmonids and stickleback is somewhere between 0.096 and 0.180 µg/L, but probably would still not protect cladocerans. The Services assumed the 304(a) cadmium chronic aquatic life criterion can and will be revised by EPA to be sufficiently protective of sticklebacks and salmonids in California by no later than January 2001. The Services assumed that this revision would result in lowering the permissible concentrations of cadmium. Further, the Services assumed this scientific guidance can and will be used in revising permits during the interim period prior to promulgation of this criterion in California. If, however, the criterion proposed by EPA is less stringent than that suggested by the effects analysis of the Services, EPA will provide a new biological assessment with new information that indicates why a criterion less stringent than that suggested by the Services will be sufficiently protective. (See CTR BO)

EPA's Conclusion for Cadmium: In comparing the existing BO findings in other states to the acute non-trout, acute trout, and chronic all waters cadmium criteria adopted by the state, the EPA determined that North Carolina's acute non-trout criterion was less stringent than the positive and adverse findings of the existing BOs, the acute trout criterion was within the range of positive and adverse findings, and the chronic criterion was within the range of positive and adverse findings of the non-CTR BOs. With regard to the CTR, which was considering a chronic criterion of 1.4 µg/L, it appears that the alternative chronic criterion published by EPA in 2001 was 0.25 µg/L, which was much closer to the recommended values provided by the Services in the CTR BO (0.096-0.18 µg/L), and is equivalent (at a hardness of 50 mg/L) to the chronic criterion adopted by North Carolina. To supplement the older CTR information and the west coast BO findings, the EPA looked at additional information, which was determined to more closely represent toxicity for species expected to be in North Carolina waters and/or represent newer data. Based on the results of the EPA's cadmium literature analysis contained in Attachment C, the observed toxicity levels in mussels are greater than the adopted criteria for both acute and chronic cadmium values.

For mussels, the acute toxicity results ranged from 3.5-488 times the acute non-trout criterion, 8.5-784 times the acute trout criterion, and 2-666 times the chronic criterion (although the chronic relevant low end values were not associated with mortality in the respective study). In the three papers available for cadmium effects on fish, the analysis indicated that the toxicity results were 1.5 – 22 times the acute non-trout, 2.4 – 35.5 times the acute trout criteria, and 2 – 6 times the adopted chronic criterion at the equivalent hardness levels from the respective studies. These ranges are intended to capture the range of differences found in the available cadmium studies, without specifying which test the value resulted from.

Although LC50s at 48 and 96 hours were preferred, some of the studies utilized shorter durations, such as LC50s at 24 hours or were EC50 based. The values selected for comparison were typically the most sensitive endpoint that could be compared to either the acute or chronic values (or both, where the study contained multiple endpoints) and reflected the most sensitive species from the study, when that information was articulated. As noted before, Attachment C contains more detailed information for each study's analysis, but was intended to highlight a conservative assumption, reflecting the amount difference between the study results and the equivalent state criteria concentrations. Given the general sensitivity of mussel and fish species to metals, EPA determined the adopted criteria reflect an insignificant amount of possible exposure compared to the toxicity results based on more locally relevant species information as a supplement to the information provided previously by the historical BOs. Therefore, based on the mussel and fish specific information, the EPA concludes the findings support a may affect, NLAA-insignificant determination.

Pollutant Details (Left Column) /Info. Source (Top Row)	NC µg/L criterion at 25 hardness	*NC µg/L criterion equivalent at 50*	*NC µg/L criterion equivalent at 100*	OR WQS		ID WQS (2000)	ID cadmium and low end hardness cap of 10	CTR BO µg/L range for "salmonids and stickleback"
Hardness (or labeled non HD if not hardness dependent)	25	50	100	100		100	100	50
Which Services BO?	n/a			FWS[1]	NMFS[2]	NMFS[3]	NMFS[4], FWS[5]	NMFS and FWS[6]
Chromium III (acute)	180	323 323 is greater than one positive BO finding	570 570 is equal to one positive BO finding and equal to one adverse BO finding	570	570	311 (at hardness of 50)	n/a	n/a
Chromium III (chronic)	24	42 42 is less than one positive BO finding	74 74 is equal to one positive BO finding and equal to one adverse BO finding	74	74	101 (at hardness of 50)	n/a	n/a

Chromium III Discussion: In two BOs, it was determined by the Services that insignificant effects existed and/or they did not rise to level of take determined for the acute and chronic criteria. (See Oregon FWS and Idaho NMFS BOs)

In this BO, the effects were less than jeopardy and although modification was determined for acute and chronic chromium III criteria the effects were not on the scale of any population level. (See Oregon NMFS BO)

EPA's Conclusion for Chromium III: In comparing the existing BO findings in other states to the acute and chronic chromium III criteria adopted by the state the EPA determined that the State's acute and chronic criteria were within the range of positive findings and equivalent to the values associated with adverse finding. Given that the adverse finding did not rise to the scale of any population level, the EPA determined the available information supports a may affect, NLAA-insignificant determination.

Pollutant Details (Left Column) /Info. Source (Top Row)	NC µg/L criterion at 25 hardness	*NC µg/L criterion equivalent at 50*	*NC µg/L criterion equivalent at 100*	OR WQS		ID WQS (2000)	ID cadmium and low end hardness cap of 10	CTR BO µg/L range for "salmonids and stickleback"
Hardness (or labeled non HD if not hardness dependent)	25	50	100	100		100	100	50
Which Services BO?	n/a			FWS[1]	NMFS[2]	NMFS[3]	NMFS[4], FWS[5]	NMFS and FWS[6]
Chromium VI (acute)	16 (non HD) 16 is within range of two positive BO findings, equal to one adverse BO finding			16 (non HD)	16 (non HD)	15 (non HD)	n/a	n/a
Chromium VI (chronic)	11 (non HD) 11 is within range of two positive BO findings, equal to one adverse BO finding			11 (non HD)	11 (non HD)	10 (non HD)	n/a	n/a

Chromium VI Discussion: In two BOs, it was determined there were insignificant effects or the effects did not rise to level of take determined for the acute and chronic chromium VI criteria. (See Oregon FWS and Idaho NMFS BOs)

In this BO, the effects were less than jeopardy and although modification was determined for acute and chronic chromium VI criteria the effects were not on the scale of any population level. (See Oregon NMFS BO)

EPA's Conclusion for Chromium VI: In comparing the existing BO findings in other states to the acute and chronic chromium VI criteria adopted by the state the EPA determined that the State's acute and chronic criteria were within the range of positive findings and equivalent to the values associated with the adverse finding. Given that the adverse finding did not rise to the scale of any population level, the EPA found this to be positive information. In reviewing the available papers for other parameters, the EPA found that additional information was available for consideration of chromium VI, based on the Keller and Zam study from 1991. Based on the most stringent toxicity level reported, the toxicity level was 2.4 times greater than the State's acute criterion. No information was available for chronic toxicity. Along with the BO based information, the EPA concluded the information supports a may affect, NLAA-insignificant determination.

Pollutant Details (Left Column) /Info. Source (Top Row)	NC µg/L criterion at 25 hardness	*NC µg/L criterion equivalent at 50*	*NC µg/L criterion equivalent at 100*	OR WQS		ID WQS (2000)	ID cadmium and low end hardness cap of 10	CTR BO µg/L range for "salmonids and stickleback"
Hardness (or labeled non HD if not hardness dependent)	25	50	100	100		100	100	50
Which Services BO?	n/a			FWS[1]	NMFS[2]	NMFS[3]	NMFS[4], FWS[5]	FWS[6]
Copper (acute)	3.6	7.0	13 13 is equal to one positive BO finding, equal and lower than two adverse BO findings	13	13	17	n/a	n/a
Copper (chronic)	2.70	5.0	9 9 is equal to one positive BO finding, equal and lower than two adverse BO findings	9	9	11	n/a	n/a

Copper Discussion: North Carolina's values are consistent with the FWS's NLAA finding for Oregon. (See Oregon BO from FWS)

North Carolina's values are consistent with the NMFS's original LTAA for Oregon. However, the EPA considers other information contained in the RPAs as part of its analysis relevant to copper criteria. In the BO, the NMFS suggested that EPA disapprove the acute and chronic criteria of 13 and 9 µg/L , respectively, and that Oregon adopt (or EPA promulgate if necessary) alternative acute and chronic copper criteria of 2.3 and 1.45 µg/L. It was noted that these alternative criteria, "supported by the best available information [as well as] recent reanalysis by EPA under the CWA," would avoid jeopardy and adverse modification conclusions for the subset of species identified. For other species described in footnote 2 above, a may affect, NLAA determination had been made. Therefore, the EPA further analyzed the potential effects of copper on more locally relevant species to North Carolina, which is discussed in EPA's conclusion section below, in conjunction with the findings of this BO. (See Oregon BO from NMFS)

North Carolina's values are lower than the NMFS's original LTAA for Idaho. Additionally, the EPA considers other information contained in the RPAs as part of its analysis relevant to copper criteria. In addition, the Services were concerned with toxicity that can occur at low hardness values, due to the State's hardness floor value of 25 mg/L. The RPAs identified for copper and the hardness floor indicated that: 1) a zone of passage must be maintained around any mixing zone for discharges with copper for interim protection of the listed species, 2) the State should adopt (or EPA promulgate if necessary) new copper criteria based on the 2007 criteria for copper for final protection of the

listed species, and 3) the State should remove its hardness floor provision (or EPA promulgate such change if necessary). Similar to the Oregon BO, the NMFS found concern with the state's criteria for certain species. As noted above, the EPA further analyzed the potential effects of copper on more locally relevant species to North Carolina, which is discussed in EPA's conclusion section below, in conjunction with the findings of this BO. (See Idaho BO from NMFS)

EPA's Conclusion for Copper: In comparing the existing BO findings in other states to the acute and chronic copper criteria adopted by the state the EPA determined that the State's acute and chronic criteria were within the range of positive and adverse findings. In both the BO findings and the EPA's review of available literature, it was clear that the use of the copper BLM based recommendations is preferable by the Service and noted by many in the more recent scientific literature. Much of the adverse information contained in the historical BOs related to those state's lack of use of the copper BLM or concern with lower hardness levels.

As noted above, the EPA looked at additional information, which was determined to more closely represent toxicity for species expected to be in North Carolina waters and/or represent newer data. Based on the results of the EPA's copper literature analysis contained in Attachment C, the observed toxicity levels in fish and mussels tested tended to be much greater than in other metals, discussed in this table. However, compared to those other metals, the analyses for copper were also complicated by additional factors such as the use of the BLM in deriving equivalent criteria values and the multiple hardness and in some instances DOC values or other influencing factors that were tested as part of certain studies. And as with cadmium, although LC50s at 48 and 96 hours were preferred, many of the studies utilized shorter durations, or different endpoints, sometimes even resulting in comparisons against NOEC and LOEC or "not acutely toxic values".

The values selected for comparison were typically the most sensitive endpoint that could be compared to either the acute or chronic values (or both, where the study contained multiple endpoints) and reflected the most sensitive species from the study, when that information was articulated. As noted before, Attachment C contains more detailed information for each study's analysis, and the ranges provided below are intended to simply capture the smallest and largest differences without specifying which test the value resulted from. For mussels, the acute comparison results ranged from 42% of the equivalent acute criterion for copper (except for the zebra mussel studied which was 5%) to 15 times the acute criterion, with many of the values being greater than State's equivalent criterion values. The chronic mussel results varied from 30-60% of (based on ChVs), to 18.5 times (based on 6 day test) greater than, the chronic criterion equivalent. For fish, the range in acute values were 42-57% of, to 4.8 times greater than, the acute criterion. For the fish chronic criterion comparison, values ranged from 25% (based on BLM derived LC50) and 38% (based on NOEC and LC20s) to 1.1 times greater than the chronic criterion (based on an LC20).

Given the general sensitivity of mussel and fish species to metals, EPA determined the adopted criteria reflects an insignificant exposure compared to the toxicity data of locally relevant species (supplement to the information provided previously by the historical BOs). Where the exposure concentrations, if the ambient water quality achieved concentrations up to the adopted criteria levels, could have the potential to be unprotective of a given species, the EPA has determined the above discussion regarding the State's option to use an alternative copper criterion, addresses any concerns with the unrealized toxicity. Therefore, based on all of the available information, the EPA concludes the findings support a may affect, NLAA-insignificant determination.

Pollutant Details (Left Column) /Info. Source (Top Row)	NC µg/L criterion at 25 hardness	*NC µg/L criterion equivalent at 50*	*NC µg/L criterion equivalent at 100*	OR WQS		ID WQS (2000)	ID cadmium and low end hardness cap of 10	CTR BO µg/L range for "salmonids and stickleback"
Hardness (or labeled non HD if not hardness dependent)	25	50	100	100		100	100	50
Which Services BO?	n/a			FWS[1]	NMFS[2]	NMFS[3]	NMFS[4], FWS[5]	FWS[6]
Lead (acute)	14	30	65 65 is equal to two positive BO findings, equal to one adverse BO finding	65	65	65	n/a	n/a
Lead (chronic)	0.54	1.2	2.5 2.5 is equal to two positive BO findings, equal to one adverse BO finding	2.5	2.5	2.5	n/a	n/a

Lead Discussion: The effects were insignificant effects or did not rise to level of take determined for the acute and chronic lead criteria in two BOs. (See Oregon FWS and Idaho NMFS BOs)

The effects were less than jeopardy and modification determined for acute and chronic chromium III criteria but effects were not on the scale of any population level. (See Oregon NMFS BO)

EPA's Conclusion for Lead: Among the mussel information provided for lead, the acute toxicity levels were 2.3-6 times greater than the criterion equivalent. With regard to the mussel chronic toxicity information, the 28 day chronic value was 8.5-18.5 times greater than the adopted criterion equivalent and the NOEC for chronic is 5 to 11 times greater than the chronic equivalent. One paper also indicated that the equivalent chronic criterion level was comparable to a level found in natural populations of mussels in North Carolina and was associated with a NOEC. For fish, the acute toxicity information indicates levels at 3.3 to 36 times the acute criterion equivalents. This information supports a may affect, NLAA-insignificant determination.

Pollutant Details (Left Column) /Info. Source (Top Row)	NC µg/L criterion at 25 hardness	*NC µg/L criterion equivalent at 50*	*NC µg/L criterion equivalent at 100*	OR WQS		ID WQS (2000)	ID cadmium and low end hardness cap of 10	CTR BO µg/L range for "salmonids and stickleback"
Hardness (or labeled non HD if not hardness dependent)	25	50	100	100		100	100	50
Which Services BO?	n/a			FWS[1]	NMFS[2]	NMFS[3]	NMFS[4], FWS[5]	FWS[6]
Nickel (acute)	140	260	470 470 is equal or lower than two positive BO findings, equal to one adverse BO finding	470	470	470 (revised)	n/a	n/a
Nickel (chronic)	16	29	52 52 is equal or lower than two positive BO findings, equal to one adverse BO finding	52	52	52 (revised)	n/a	n/a

Nickel Discussion: Insignificant effects or did not rise to level of take determined for the acute and chronic nickel criteria in two BOs. (See Oregon FWS and Idaho NMFS BOs).

Effects less than jeopardy and modification determined for acute and chronic chromium III criteria but effects not on the scale of any population level. (See Oregon NMFS BO).

EPA's Conclusion for Nickel: It appears that the mussel toxicity information for nickel is much more comparable to the adopted state acute and chronic values. The acute values ranged from 72% of, to 1.4 times greater than, the acute criterion. For chronic considerations, a NOEC for survival was determined to be 1.3 times the chronic criterion. This information supports a may affect, NLAA-insignificant determination.

Pollutant Details (Left Column) /Info. Source (Top Row)	NC µg/L criterion at 25 hardness	*NC µg/L criterion equivalent at 50*	*NC µg/L criterion equivalent at 100*	OR WQS		ID WQS (2000)	ID cadmium and low end hardness cap of 10	CTR BO µg/L range for "salmonids and stickleback"
Hardness (or labeled non HD if not hardness dependent)	25	50	100	100		100	100	50
Which Services BO?	n/a			FWS[1]	NMFS[2]	NMFS[3]	NMFS[4], FWS[5]	FWS[6]
Silver (acute)	0.30	0.976	3.20 3.20 is equal to two positive BO findings, equal to one adverse BO finding	3.20	3.20	3.2	n/a	n/a
Silver (chronic)	0.06 (non HD) 0.06 is less than two positive BO findings, and less than one adverse BO finding			0.1	0.1	0.1	n/a	n/a

Silver Discussion: Two BOs found insignificant effects or that the effects did not rise to level of take determined for the acute and chronic silver criteria. (See Oregon FWS and Idaho NMFS BOs).

The effects were less than jeopardy and modification was determined for acute and chronic silver criteria but the effects were not on the scale of any population level. (See Oregon NMFS BO).

EPA's Conclusion for Silver: In comparing the existing BO findings in other states to the acute and chronic silver criteria adopted by the state, the EPA determined that the State's acute and chronic criteria were equivalent to positive and adverse findings. Given that the adverse finding did not rise to the scale of any population level, the EPA determined the available information supports a may affect, NLAA-insignificant determination.

Pollutant Details (Left Column) /Info. Source (Top Row)	NC µg/L criterion at 25 hardness	*NC µg/L criterion equivalent at 50*	*NC µg/L criterion equivalent at 100*	OR WQS		ID WQS (2000)	ID cadmium and low end hardness cap of 10	CTR BO µg/L range for "salmonids and stickleback"
Hardness (or labeled non HD if not hardness dependent)	25	50	100	100		100	100	50
Which Services BO?	n/a			FWS[1]	NMFS[2]	NMFS[3]	NMFS[4], FWS[5]	FWS[6]
Zinc (acute)	36	65	120 120 is equal or greater than two positive BO findings, equal to one adverse BO finding	120	120	114	n/a	n/a
Zinc (chronic)	37	65.7	120 120 is equal or greater than two positive BO findings, equal to one adverse BO finding	120	120	105	n/a	n/a

Zinc Discussion: Two BOs found insignificant effects or that the effects did not rise to level of take determined for the acute and chronic zinc criteria. (See Oregon FWS and Idaho NMFS BOs). The effects were less than jeopardy and modification was determined for acute and chronic zinc criteria but the effects were not on the scale of any population level. (See Oregon NMFS BO).

EPA's Conclusion for Zinc: In comparing the existing BO findings in other states to the acute and chronic zinc criteria adopted by the state, the EPA determined that the State's acute and chronic criteria were equivalent to positive and adverse findings. Given that the adverse finding did not rise to the scale of any population level, the EPA determined the available information supports a may affect, NLAA-insignificant determination. In addition, the EPA looked at the available literature provided and in nearly all instances, the mussel toxicity values were greater than the acute criterion equivalent, ranging from 1.4 to 14 times greater. In one instance, where hardness could not be verified, the toxicity information potentially resulted in a value 73% of the acute criterion equivalent. The chronic toxicity information of mussels showed a similar range of greater than values, ranging from 1.3 to 13.5 greater than the chronic criterion adopted by the state. Additionally, fish information was considered, although the most sensitive species in these studies did not reflect local species. The toxicity values for acute and chronic effects ranged from, 85% of to 9.5 times greater and 86% of to 2 times greater, than the acute and chronic criteria, respectively. This information supports a may affect, NLAA-insignificant determination.

Details from Existing Biological Opinions

As referenced in footnote 1, the July 30, 2012 Biological and Conference Opinion addressed the findings of the US FWS in regard to Oregon's revised criteria for toxics. Additional information from the document is as follows:

USEPA's biological evaluation (BE) was received on January 16, 2008, with a request for formal section 7 consultation. This document is USFWS's Bological and Conference Opinion which addresses the effects of the proposed action on the threatened bull trout (*Salvelinus confluentus*) and its designated critical habitat, the threatened Oregon chub (*Oregonichthys crameri*) and its designated critical habitat, the endangered Lost River sucker (*Deltistes luxatus*) and its proposed critical habitat, the endangered shortnose sucker (*Chasmistes brevirostris*) and its proposed critical habitat, the threatened vernal pool fairy shrimp (*Branchinecta lynchi*) and its designated critical habitat, and the threatened marbled murrelet (*Brachyramphus marmoratus marmoratus*) and its designated critical habitat. This document also includes our formal concurrence on USEPA's determinations that the proposed action may affect, but is "not likely to adversely affect", the other listed species and their respective critical habitats (discussed in the Concurrences section below). The Conference Opinion addresses the effects of the proposed action on proposed critical habitat for the Lost River and shortnose suckers.

In the BE (USEPA 2008), USEPA made initial effects determinations for all aquatic listed species and critical habitats by chemical. Based on our preliminary analysis of exposure potential (see Section 4.1), we disagreed with some of USEPA's determinations; see Table 1 for USEPA's original effect determinations and those with which we disagreed. Following further analysis and subsequent correspondence between our agencies, USEPA determined their proposed action was not likely to adversely affect (NLAA) many of the listed species and critical habitat designations under the jurisdiction of USFWS in Oregon. These NLAA determinations were based on: (1) lack of exposure to the chemicals considered in this opinion, or (2) where exposure could occur, it was the likely that the effects would be insignificant or discountable. See Table 2 for a summary of USEPA's revised effects determinations and the USFWS's findings relative to these determinations for each species and critical habitat designation addressed in this opinion.

Service agreed with EPA's NLAA in all cases except:
Arsenic (freshwater) – bull trout, Oregon chub, lost river sucker, shortnose sucker
Cadmium (freshwater) - bull trout, lost river sucker, shortnose sucker
Chromium (III freshwater) - Oregon chub, lost river sucker, shortnose sucker (EPA and FWS agreed on LTAA for bull trout)
Chromium (VI (freshwater) - Oregon chub, lost river sucker, shortnose sucker, vernal pool fairy shrimp
Copper (freshwater) – bull trout, Oregon chub, lost river sucker, shortnose sucker (EPA and FWS agreed on LTAA for vernal pool fairy shrimp)
Lead (freshwater) – bull trout, Oregon chub, lost river sucker, shortnose sucker, vernal pool fairy shrimp
Nickel (freshwater) - bull trout, Oregon chub, lost river sucker, shortnose sucker
Silver (freshwater) – bull trout, Oregon chub. (EPA and FWS agreed on LTAA for both lost river sucker and shortnose sucker) (EPA said LTAA for Warner sucker but Service said NLAA)
Zinc (freshwater) - bull trout, Oregon chub, lost river sucker, shortnose sucker (EPA and FWS agreed on LTAA for vernal pool fairy shrimp)

Concurrence or non-concurrence with USEPA's determination of NLAA is based on the likelihood that a particular species will be exposed to the subject chemical via anthropogenic sources (point and nonpoint sources) and adverse effects from aqueous or dietary exposure and accumulation to the chemical. In areas where there is very low potential for co-occurrence of a listed species with the chemicals considered in this consultation, then approval of the criteria is not likely to adversely affect the listed species because the possibility the species will be exposed to the chemical is low and effects are considered discountable. The potential for co-occurrence is based on review of National Pollutant Discharge Elimination System (NPDES) permits, abandoned or active mines, and land-use activities that are nonpoint sources of pollutants. Alternatively, where there is potential for exposure to anthropogenic sources of a chemical, then effects from exposure to

the chemical are analyzed to determine if the action is likely to adversely affect the listed species. Although potential sources of exposure could change in the future, conditions in remote parts of Oregon (especially eastern Oregon) are not anticipated to change appreciably in the foreseeable future. However, if conditions do change such that there is an increase in potential exposure, this constitutes new information which would trigger reinitiation of consultation. A conceptual flowchart of this approach is diagramed in Figure 4-1. Therefore, a NLAA/LAA is based on co-occurrence and adverse effects associated with criteria concentration.

After reviewing the current status of the affected species and critical habitats, the environmental baseline for the action area relative to those species and critical habitats, the effects of USEPA's proposed approval of revised water quality standards for toxics on listed species and critical habitats, and cumulative effects relative to those species and critical habitats, it is the USFWS's biological opinion that the proposed action is not likely to jeopardize the continued existence of the bull trout, Oregon chub, Lost River sucker, shortnose sucker, vernal pool fairy shrimp, and the marbled murrelet, and is not likely to destroy or adversely modify critical habitat for the bull trout, Oregon chub, vernal pool fairy shrimp, or marbled murrelet. Critical habitat has been proposed for the Lost River sucker and the shortnose sucker. After reviewing the current status of the critical habitat, the environmental baseline for the action area relative to that critical habitats, the effects of USEPA's proposed approval of revised water quality standards for toxics on the proposed critical habitats, and cumulative effects, it is USFWS's conference opinion that the proposed action is not likely to destroy or adversely modify the proposed critical habitat.

In the analysis above, we have used the best available information to estimate the expected take associated with the proposed project. However, given the large geographical scale of the proposed project, we anticipate that incidental take of bull trout, Oregon chub, Lost River sucker, shortnose sucker and vernal pool fairy shrimp will be difficult to detect and measure as finding dead or impaired specimens is unlikely. Furthermore, we do not expect that it will be possible to detect chronically or sublethally affected individuals attributable to the proposed action. Not only are these effects difficult to detect in the complex natural environment, but take associated with the proposed project may be masked by seasonal fluctuations in numbers or other confounding effects. Therefore, we will use quantitative measurements of ambient concentrations of criteria chemicals within the action area as a surrogate for the extent of incidental take due to individual criteria.

In the accompanying Biological and Conference Opinion, USFWS determined that this level of anticipated take is not likely to result in jeopardy to the bull trout, Oregon chub, shortnose sucker, Lost River sucker, or vernal pool fairy shrimp or result in destruction or adverse modification of critical habitat or proposed critical habitat for any of these species. These reasonable and prudent measures, and their implementing terms and conditions, are designed to minimize the impact of incidental take that might otherwise result from the proposed action.

As referenced in footnote 2, the August 14, 2012 Biological Opinion addressed the findings of the NMFS's review of Oregon's revised WQS. Additional information from the document is as follows:

After reviewing the best available scientific and commercial information regarding the biological requirements and the status of LCR Chinook salmon, UWR Chinook salmon, UCR spring-run Chinook salmon, SR spring/summer-run Chinook salmon, SR fall-run Chinook salmon, CR chum salmon, LCR coho salmon, SONCC coho salmon, OC coho salmon, SR sockeye salmon, LCR steelhead, UWR steelhead, MCR steelhead, UCR steelhead, SRB steelhead, green sturgeon, Eulachon and Southern Resident killer whales considered in this opinion (section 2.4), the environmental baseline (section 2.5) for the action area, the effects of the proposed action (section 2.6), and the cumulative effects (section 2.6.8), NMFS concludes that the proposed action is likely to jeopardize the continued existence of LCR Chinook salmon, UWR Chinook salmon, UCR spring-run Chinook salmon, SR spring/summer-run Chinook salmon, SR fall-run Chinook salmon, CR chum salmon, LCR coho salmon, SONCC coho salmon, OC coho salmon, SR sockeye salmon, LCR steelhead, UWR steelhead, MCR steelhead, UCR steelhead, SRB steelhead, green sturgeon, Eulachon, and Southern Resident killer whales. Furthermore, NMFS has determined NMFS has determined that the proposed action

will result in the destruction or adverse modification of critical habitat as a result of degraded water quality in Oregon for LCR Chinook salmon, UWR Chinook salmon, UCR spring-run Chinook salmon, SR spring/summer-run Chinook salmon, SR fall-run Chinook salmon, CR chum salmon, SONCC coho salmon, OC coho salmon, SR sockeye salmon, LCR steelhead, UWR steelhead, MCR steelhead, UCR steelhead, SRB steelhead, green sturgeon, and Eulachon.

The summary conclusions provided in this section are based on an analysis of toxicity exposure-response potential for each listed species considered in this opinion and for each freshwater compound listed in Table 1.1. The NMFS based these analyses exclusively on an examination of the available toxicity data from exposure to a single compound. The NMFS also rated the magnitude of effects for each endpoint. The NMFS used a scale of *low intensity* increase in toxicity effects on listed species at the scale of individuals or groups of individuals, *moderate intensity* increase in toxicity effects on listed species at the scale of individuals or groups of individuals, *moderately-high-intensity* increase in toxicity effects on listed species at the scale of individuals or groups of individuals, but not at the scale of any population, **and *high-intensity* increase in toxicity effects on listed species that affects one or more population attribute as a means to qualitatively assess the magnitude of acute or chronic toxics effects associated with the toxicity data**. The summary conclusions do not take into account effects to the listed species considered in this opinion from exposure to multiple compounds. The issue of chemical mixtures, as well as criteria development issues, direct mortality population modeling, *etc.*, are examined in the *Integration and Synthesis*.

For aluminum, ammonia, cadmium, and copper, the NMFS determined that the freshwater acute and chronic criteria are likely to reduce appreciably the likelihood of both the survival and recovery (S/R), and are likely to reduce appreciably the conservation value (CV) of their critical habitat for the other species present and not included in the above NLAA conclusions. [*See NMFS tally of different intensity conclusions for each pollutant. The four pollutants noted here had the highest intensity (++++). See following section for more details on effects decision criteria. All other freshwater pollutants and all marine pollutants were reflected as lower intensity conclusions, +++ or less*.]

Multiple Lines of Evidence and Effects Decision Criteria.
The foremost line of evidence applied in NMFS' effects decision is the criterion-specific toxicity data. The NMFS coupled this toxicity data analysis with the summary analysis, the chemical mixtures analysis, the direct mortality population modeling, and exposure to baseline chemical stressors. The NMFS then used this information used to assess the risk associated with exposure to the compounds in Table 1.1 on each of the affected species considered in this opinion.

To examine the significance of the effects of all freshwater criteria, NMFS ran the acute criteria (for all chemicals) and chronic criteria (for ammonia, cadmium, and copper only) through a direct mortality population model (see section 2.6.5 and Appendix 3) to evaluate the magnitude of the effects of juvenile mortality on productivity for the salmonid fish species considered in this opinion. The NMFS also examined the available toxicity data on ammonia, cadmium, and copper for inclusion in a somatic growth model to assess changes in fry growth that would affect population growth rates, but the available data for these compounds could not be translated into appropriate input parameters for this model (see Appendix 3). Therefore, NMFS relied on the chronic toxicity data analysis for determining the risks of growth impairment and other sublethal effects associated with the chronic criteria and the significance of those risks to the listed species considered in this opinion.

The NMFS applied the results of the direct mortality population model as secondary line of evidence to assess the potential impact that EPA's approval of the numeric criteria would have on species' productivity. The NMFS applied the modeling results to the effects analysis in the following manner:

1. For compounds where all four modeling scenarios (described above in section 2.6.5.1) predicted a measurable level of mortality with a resulting change in λ (except for the legacy compounds), then NMFS considered these compounds to have a very high probability to appreciably reduce productivity such that the species' survival and recovery would be at increased risk.
2. For compounds where three of the four modeling scenarios predicted a level of mortality with a resulting change in λ (except for the legacy compounds), NMFS considered these compounds to have a high probability to appreciably reduce productivity such that the species' survival and recovery would be at increased risk.
3. For compounds where two of the four modeling scenarios predicted a level of mortality with a resulting change in λ (except for the legacy compounds), NMFS considered these compounds to have a moderate-to-high probability to appreciably reduce productivity such that the species' survival and recovery would be at increased risk.
4. For compounds where one of the four modeling scenarios predicted a level of mortality with a resulting change in λ (except for the legacy compounds), NMFS considered these compounds to have a moderate probability to appreciably reduce productivity such that the species' survival and recovery would be at increased risk.
5. For compounds where none of the four modeling scenarios predict a level of mortality, NMFS considered these compounds to have a low probability to appreciably reduce productivity such that the species' survival and recovery would be at increased risk.

Synthesis

Even though our predicted outcomes regarding the survival and recovery of the listed species considered in this opinion, as well the conservation value of their critical habitats, is based on the effects of the proposed action as a whole, **our analysis is structured such that the proposed numeric criteria with the highest-intensity adverse toxicological and adverse biological effects on the listed species can be separated and identified**. The multiple lines of evidence used in our analysis to identify the numeric criteria with the highest-intensity adverse toxicological and adverse biological effects include: the compound-specific acute and chronic toxicity data analyses; the analysis on considerations of the shortcomings and implications of laboratory-derived toxicity tests (uncertainty analysis); the relative percent mortality analysis; the chemical mixtures analysis; the direct mortality population model; and the summary analysis. Table 2.7.3 provides a summary of the relative percent mortality analysis in section 2.6. Table 2.7.4 then provides a list of the proposed criteria that are likely to cause the highest-intensity adverse toxicological and adverse biological effects. Table 2.7.4 also shows which compounds, individually and in combination with other compounds and environmental stressors, are likely to reduce appreciably the likelihood of both the survival and recovery of the listed species, or reduce appreciably the conservation value of their critical habitat.

Proposed RPA Information

The NMFS identified seven criteria (*i.e.*, copper [acute and chronic], ammonia [acute and chronic], cadmium [acute], and aluminum [acute and chronic])—that would cause significant adverse toxicological and biological effects on the listed species considered in this opinion. Individually and in combination with exposure to multiple compounds and stressors, these criteria are likely to reduce appreciably the likelihood of both the survival and recovery of the listed species, and are likely to reduce appreciably the conservation value of their critical habitats.

The NMFS and the EPA considered a variety of alternatives to avoid jeopardy and destruction or adverse modification of critical habitat to the listed species considered in this opinion. Based on the best available information, NMFS and EPA were able to identify alternative numeric criteria for three of the seven criteria (acute and chronic copper, chronic ammonia). The alternative criteria are supported by both the best available information considered in this opinion as well as recent reanalysis conducted by EPA under the CWA. These criteria will avoid jeopardy/adverse modification and are also within EPA's authority to implement.

For the remaining four criteria found to result in jeopardy/adverse modification, discussions between NMFS and EPA about the availability of an RPA that meets the regulatory criteria did not result in revised numeric criteria. Instead, the RPA specifies biological requirements to satisfy the conservation needs of the affected species and specific parameters EPA must work within to derive criteria that meet those requirements and avoid jeopardy and adverse modification of critical habitat.

Copper

Acute. The EPA shall disapprove the State of Oregon's acute criterion of 13 µg/L at 100 mg/L CaCO3 for freshwater copper.

The EPA shall recommend that the State of Oregon adopt, and EPA will promulgate if necessary, a new acute criterion of 2.3 µg/L for freshwater copper using EPA's 2007 BLM-based aquatic life criteria. The EPA will ensure that the new acute copper criterion will be effective within 24 months after EPA's final action to approve or disapprove Oregon's proposed water quality criteria under the CWA.

Chronic. The EPA shall disapprove the State of Oregon's chronic criterion of 9 µg/L at 100 mg/L CaCO3 for freshwater copper.

The EPA shall recommend that the State of Oregon adopt, and EPA will promulgate if necessary, a new chronic criterion of 1.45 µg/L for freshwater copper using EPA's 2007 BLM-based aquatic life criteria. The EPA will ensure that the new chronic copper criterion will be effective within 24 months after EPA's final action to approve or disapprove Oregon's proposed water quality criteria under the CWA.

Cadmium

Acute.The EPA shall disapprove the State of Oregon's acute criterion of 2.0 µg/L at 100 mg/L CaCO3 for freshwater cadmium.

The EPA shall use the Process for Deriving Criteria, specified below, to derive an acute criterion for the State of Oregon for freshwater cadmium. The EPA shall recommend that the State adopt, and EPA will promulgate if necessary, the derived acute cadmium criteria. The EPA will ensure that the derived acute ammonia criteria will be effective within 24 months after EPA's final to approve or disapprove Oregon's proposed water quality criteria under the CWA.

Process for Deriving Criteria

The EPA shall utilize analytical methods that meet specified requirements to derive numeric criteria for aquatic life, taking into account the same factors that NMFS did in completing its analysis for the other criteria in this opinion. The EPA will then evaluate the analytical results with a population model that meets the requirements set out below, and thus is equivalent to that used by NMFS in this opinion, to confirm that the derived criteria will not jeopardize listed fish or adversely modify their critical habitat.

In particular, the EPA shall derive criteria for acute ammonia, acute cadmium, and acute and chronic aluminum in compliance with the following five requirements:

1) Only use toxicity data for ammonia, cadmium, and aluminum that is specific to salmonid fishes (if new information becomes available for these compounds for green sturgeon and eulachon, then EPA shall include this data in its analysis);
2) All toxicity data used to derive the numeric criteria must be curve-fitted, where the literature provides the necessary data to perform this step;
3) When available, the curve-fitted toxicity data must be used to extrapolate threshold acute and chronic toxic effect concentrations;
4) Derived criteria must be model-adjusted to account for chemical mixtures; and,
5) An appropriate population model must be applied to the derived criteria, and must predict no negative change in the intrinsic population growth rate (*e.g.*, lambda, λ).

More specifically, EPA shall ensure that the derived criteria are developed in compliance with the following mandatory sideboards:

• The EPA shall use toxicity data specific to salmonid fishes. The EPA shall use the acute and chronic toxicity data in this opinion as a minimum data set. For green sturgeon and eulachon, EPA shall use the salmonid fishes toxicity data for this analysis, as described in section 2.6.2 in this opinion, in addition to any new data that becomes available for green sturgeon and eulachon.
• The EPA shall use toxicity data based on exposure-response curves and fixed durations toxicity tests to estimate acute and chronic toxic effect thresholds to assess effects on multiple life stages and multiple endpoints, to include at a minimum: mortality, latent mortality, reproduction, growth, physiological, cellular, behavioral, and biochemical effects, where the data exists. The EPA may use existing toxicity data for ammonia, cadmium, and aluminum or generate new data, but the data shall be curve-fitted (see Figure 2.6.1.1) to determine the minimum effect thresholds (*e.g.*, 5%) at which acute and chronic toxic effects are predicted. The minimum effects thresholds shall be used to derive the criteria instead of using the EPA acute adjustment factor or the acute-to-chronic ratio to derive criteria.
• The EPA shall ensure that each derived criterion for ammonia, cadmium, and aluminum is adjusted to account for chemical mixtures using a concentration–addition model or response-addition model to determine whether or not exposure to multiple compounds will result in additive effects to the listed species considered in this opinion. The concentration–addition model or response-addition model shall include all compounds listed in Table 1.1. If the mixture effects prediction is greater than one, EPA shall adjust the concentrations for ammonia, cadmium, and aluminum until the mixture effects prediction is less than one.
• The EPA shall ensure that the derived criteria for ammonia, cadmium, and aluminum do not result in a negative change in the intrinsic population growth rate based on the geometric mean abundance data for each life history type, *i.e.*, coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*) and ocean-type and stream-type Chinook salmon (*O. tshawytscha*), of salmonid fish considered in this opinion, at the population scale. The EPA shall use stream-type Chinook salmon as a surrogate for steelhead, and ocean-type Chinook salmon as a surrogate for chum salmon in the population model, as described in section 2.6.5.1 of this opinion. Pacific salmon and steelhead abundance data is available from the Northwest Fisheries Science Center Salmon Population Summary Database12 or from the Columbia Basin Fish and Wildlife Authority Status of the Fish and Wildlife Resources Database13. The abundance data used for the population growth rate analysis shall include data from all years with available abundance data. For green sturgeon and eulachon, EPA shall use the salmonid fishes toxicity data and modeling results as surrogate data and outputs for this analysis.

- To ensure that the derived numeric criteria for ammonia, cadmium, and aluminum meet the population growth rate condition of the RPA, EPA shall run the criteria for ammonia, cadmium, and aluminum through a population model (*e.g.*, Leslie Matrix), parameterized for Pacific salmonid fishes. Model requirements include: (1) scenarios based on change in first year survival; (2) an assumption that the populations are density-independent, to reduce the probability of Type II errors; (3) sigmoid slopes are generated from the data used to derive the numeric criteria, and if a slope cannot be generated from the data, EPA shall use the default sigmoid slope of 3.6 used in this opinion; and (4) exposure-response scenarios using the geometric mean of the curve-fitted data, and the minimum species mean value of the curve-fitted data, from the toxicity data used to derive the numeric criteria.

Implementation of the RPA avoids jeopardy to the listed species of fish because:
• We find that, based on the acute and chronic data in this opinion, effects of the revised action will not manifest at the population scale.
• We considered factors such as latent mortality and hypothesis tests in our effects analysis to assess the uncertainty of the revised action.
• The revised action will not result in appreciable population-level effects, (*i.e.*, lethal and sublethal effects do not result in a negative change in the intrinsic population growth rate, *e.g.,* lambda, λ).
• The available evidence indicates that the revised action is unlikely to appreciably affect invertebrate productivity and abundance.
• The requirement to adjust the criteria using a concentration–addition model or response-addition model will ensure that the revised action has a low probability of causing additive effects to the listed species.
• It can reasonably be concluded that the time needed to fully implement the revised action will not measurably impact the listed ESUs/DPSs or their critical habitat affected by this action.

For similar reasons, implementation of the RPA avoids adverse modification of the critical habitats for the listed species fish because:
• The revised action will not adversely modify critical habitats for the listed species considered in this opinion as the data suggests that the criteria concentrations are likely to have low-intensity adverse effects on the PCEs substrate, forage, or water quality at the watershed and designation scales. The available evidence indicates that the revised action is unlikely to appreciably affect invertebrate productivity and abundance.
• The revised action will minimize loading of copper, ammonia, cadmium, and aluminum in the affected watersheds so that habitat functions are maintained consistent with the conservation needs of the species.
• It can reasonably be concluded that the delay in implementing the revised action will not measurably impact the listed ESUs/DPSs or their critical habitat affected by this action.

The NMFS finds that all effects of the action are likely to be discountable or insignificant, and therefore concludes that the proposed action is not likely to adversely affect Steller sea lions, humpback whales, blue whales, fin whales, Sei whales, sperm whales, North Pacific Right whales, loggerhead sea turtles, green sea turtles, leatherback sea turtles, or Olive Ridley sea turtles. The NMFS finds that all effects of the action are likely to be insignificant, and therefore concludes that the proposed action is not likely to adversely affect Steller sea lion and leatherback turtle critical habitat.

As referenced in footnote 3, the May 7, 2014 Biological Opinion and letters of concurrence addressed the findings of NMFS in regard to Idaho's revised criteria for toxics. Additional information from the document is as follows:

In the May 7, 2014 Biological Opinion and letters of concurrences, NMFS found elements of the action that will likely contribute to jeopardizing the continued existence of listed Snake River anadromous salmonids or adversely modify critical habitat with regard to the hardness floor, chronic arsenic, and copper. NMFS found elements of the action that are likely to adversely affect listed species, but the magnitude of potential take is unlikely to reach levels that jeopardize the continued existence of listed Snake River anadromous salmonids or adversely modify critical habitat with regard to chromium III, chromium VI, lead, nickel, silver, and zinc.

Arsenic

If only direct water exposures were considered, arsenic would be of minimal concern to listed salmonids at typical ambient concentrations or at the criteria concentrations under review. The risk of harm from short-term water-only exposures to arsenic concentrations at the acute criterion is unlikely enough to be considered a minor risk for short-term exposures.

The chronic criterion appears to avoid chronic adverse effects to the adult and juvenile salmonid life stages from water-only exposures; however, arsenic concentrations below the chronic criterion have been reported to cause mortality in salmonid embryos. The chronic arsenic criterion is far higher than concentrations of arsenic sufficient to bioaccumulate in invertebrates to concentrations that cause harm to the salmonids that feed on them. Bioaccumulation of arsenic in prey organisms to concentrations that could be harmful to salmonids has occurred in streams at exposures less than 10 µg/L. As such, adverse effects can occur at the chronic criterion, through reduced growth of juveniles via food web transfer.

Copper

The results of this analysis suggest that concentrations below the proposed acute and chronic criteria for copper can cause acute and chronic toxicity to salmon and steelhead. At the lower range of hardness values encountered in Idaho streams and lakes the acute standard could result in injury and death.
Listed salmon and steelhead can experience a variety of adverse effects at or below the chronic Idaho copper criterion. These include:

• Deprivation of chemosensory function which in turn causes maladaptive behaviors including the loss of ability to avoid copper, and the loss of ability to detect chemical alarm signals. Appreciable adverse effects can be expected with increases as small as 0.6 µg/L above background concentrations.

• Reduced growth in juvenile Chinook salmon and rainbow trout under conditions of low hardness and low organic carbon.

• Because survival of juvenile salmon and steelhead in their migration to sea is strongly size-dependent, small reductions in size will result in disproportionately larger reductions in survival during migration to sea. Using population modeling, growth reductions at the chronic copper criterion were projected to result in slight increases in extinction risk and pronounced delays in recovery time in a model Chinook salmon population.

• The diversity and abundance of the macroinvertebrate food base for rearing juvenile salmon and steelhead could be reduced at copper concentrations near or below the Idaho chronic criterion.

While a variety of adverse effects relevant to listed salmonids have been demonstrated at copper concentrations less than the copper criteria under consultation, the most important issue is that the hardness-toxicity equation embedded into the criteria commonly results in fundamentally inaccurate and misleading indications of risk in critical habitats. This is because the best available science indicates that organic carbon is a more important mediator of copper risks than water hardness. During late summer or fall base flow conditions, copper would be expected to be most toxic because organic carbon tends to be low. Yet this is the time of year that hardness tends to be highest, and the hardness-based copper criteria wrongly indicate that copper would be of least risk at this time of year (Appendix C).

Hardness Floor

Exposure of listed Snake River salmon and steelhead to levels of metals in discharges at proposed criteria levels will result in adverse effects. Many of the streams in the Salmon River and Clearwater River drainages of Idaho also have hardness concentrations that average less than 25 mg/L which is the current floor in the hardness equation. For copper and lead, hardness is less important than DOC, but if DOC is low, toxicity does increase below the hardness floor. For nickel, and zinc, acute toxicity to fish rises as hardness declines below the 25 mg/L. For silver, acute toxicity increases modestly in early life stages, below the hardness floor.

The use of a hardness floor of 25 mg/l in calculating metals discharge limits will allow for increased exposures of listed fish to levels of metals that result in adverse effects. These effects range from a direct increase in mortality to decreases in growth and survival of juvenile Snake River spring/summer Chinook salmon, Snake River fall Chinook salmon, Snake River Sockeye salmon and Snake River Basin steelhead.

It reasonable to assume that listed Snake River spring/summer Chinook salmon and Snake River Basin steelhead will be exposed to levels of metals that are harmful to fish based on exposures to metals that are currently occurring in the action area. These exposures are also described in more detail in the sections that follow for each metal. However, is not possible to estimate within the ESU the number of locations where future metals discharges will overlap with areas that also have low water hardness values. Some examples of current discharges that meet both criteria are shown in Table 2.4.2.1. Two of these discharges are into the mainstem of Panther Creek and Yankee Fork of the Salmon River and have the potential to affect nearly all of the fish that occupy the population due to their location low in the watershed. It is reasonable to assume that future discharges may be located similarly in these areas or in a location that affects a different population in a similar fashion. Because of this, it is reasonable to assume that a large percentage of at least one population of Snake River spring/summer Chinook salmon, Snake River fall Chinook salmon, Snake River sockeye salmon or Snake River Basin steelhead within their respective ESUs will be exposed to levels of metal toxicity in early life phases which may reduce egg survival in redds or reduce growth and survival of smolts in the exposed population.

2.8.1. The RPA for the Hardness Floor

2.8.1.1. New Aquatic Life Criteria

The EPA shall recommend that the state of Idaho adopt, and EPA will promulgate if necessary, removal of the low end hardness floor on the hardness dependent metals criteria equations within 3 years of the date of this Opinion.

2.8.2. The RPAs for Arsenic

2.8.2.1. Interim Protection for Listed Species

Until a new chronic criterion for arsenic is adopted, EPA shall ensure that the 10 µg/L recreational use standard is applied in all Water Quality Based Effluent Limitations (WQBELs) and Reasonable Potential to Exceed Calculations using the human health criteria and the current methodology for developing WQBELs to protect human health. The recreational use standard is interpreted to apply as inorganic, unfiltered, arsenic.

2.8.2.2. New Chronic Aquatic Life Criterion for Arsenic

The EPA shall ensure, either through EPA promulgation of a criterion or EPA approval of a state-promulgated criterion, that a new chronic criterion for arsenic is in effect in Idaho within 7 years of the date of this Opinion. The new criterion shall be protective of listed salmon and steelhead, consistent with the discussion and analysis in this Opinion. If ESA consultation is required for the new criterion, EPA shall provide an adequate biological evaluation to NMFS and initiate consultation within 6 years of the date of this Opinion, unless NMFS and EPA mutually agree to a different time-frame, to allow for consultation to be completed prior to EPA promulgation or approval of the new criterion.

2.8.3. The RPAs for Copper

2.8.3.1. Interim Protection for Listed Species

Until new criteria are adopted, a zone of passage must be maintained around any mixing zone for discharges that include copper, sufficient to allow unimpeded passage of adult and juvenile salmonids as defined in Appendix F Salmonid Zone of Passage Considerations.

Permits for new discharges must ensure a zone of passage persists under seasonal flow conditions (see Appendix D). If the regulatory mixing zone is limited to less than or equal to 25% of the seasonal flow conditions, then a sufficient zone of passage is presumed to be present.

Permits reissued for existing discharges must ensure a zone of passage persists under seasonal flow conditions. If the regulatory mixing zone is limited to less than or equal to 25% of the volume of a stream, then sufficient zone of passage is presumed to be present. If existing discharges were calculated using greater than 25% of the seasonal flow conditions for applying aquatic life criteria the mixing zone must be reduced to 25% unless one of the following conditions exists:

1. An evidence-based “Salmonid Zone of Passage Demonstration” (see Appendix F) indicates that impeding fish movements is unlikely, or;

2. Biological monitoring of aquatic communities in the downstream receiving waters shows no appreciable adverse effects relative to reference conditions as described in Appendix E Biomonitoring of Effects, and biological whole-effluent toxicity testing is consistently negative, defined as follows:

a. Whole effluent toxicity (WET) testing shall be required, using at least the 7-day *Ceriodaphnia dubia* 3-brood test and the 7-day fathead minnow growth and survival test. If previous testing of a facility's effluents have demonstrated that one test is more sensitive, at EPA's discretion it is acceptable to base further testing on only the more sensitive test. Toxicity trigger concentrations for WET tests shall also be established using dilution series based upon no more than 25% of the applicable critical flow volume. The dilution series for WET testing (7Q10) shall be designed such that one treatment consists of 100% effluent, and at least one treatment is more dilute than the targeted critical flow conditions. Receiving waters upstream of the effluent discharge should be used as dilution water. The "critical concentration" is defined here as the condition when the smallest permitted dilution factor occurs, modified by a 25% mixing zone fraction. For example, if the minimum effluent dilution occurring at a site is a 1:4 ratio (one part effluent to four parts streamwater), then because only 25% of the measured streamflow is authorized for dilution; then the dilution factor for effluent testing is likewise reduced to 1:1. The critical concentration would then be 50% effluent, i.e., one part each effluent and dilution water.
WET tests results need to be consistently negative to indicate the absence of appreciable instream toxicity in test conditions that reflect the critical effluent concentration, above. A "negative test result" is produced by a test meeting the performance objectives of a passing test according to EPA (2002c) or EPA (2010c). Test results are considered to be consistently negative if the failure rate is less than one in 20.

b. If instream biological monitoring shows adverse effects or if WET tests are not consistently negative, then a toxicity identification evaluation and toxicity reduction evaluation (TIE/TRE) must be undertaken to identify and remedy the causes of toxicity, which may include reducing effluent limits as warranted. Because considerable judgment may be involved in designing and carrying out a TIE/TRE, and because the results are performance-based (no detectable toxicity per A.2), more specific guidance is inappropriate to provide here. Mount and Hockett (2000) provide one example of a TIE/TRE.

2.8.3.2. New Acute and Chronic Aquatic Life Criteria for Copper
The EPA shall ensure, either through EPA promulgation of criteria or EPA approval of a state-promulgated criteria, that new acute and chronic criteria for copper are in effect in Idaho within 3 years of the date of this Opinion. The new criteria shall be no less stringent than the Clean Water Act section 304(a) 2007 national recommended aquatic life criteria (i.e. the BLM Model) for copper. NMFS does not anticipate that additional consultation will be required if the 2007 national recommended aquatic life criteria for copper are adopted.

2.8.8.1. Analysis of the Reasonable and Prudent Alternative for the Hardness Floor
Use of rules and guidance that require hardness-dependent metals criteria to be implemented using ambient water hardness without a hardness floor was analyzed as being protective in this Opinion. The RPA requires that the hardness floor be removed within 3 years. In the interim, within the action area, only one major discharger is known to be permitted to discharge metals into a water body with water hardness values that are consistently lower than the 25 mg/L hardness floor. This facility, the Beartrack Mine discharges to Napias Creek upstream of a waterfall which is considered to be impassible by Snake River Chinook salmon and thus excluded from critical habitat for Snake River salmon or steelhead (50 CFR §226.205, 226.212). The facility discharges high in the Napias Creek watershed; in lower Napias Creek, where it becomes designated as critical habitat downstream of Napias Creek falls, streamflows are estimated to increase by a factor of about 1.9 (USGS 2012). Thus, assuming discharges from the Beartrack Mine resulted in instream metals concentrations that approached adverse effects thresholds, i.e., criteria constrained by the hardness floor, this increase in dilution would effectively result in reducing metals concentrations by 0.54 times, assuming no intervening sources in the Napias Creek drainage. Because the amount of critical habitat downstream of Napias Creek Falls is small (less than 2 linear miles), in the interim time before the hardness floor is removed it is unlikely to result in appreciable reductions of any of the listed species' survival or

recovery. The likelihood of new, major facilities coming online and discharging metals into low-hardness waters within this 3 year time-frame is considered unlikely.

2.8.8.2. Analysis of the Reasonable and Prudent Alternative for Arsenic

An interim protection for arsenic is available through use of the human health criterion, which is 10 µg/L. This criterion is applicable to all waters in the action area. Because it is more stringent than the chronic criterion of 150 µg/L, the criterion for the protection of human health is the controlling criterion for permitting actions. While bioaccumulation has been found in salmonid prey from exposures at concentrations at or near 10 µg/L the application of this lower standard, coupled with biological monitoring, will provide adequate information to review effects in a site specific manner. Because any new or reissued permits will be subject to individual ESA consultation to assure they avoid jeopardy or adverse modification of habitat, EPA will make adjustments as necessary during the NPDES permitting cycle taking into account local conditions to avoid measureable direct effects to the listed species. Some minor adverse effects, as described in the effects section, may still occur during the early life history phases for all listed Snake River salmon and steelhead. Use of the human health criterion will provide adequate protection in the interim to avoid jeopardy.

The adoption of a new chronic aquatic life criterion within the next 7 years will be subject to ESA consultation to ensure that the new criterion will be adequately protective. Therefore, NMFS concludes that the arsenic RPA will not jeopardize any of the listed species considered in this Opinion or adversely modify their critical habitats.

2.8.8.3. Analysis of the Reasonable and Prudent Alternative for Copper

For the next 3 years, the interim requirement of assuring an adequate zone of passage for any permits that contain copper discharge limits as described in the copper RPA will minimize adverse effects to listed salmon and steelhead. Any new permits will also be subject to individual consultation to assure they avoid jeopardy or adverse modification of habitat. NMFS found five existing permits that contain copper limits and these will be updated to the new criteria when they are reissued. Over the next permitting cycle this should reduce the adverse effects described in the effects section to acceptable levels.

In Appendix C of this Opinion, we analyze implementation of the 2007 BLM EPA copper criteria and conclude that they will be adequately protective to avoid jeopardy to the listed species or critical habitat considered in this Opinion.

Therefore, NMFS concludes that the copper RPA will not jeopardize any of the listed species considered in this Opinion or adversely modify their critical habitats.

As noted in footnote 6, the CTR was addressed by both Services. Relevant discussion from the BO includes the following:

The Services concur with EPA's determination that the CTR is not likely to adversely affect these species and critical habitats. Species the Services considered not likely to be adversely affected by the final CTR are listed in Table 2.

Pages 120-121:

For the purposes of this opinion the Services have conducted their effects analysis based on the potential for the numeric criteria to result in effects to the aquatic ecosystem and the species that are dependent on its function for their survival and recovery. While 126 priority pollutants are addressed within the CTR, the Services have focused upon the numeric criteria for selenium, mercury, pentachlorophenol, cadmium and formula based criteria for metals on a dissolved basis as the most problematic for listed species and critical habitat. The Services have prepared this analysis of criteria for priority pollutants based on: (1) the adequacy of the proposed aquatic life criteria, including the necessity of wildlife criteria where aquatic life criteria are not sufficiently protective of wildlife; (2) the toxic effects to listed species or surrogates which may occur at proposed criteria concentrations; (3) the bioaccumulative nature of the priority pollutants at issue; and (4) the

potential for interactive effects of pollutants at the proposed criteria concentrations. In some cases, such as mercury, if the aquatic life criteria were not protective and the human health criteria were lower, the adequacy of the human health numeric criteria to protect aquatic life was also considered.

Our analysis of criteria assessed whether there was the potential for toxicity that would affect listed species to occur at concentrations at or below the proposed criteria concentrations in water. EPA has stipulated that the promulgation of the CTR is solely for the purpose of providing the State of California with criteria. Although the Services recognize that criteria are sometimes not met within some California waterbodies and that implementation and enforcement issues also determine the degree of protection, the analysis within this opinion assesses the degree of protection likely to be afforded to listed species by the CTR if concentrations of toxic pollutants allowable by the proposed CTR are achieved. While EPA has not specifically proposed any wildlife criteria as part of the CTR, the Services are required to evaluate the degree of protection afforded to listed wild life species by the proposed criteria for all California waterbodies.

The Services have evaluated the effects of the proposed action based on the assumptions that: (1) the proposed numeric criteria will apply throughout the geographic distribution of the species; and (2) the ambient concentrations of constituents could rise to the concentrations allowed by the numeric criteria proposed by EPA. Included in these findings are the Services' analysis of the demonstrated potential for adverse effects to occur to species at or below the proposed criteria concentrations, the likelihood of these problematic concentrations being achieved within the range of the species, and the degree to which these adverse effect s will impact the species' environmental baseline.

Page 12: EPA Modifications Addressing the Services' April 9, 1999 draft Reasonable and Prudent Alternatives for Cadmium:

EPA will develop a revision to its recommended 304 (a) chronic aquatic life criterion for cadmium by January 2001 to ensure the protection of federally listed species and/or critical habitats and will propose the revised criterion in California by January 2002.

Pages 13-15:
EPA Modifications to Address the Services' April 9, 1999 draft Reasonable and Prudent Alternatives for Dissolved Metals:

A. By December of 2000, EPA, in cooperation with the Services, will develop sediment criteria guidelines for cadmium, copper, lead, nickel and zinc, and by December of 2002, for chromium and silver. When the above guidance for cadmium, copper, lead, nickel and zinc is completed, Region 9, in cooperation with the Services, will draft implementation guidelines for the State of California to protect federally listed threatened and endangered species and critical habitat in California.
B. EPA, in cooperation with the Services, will issue a clarification to the *Interim Guidance on the Determination and Use of Water-Effect Ratios for Metals* (EPA 1994) concerning the use of calcium-to-magnesium ratios in laboratory water, which can result in inaccurate and under-protective criteria values for federally listed species considered in the Services' opinion. EPA, in cooperation with the Services, will also issue a clarification to the *Interim Guidance* addressing the proper acclimation of test organisms prior to testing in applying water-effect ratios (WERs).
C. By June of 2003, EPA, in cooperation with the Services, will develop a revised criteria calculation model based on best available science for deriving aquatic life criteria on the basis of hardness (calcium and magnesium), pH, alkalinity, and dissolved organic carbon (DOC) for metals. This will be done in conjunction with "Other Actions A." below.
D. In certain instances, the State of California may develop site-specific translators, using EPA or equivalent state/tribe guidance, to translate dissolved metals criteria into total recoverable permit limits. A translator is the ratio of dissolved metal to total recoverable metal in the receiving water downstream, from a discharge. A site-specific translator is determined on site-specific effluent and ambient data. Whenever a threatened or endangered species or critical habitat is present within the geographic range downstream from a discharge where a State developed translator will be used and the conditions listed below exist, EPA will work, in cooperation with the Services and the State of California, to use available ecological safeguards to ensure protection of federally listed species and/or

critical habitat. Ecological safeguards include: (1) sediment guidelines; (2) biocriteria; (3) bioassessment; (4) effluent and ambient toxicity testing; or (5) residue-based criteria in shellfish.

Conditions for use of ecosystem safeguards:
1. A water body is listed as impaired on the CWA section 303(d) list due to elevated metal concentrations in sediment, fish, shellfish or wildlife; or,
2. A water body receives mine drainage; or,
3. Where particulate metals compose a 50% or greater component of the total metal measured in a downstream water body in which a permitted discharge (subject to translator method selection) is proposed and the dissolved fraction is equal to or within 75% of the water quality criteria.
Whenever a threatened or endangered species is present downstream from a discharge where a State developed translator will be used, EPA will work with the permitting authority to ensure that appropriate information, which may be needed to calculate the translator in accordance with the applicable guidance, will be obtained and used.

Appropriate information includes:
1. Ambient and effluent acute and chronic toxicity data;
2. Bioassessment data; and/or
3. An analysis of the potential effect s of the metals using sediment guidelines, biocriteria and residue-based criteria for shellfish to the extent such guidelines and criteria exist and are applicable to the receiving water body. EPA, in cooperation with the Services, will review these discharges and associated monitoring data and permit limits, to determine the potential for the discharge to impact federally listed species and/or critical habitats. If discharges are identified that have the potential to adversely affect federally listed species and/or critical habitat, EPA will work with the Services and the State of California in accordance with procedures agreed to by the Agencies in the draft MOA published in the Federal Register at 64 FR 2755 (January 15, 1999) or any modifications to those procedures agreed to in a finalized MOA.

Other Actions
A. EPA will initiate a process to develop a national methodology to derive site-specific criteria to protect federally listed threatened and endangered species, including wildlife, in accordance with the draft MOA between EPA and the Services concerning section 7 consultations.

Services' Assumptions Regarding EPA's Modifications for Removing Jeopardy for Cadmium. Page 200.
The Services assume the 304(a) cadmium chronic aquatic life criterion can and will be revised by EPA to be sufficiently protective of sticklebacks and salmonids in California by no later than January 2001. The Services assume that this revision will result in lowering the permissible concentrations of cadmium. Further, the Services assume this scientific guidance can and will be used in revising permits during the interim period prior to promulgation of this criterion in California.

If, however, the criterion proposed by EPA is less stringent than that suggested by the effects analysis of the Services, EPA will provide a new biological assessment with new information that indicates why a criterion less stringent than that suggested by the Services will be sufficiently protective.

Attachment C

Summary of Mussel and Fish Specific Results from Existing Cadmium Papers and Comparison to NC Criteria for Cadmium

Green highlighting indicates 1) where 48 hour or 96 hour LC50 tests were greater than NC's acute criteria to demonstrate when toxicity levels were higher than the State's acute criterion or 2) longer term toxicity results were greater than the State's chronic criterion. Other information that is relevant to showing effects but based on some other metric (EC50, NOEC or LOEC, etc) is highlighted in yellow as additional evidence considered in determining any potential effects from given exposure concentrations of cadmium.

Cadmium Papers provided by Tom A for mussels Listed by Author	Hardness	Results/Notes from Studies	Comparable NC cadmium acute/chronic criterion based on similar hardness
Mussel Specific Information			
Black (2001)	80-88	Results are all in µg/L o U. imbecilis gloc Cadmium LC50 average of 4 tests: 24 hr 56.76, 48 hr 27.85 (control failure) o F. masoni gloc Cadmium LC50 average of 1-2 tests: 6 hr >300, 12 hr 306.30, 24 hr 168.1 o U. imbecilis juven Cadmium LC50 average of 2-3 tests: 48 hr 70.99, 96 hr 20.42 (control failure) o L. subviridis juven Cadmium LC50 average of 3 tests: 48 hr 107.16, 96 hr 57.77, 24 hr test 280 o C. daphnia Cadmium LC50 average of 3 tests: 24 hr 80.30, 48 hr 64.26	Acute at 50/100: 1.50/2.74 Trout at 50/100: 0.93/1.70
EPA's conclusion: The 48 hr LC50 values range from 64.26 to 107.16 µg/L and the 96 hr LC50 was 57.77 µg/L (not including results from control failure tests). With a hardness between 50 and 100 mg/L, the comparable North Carolina criteria values would be 1.50-2.74, or 0.93-1.70 for trout waters. Comparing the state concentrations against the lowest LC50 concentration in these studies, the toxicity results are ~21-38 times greater than the state's criteria for non-trout waters and ~34-62 times greater than the state's criteria for trout waters. Chronic cadmium information was not available in this paper so it was not addressed in this conclusion box.			
Clem S. A (1998)	Used dechlorinated tap water (40-50) or moderately hard synthetic	Glochidial response of five species (L. fragilis, L.teres, P.purpuratus, P. occidentalis, and L. suborstrata) assessed using 24 hr acute tox tests with Al, Cd, Cu, Fe, Mn, Ni, and Zn. • LC50 values for cadmium ranged from 197 (for L. fragilis) to 720 µg/L (for L. subrostrata)	Acute at 50/100: 1.50/2.74 Trout at 50/100: 0.93/1.70

	water (80-100)		
EPA's conclusion: The 24hr LC50 values ranged from 197 to 720 µg/L. With hardness between 40 and 100 mg/L, the North Carolina criteria values are given at 50 and 100 hardness, 1.50-2.74 for non-trout waters and 0.93-1.70 for trout waters. Comparing the state concentrations against the lowest LC50 concentration in these studies, the toxicity results are more than ~72-131 times greater than the state's criteria for non-trout waters and ~ 116-212 times greater than the state's criteria for trout waters. Chronic cadmium information was not available in this paper so it was not addressed in this conclusion box.			
Falfushynska, H. I., Gnatyshyna, L. L. and Stoliar, O. B. (2013)	Did Not Use Study	Did Not Use Study Focused on molecular responses in relation to their in situ exposure history.	n/a
EPA's conclusion: Did not use study due to lack of LC50 or other lethality related information.			

Hansten, C., Heino, M., and Pynnönen, K. (1996).	25.7	• Looked at the effects of humic acid (200 mg Pt/l as color), EDTA (used in excessive amounts to achieve maximal chelation), Fe (1000 µg/L) and Mn (400 µg/L) on the toxicity of Cd, Cu, and Zn on glochidia.
		  ○ Used concentrations which were non-toxic and matched maximums found in natural environments (values given above in parentheses).
		• Copper was the most toxic and Zinc was the least toxic. Toxicity increased with exposure time.
		  ○ Cadmium 50, 100, 400, and 1000 µg/L
		  ▪ After 24 hrs, Cd showed toxic effects at concentrations exceeding 400 µg/L
		  ▪ Zero gloc viability approached after 144 hrs when above 100
		• Humic acid decreased toxicities of Cadmium and Copper, but increased Zinc toxicity.
		• EDTA and Fe decreased the toxicity of all three metals.
		• Manganese did not effect Cadmium and Copper, but increased toxicity of Zinc.
			Acute at 25: 0.82
			
			Trout at 25: 0.51
			
			Chronic at 25: 0.15

EPA's conclusion: This study showed that levels exceeding 400 µg/L, resulted in toxic effects at 24 hours and that 100 µg/L resulted in zero viability after 144 hours (6 days). When comparing the short term exposure concentration of 400 µg/L to the North Carolina criteria values at 25 hardness, the criteria should be compared to 0.82 and 0.51 µg/L for non-trout and trout waters, respectively. Comparing the state concentrations against the shortest term concentration in this study, the toxicity results are more than almost 488 times greater than the state's criteria for non-trout waters and 784 times greater than the state's criteria for trout waters. When comparing the state's chronic criterion of 0.15 µg/L to the 6 day exposure of 100 µg/L, the toxicity endpoint was 666 times greater than the state's criterion. While this study did not include typical durations of exposure, the information still provides some estimates by which to assess the state's criteria against for consultation purposes.			

Huebner, J. D. and Pynnonen, K. S. (1992).	35	• EC50 for µg/L cadmium: 24 hr 154.7 (ranged 112.4-210.8), 48 hr 46.8 (ranged 0.1-81.1), 72 hr 4.8 (0.1-13.6) • Threshold concentration to cause significant decrease in gloc response for µg/L Cadmium: 24 hr 500, 48 hr 100, 72 hr 50	Acute at 25/50: 0.82/1.50 Trout at 25/50: 0.51/0.93
EPA's conclusion: The average 48 hr EC50 value was 46.8 although it ranged from 0.1 to 81.1 µg/L and there was a significant decrease in response at 100 µg/L at the 48 hr mark. With a hardness of 35 mg/L, the North Carolina criteria values are given at 25 and 50 hardness, 0.82-1.50 for non-trout waters and 0.51-0.93 for trout waters. Comparing the state concentrations against the lowest EC50 concentration in these studies, the toxicity results are ~ 31-57 times greater than the state's criteria for non-trout waters and ~50-92 times greater than the state's criteria for trout waters. When compared to the threshold concentration the differences become even greater. However, it should be noted this study used low pH (3-6.5) and simultaneously included exposure to other metals, including aluminum and copper so there could be confounding factors influencing these results. While this study did not include typical durations of exposure, the information still provides some estimates by which to assess the state's criteria against for consultation purposes. Chronic cadmium information was not available in this paper so it was not addressed in this conclusion box.			
Keller, A. E., and Zam, S. G. (1991).	39-45 (range observed for soft water in this study)	• "Overall, mussels were found to be as sensitive to metals as zooplankton and more sensitive than commonly tested fish and aquatic insects." "In an effort to obtain basis experimental data, a series of acute toxicity (96 hr) tests were performed to determine whether juvenile mussels were sensitive to mercury, zinc, nickel, cadmium, copper, and chromium, the metals most toxic to other aquatic biota." • In soft water, the order of LC50 averages for juvenile A.imbecilis at 48hr was: Cd (0.057mg/L)> Cu (0.171 mg/L)>Hg (0.216mg/L)>Ni (0.240 mg/L)>Cr (0.295mg/L)>Zn (0.355mg/L) • In soft water, the order of LC50 averages for juvenile A.imbecilis at 96hr was: Cd (0.009mg/L) >Cr (0.039mg/L)> Cu (0.086 mg/L)>Hg (0.147mg/L)>Ni (0.190 mg/L)> Zn (0.268mg/L) ○ Cr and Cu increased tox much more than the other metals between 48 and 96 hrs • In moderately hard water, the order of LC50 averages for juvenile A.imbecilis at 48hr was: Cd (0.137mg/L)>Hg (0.233mg/L)> Cu (0.388 mg/L)>Ni (0.471 mg/L)>Zn (0.588mg/L)>Cr (1.187mg/L)	Acute at 25/50: 0.82/1.50 Trout at 25/50: 0.51/0.93

		• In moderately hard water, the order of LC50 averages for juvenile A.imbecilis at 96hr was: Cd (0.107mg/L)>Hg (0.171mg/L)> Cu (0.199 mg/L)>Ni (0.252 mg/L)>Zn (0.438mg/L)>Cr (0.618mg/L) • Comparison of LC50 values for metals and ambient water quality guidelines established by the EPA indicates current standards may be adequate to protect mussels from acute exposures to metals. The 4 day average concentrations of all 6 metals tested are lower than the mussel 96 hr LC50 in soft water. However, sensitivity of A.imbecilis to Cr, Zn, and Ni is close enough to the WQS to bear further study.	
EPA's conclusion: In soft water, the average 48 hr LC50 value was 57 µg/L and the average 96 hr LC50 was 9 µg/L. In moderately hard water, the average 48 hr LC50 value was 137 µg/L and the average 96 hr LC50 was 107 µg/L. With hardness of 39 mg/L, the North Carolina criteria values are given at 25 and 50 hardness, 0.82-1.50 for non-trout waters and 0.51-0.93 for trout waters. Without details on what was characterized as "moderately hard water" the EPA chose to just compare using the 25 and 50 hardness range as described since this would be the most conservative assumption. Comparing the state concentrations against the lowest LC50 concentration in these studies (the 96 hr in soft water), the toxicity results are 6 to ~11 times greater than the state's criteria for non-trout waters and ~10-18 times greater than the state's criteria for trout waters. Chronic cadmium information was not available in this paper so it was not addressed in this conclusion box.			
Klaine, S. J., Warren, L .W. and Summers, J. M. (1997).	99-107	Responses among age groups was similar for Cd but more variable for copper. • 24 hr / 48 hr / 96 hr LC50 for mussels (in µg/L) o 2 day: 80 to >130 / 48-173 / 34-55 [MEAN 48 hr LC50 91 µg/L] o 9 day: 104 to >130 / 52-175 / 33-102 [MEAN 48 hr LC50 101 µg/L] o 16 day: >47 to >86 / 84-251 / >23 to 132 [MEAN 48 hr LC50 157 µg/L]	Acute at 100: 2.74 Trout at 100: 1.70
EPA's conclusion: Depending on the age group tested, the average 48 hr LC50 values ranged from 91 to 157 µg/L, with lowest 48 hr LC50 being 48 µg/L. For the 96 hr LC50 the lowest value was >23 µg/L. With a hardness concentration around 100 mg/L, the comparable North Carolina criteria values would be 2.74 and 1.70 for non-trout and trout waters, respectively. Comparing the acute state concentrations against the lowest LC50 concentration from all of the results (>23 µg/L), the toxicity results are ~8 times greater than the state's criteria for non-trout waters and ~14 times greater than the state's criteria for trout waters. Using other individual LC50s (either 48 hr or 96 hr tests) or the most stringent average 48hr LC50 would result in greater differences in the toxicity results and the acute criteria. Chronic cadmium information was not available in this paper so it was not addressed in this conclusion box.			
Lasee, B. A. (1991).	Hardness for 48 hr test was 149+6.3, 7 day test was 145+4	• Effects of cadmium on larval and juvenile L. ventricosa. ○ Early juvenile stages were more sensitive than older juveniles and gloc were very tolerant to Cd exposures. ○ 10µg/L for 7 days significantly reduced anterior shell growth ○ Exposures of 30-100 µg/L resulted in dissolution of the crystalline style in several juveniles. Also juvenile feeding was reduced. ○ Larval and juvenile mussels were exposed to 5 Cd concentrations (50-1500 µg/L) and a control for 0, 7, and 14 days.	Acute at 150: 3.9 Trout at 150: 2.42 Chronic at 150: 0.58

		○ There was low mortality (<4%) of control juveniles in 48 hr tests. ○ Acute 48 hr LC50s: ▪ Glochidia: >1000 µg/L Cd ▪ Juvenile 0 day: 141 µg/L Cd ▪ Juvenile 7 day: 166 µg/L Cd ▪ Juvenile 14 day: 345 µg/L Cd ○ Acute 48 hr EC50s: ▪ Juvenile 0 day: 91 µg/L Cd ▪ Juvenile 7 day: 107 µg/L Cd ▪ Juvenile 14 day: 291 µg/L Cd	
EPA's conclusion: Depending on the age group tested, the 48 hr LC50 values ranged from 141 to >1000 µg/L, with lowest 48 hr LC50 being 141 µg/L. For the 48 hr EC50 the lowest value was 91 µg/L. With a hardness concentration around 150 mg/L, the comparable North Carolina criteria values would be 3.9 and 2.42 for non-trout and trout waters, respectively. Comparing the acute state concentrations against the lowest EC50 concentration (91 µg/L), the effect concentration results are ~23 times greater than the state's criteria for non-trout waters and ~38 times greater than the state's criteria for trout waters. Comparing the criteria to the most stringent 48 hr LC50 (141 µg/L) would result in greater differences, ~36 times greater than the state's criteria for non-trout waters and ~58 times greater than the state's criteria for trout waters. Additional information in this study indicates a concentration as low as 10 µg/L for 7 days can have effects on shell growth. This concentration is ~17 times greater than the chronic criterion at a hardness of 150.			
Marasinghe Wadige, C. P., Maher, W. A., Taylor, A. M., and Krikowa, F. (2014)	Not noted in paper	• Tested spiked sediments and exposure response of Hyridella australis. • Cadmium concentrations ranged from 5µg/g to 15 µg/g, which represent half and 1.5 times the high effects trigger value concentration of cadmium in the ANZECC/ARMCANZ (2000) ISQG. • No mortality was observed in any treatment over the exposure period (7, 14, 21, and 28 days) although accumulation of metals in whole body tissues over all treatments • The overlaying water collected weekly ranged from 0.33-0.43 µg/L in low dose to 0.61-1.04µg/L in high dose sediment treatments. Low levels in water may be affected by water changes to reduce confounding effects of ammonia on responses.	Chronic at 25: 0.15
EPA's conclusion: Although this study looked at spiked sediments and there was accumulation of metals in the organism, no mortality was observed at the listed sediment concentrations, which included overlaying water concentrations for comparison. The study also represented a longer term exposure than other toxicity tests reviewed by EPA. When comparing to the State's criterion at the lower hardness value of 25, the concentrations were much closer to the chronic criteria adopted by the state than some of the previous results noted for cadmium above, although this is potentially a conservative estimate due to the fact the hardness was not noted in the paper. If the hardness values are considered comparable, then the overlaying water from the low dose sediment treatment was ~2-3 times the chronic criterion and the high dose sediment treatment was ~4-7 times higher than the state' chronic criterion.			

Naimo, T. J., Atchison, G. J. and Holland-Bartels, L. E. (1992).	Reconstituted tap water (aka "dilution water") hardness was 165±3.4 mg/L Other cited study included hardness as low as 23 mg/L	• Notes cadmium is toxic to some aquatic organisms at concentrations as low as 0.8µg/L (see reference 7 for more details). • Before study Cd was measured as <1µg/L (other metals starting concentrations are noted in paper) • Measured mean Cd concentrations: 0 (<5 µg/L detection limit), 22.1±2.5, 23.1±3.5, 107.2±3.7, 115.4±3.4, 304.7±1.2, 305.6±5.5 µg/L. • Except for food assimilation efficiency and O>N ratio, the physiological responses of the mussels exposed to increasing cadmium concentrations did not change significantly over time. Reference 7 is associated with the 1985 Contaminants Hazard Review document: Excerpts from that document are as follows: The freshwater biota is the most sensitive group; concentrations of 0.8 to 9.9 µg Cd/L (ppb) in water were lethal to several species of aquatic insects, crustaceans, and teleosts, and concentrations of 0.7 to 570 ppb were associated with sublethal effects such as decreased growth, inhibited reproduction, and population alterations. These effects were most pronounced in waters of comparatively low alkalinity. Marine organisms were more resistant than freshwater biota. Decapod crustaceans, the most sensitive saltwater group, died at concentrations of cadmium in seawater ranging from 14.8 to 420 ppb. Sublethal effects to marine animals recorded at Cd concentrations of 0.5 to 10 ppb included decreased growth, respiratory disruption, altered enzyme levels, and abnormal muscular contractions; effects were usually most obvious at relatively low salinities and high temperatures. Freshwater and marine aquatic organisms accumulated measurable amounts of cadmium from water containing Cd concentrations not previously considered hazardous to public health or to many species of aquatic life; i.e., 0.02 to 10 ppb."… "It is now conservatively estimated that adverse effects on fish or wildlife are either pronounced or probable when cadmium concentrations exceed 3 ppb in fresh water, 4.5 ppb in saltwater, 100 ppb in the diet, or 100 _g Cd/m3 in air." Hardness for lowest values reported as 23, "soft", or not listed. Highest hardness report was 350 although most values fell between 23-54mg/L.	Acute at 160: 4.13 Trout at 160: 2.6 Chronic at 160: 0.61 Acute at 25: 0.82 Trout at 25: 0.51 Chronic at 25: 0.15

EPA's conclusion: This study provides the most useful information relative to EPA's analysis through its reference to another study, which indicated that cadmium is lethal to some organisms (aquatic insects, crustaceans, and teleosts) as low as 0.8 µg/L (and up to 9.9 µg/L). Sub-lethal effects (decreased growth, inhibited reproduction, and population alterations) ranged from 0.7 µg/L to 570 µg/L. It should be noted that the lower values were from tests that usually ran for one week or as long as one month and in some instances reflected LC10s as opposed to LC50s. Comparing North Carolina's chronic criteria, at a hardness of 25, provides the most comparable comparison to the results of this 1985 study. At a hardness of 25, the values of 0.7 and 0.8 µg/L are approximately 5 times the chronic criteria adopted by the state. When compared to the conclusion regarding the conservative estimate of adverse effects (those occurring when cadmium concentrations exceed 3 ppb in fresh water), the study results are ~3.5-6 times higher than the state's acute criteria or 20 times higher than the chronic criterion.			
Pynnönen, K. (1995).	moderately hard water (35 mg/L Ca/L)	Did Not Use Study Due to inability to determine LC50, this paper is not directly helpful to BE effort. • Maternal pre-exposure at low metal concentrations often increased resistance of gloc to metals, but exposure to higher concentrations decreased resistance. Order to toxicity: Cu>Cd>Zn	n/a
EPA's conclusion: Did not use study due to lack of LC50 or other lethality related information.			
Wang, N., Ingersoll, C. G., Ivey, C. D., Hardesty, D. K., May, T. W., Augspurger, T., Roberts, A. D., van Genderen, E., and Barnhart, M. C. (2010).	reconstituted soft water (hardness 40-48mg/L)	• 24 hr EC50 for 2 hr old fatmucket gloc: 8-227 µg/L Cd (Pb and Zn also in paper), 96 hr EC50 for fatmucket 6 month juvenile: 199 µg/L Cd (Pb and Zn also in paper), 96 hr EC50 for newly transformed (5 day) fatmucket: 16 µg/L Cd and Neosho mucket: 20 µg/L (Pb and Zn also in paper) • Survival % for Cadmium: ○ Concentration 0.04 µg/L: 100 % survival ○ Concentration 1.2 µg/L: 100 % survival ○ Concentration 2.2 µg/L: 100 % survival ○ Concentration 4.4 µg/L: 95 % survival ○ Concentration 8.2 µg/L: 50 % survival ○ Concentration 22 µg/L: 0 % survival • Other info: ○ NOEC = 4.4µg/L ○ LOEC = 8.2µg/L • The results indicate that the current EPA acute and chronic WQC are protective of the tested freshwater mussels from Pb or Cd exposure, but may not be adequately protective for Zn exposure. Paper discusses BLM for Zn.	Acute at 25/50: 0.82/1.50 Trout at 25/50: 0.51/0.93

EPA's conclusions: The 24 hr EC50 values ranged from 8 to 227 µg/L. The 96 hr EC50s ranged from 16 to 199 µg/L, depending on age of test species (5 day old vs 6 month juvenile). The difference between no effect and lowest observed effect was 4.4 versus 8.8 µg/L. In considering all of these endpoints, EPA is considering the lowest effects related concentration, 8 µg/L, to be the most conservative assumption from this study. If that value is compared to the State's criteria using hardnesses of 25 and 50, the lowest effects related concentration is ~5-10 times higher than the acute non-trout criteria and ~8.5-15.5 times higher than the acute trout criteria. If comparing the criteria to the most stringent 96 hr EC50 (16 µg/L) would result in greater differences, ~10.5-19.5 times greater than the state's criteria for non-trout waters and ~17-31 times greater than the state's criteria for trout waters. Chronic cadmium information was not available in this paper so it was not addressed in this conclusion box.

Fish Specific Information

<table>
<tr>
<td>Besser, J., Mebane, C., Mount, D., Ivey, C., Kunz, J., Greer, E., May, T., and Ingersoll, C. (2007).</td>
<td>100</td>
<td>

- Table summary of all values, WQC calculated at 100 hardness

<table>
<tr><th></th><th>MN sculpin</th><th>MO sculpin</th><th>Sculpin Species</th><th>Rainbow Trout</th><th>WQC</th></tr>
<tr><td>Cadmium</td><td colspan="5"></td></tr>
<tr><td>Acute LC50</td><td>5.3</td><td>4.1</td><td>4.6</td><td>4.7</td><td>2.0</td></tr>
<tr><td>Chronic value</td><td>1.9</td><td>0.88</td><td>1.3</td><td>1.9</td><td>0.25</td></tr>
</table>

- Paper also discusses sensitivity relative to other taxa including comparison to mean toxicity values from WQC documents. Generally these species were close to most sensitive taxa
  - Results of study indicate WQC may be protective for rainbow trout but not mottled sculpins. For rainbow trout, all acute LC50s were at least two times greater than the acute WQC and all chronic values were greater than chronic WQC. Cadmium and zinc WQC provided marginal protection for sculpins.

</td>
<td>Acute at 100: 2.74

Trout at 100: 1.70

Chronic at 100: 0.42</td>
</tr>
<tr>
<td colspan="4">EPA's conclusions: When comparing the most stringent acute LC50 from the summarized table of values (4.1 for the Missouri sculpin) to the acute non-trout and acute trout criteria at 100 hardness, the toxicity concentration is 1.5 and 2.4 times the value adopted by the State. Similarly, when comparing the chronic criterion at 100 hardness, to the most stringent chronic value (0.88 for the Missouri sculpin), the toxicity concentration is ~2 times the value adopted by the state.</td>
</tr>
<tr>
<td>Vardy, D.W., Santore, R., Ryan, A., Giesy, J.P., Hecker, M. (2014).</td>
<td></td>
<td>

- Study reports results for 96hr toxicity tests for copper, cadmium, zinc, and lead from parallel studies that were conducted in laboratory water and in the field with Columbia River water.

</td>
<td></td>
</tr>
</table>

[Note: Originally included in copper reference list but included here since study addressed cadmium also. See copper record papers for more information.]	72-76 mg/L	• Cadmium 8dph lab/8dph site (all in µg/L) Hardness 76/72 LC50 14.5/72 LC50 BLM normalized to site water 9.7/na EPA WQC 1.4/1.4 LC50 BLM normalized to ref water 11/33 EPA WQC based on ref water 1.7/na • In current study, LC50s for white sturgeon exposed to lead in lab water were significantly less than average LC50s for rainbow trout and less than or equal to cutthroat trout. However, for cadmium, an opposite trend was observed whereby early life state white sturgeon exposed to cadmium in lab water were less sensitive than rainbow trout, bull trout, cutthroat trout, shorthead sculpins, and mottled sculpins, all of which exhibited LC50s that ranged between 1.7 µg/L and 3.5 µg/L. Thresholds for mortality to zinc were more consistent with rainbow, bull, and mottled sculpins (range between 114 and 251 µg/L) and approximately three times less than those of cutthroat trout and shorthead sculpins (494 and 528 µg/L respectively). • Sensitivity of early life stage white sturgeon to copper, cadmium, zinc, and lead appears to be more variable under acute exposures in comparison to trout and sculpins. • LC50s were greater than EPA recommendations for 8dph but bordered criteria for 40dph life stage • Further investigation warranted into site specific considerations….WERs were consistently >1 indicating metals were less toxic to white sturgeon exposed to site water than laboratory water.	Acute at 50/100: 1.50/2.74 Trout at 50/100: 0.93/1.70
EPA's Conclusions: For the 8dph life stage of white sturgeon, the lab water based testing resulted in LC50s of 9.7-14.5 µg/L (with the lower values reflecting BLM normalized results and the upper end of the range reflecting the traditional LC50). For the 8dph life stage of white sturgeon, the site water based testing resulted in LC50s of 33-72 µg/L (with the lower value reflecting a BLM normalized result and the upper end of the range reflecting the traditional LC50). In comparing the State's criteria at 50 and 100 hardness, the most stringent LC50 for lab water (9.7 µg/L) was ~3.5-6.5 times greater than the non-trout acute criterion and ~5.5-10.5 times greater than the acute trout criterion. In comparing the State's criteria at 50 and 100 hardness, the most stringent LC50s for site water (33 µg/L), were ~12-22 times greater than the non-trout acute criterion and ~19-35.5 times greater than the acute trout criterion.			
Vardy, D.W., Tompsett, A.R., Sigurdson, J.L., Doering, J.A., Zhang, X.,	65-70 mg/L	• The study was conducted to establish baseline toxicity data for the subchronic exposure of early life stages of white sturgeon to copper, cadmium, and zinc that can be used in metal-	

Giesy, J.P., Hecker, M. (2011). *[Note: Originally included in copper reference list but included here since study addressed cadmium also. See copper record papers for more information.]*		related risk assessment. Embryos, larvae, and fry were exposed to increasing concentrations of dissolved copper, cadmium, and zinc for 66 days using laboratory-based flow-through exposure systems. • Chronic lethal concentrations at which 20% mortality occurred (LC20s) for cadmium (1.5 µg/L), copper (5.5 µg/L), and zinc (112 µg/L) obtained for white sturgeon in present study were comparable to those of sensitive salmonid species. Based on LC20 values for 19 dph and 58dph white sturgeon, the US recommended criteria established for these three parameters protect white sturgeon early life stages. • For copper, cadmium, and zinc: Exposure of early life stages of white sturgeon resulted in concentration-dependent mortalities. Statistically significant greater mortalities relative to the reference group occurred at the two greatest concentrations of copper (36 µg/L & 217 µg/L), cadmium (8.3 µg/L & 69 µg/L), and zinc (198 µg/L & 1214 µg/L). • LC20s Measured concentrations at: 19 dph 58 dph ○ Cadmium 8.7 µg/L 1.5 µg/L • LC50s Measured concentrations at: 19 dph 58 dph ○ Cadmium 21.4 µg/L 5.6 µg/L • Early life stages of white sturgeon appear to be relatively sensitive to copper, cadmium, and zinc relative to other aquatic species. The most sensitive LC20s determined in the present study were compared with chronic values outlined in EPA's chronic toxicity to freshwater organisms dataset in each metal's ambient WQC document. The LC20s (after adjustment to comparable hardness) were almost always within a factor of two of the chronic value of the most sensitive fish species. • Based on the LC values, the US criteria are protective of white sturgeon early life stages for cadmium, copper, and zinc. • Further investigation is needed for sediment exposure potential.	Chronic at 50/100: 0.25/0.42
EPA's Conclusions: While the overall conclusion of the study was that the current EPA criteria are protective of various early life stages of the white sturgeon, for comparison, a comparison of the most stringent value of 1.5 µg/L (the LC20 at 58 dph) to the State's chronic criterion at 50-100 hardness corresponds to a toxicity value of ~3.5-6 times greater than the state's adopted chronic criterion.			
Calfee, R.D. et al. (2014). *[Note: Also included in copper and zinc reference lists but included here since study addressed cadmium*	100 mg/L	• The study was done to assess the acute sensitivity of white sturgeon and rainbow trout to copper, cadmium, and zinc. • In this study, rainbow trout are more sensitive to cadmium than white sturgeon across all life stages.	Acute at 100: 2.74 Acute Trout at 100: 1.70

also. See copper and zinc record papers for more information.]

White Sturgeon *(Acipenser transmontanus)*		**Rainbow Trout** *(Oncorhynchus mykiss)*	
Life Stage (dph)	**LC50 (ug/L)**	**Life Stage (dph)**	**LC50 (µg/L)**
2	>47.2	1	>49.4
16	>187	18	2.89
30	>355	32	4.83
61	<34.4	46	2.77
72	>149.5	60	3.71
89	>273.5	74	4.54
		95	2.96

EPA's Conclusions: For the 61 dph life stage of white sturgeon (most sensitive), the lab water based testing resulted in LC50s of less than 34.4 µg/L. It is difficult to make a quantitative comparison to the State's criteria at 100 hardness, given that the value is <34.4 µg/L. The criteria at 100 hardness is 2.74 µg/L.

However, for the 46 dph rainbow trout (most sensitive stage), the lab water based testing resulted in an LC50 of 2.77 µg/L. In comparing to the State's criteria at 100 hardness (same as the laboratory study), the most stringent LC50 for lab water (2.77) was 1.63 times greater than the acute trout criterion and ~1.01 times greater than the non-trout acute criterion.

Wang et al. (2014)

[Note: Also included in copper, lead, and zinc reference lists.]

100 mg/L

- The objective of the study was to evaluate the chronic toxicity of copper, cadmium, lead, or zinc to early life stages of white sturgeon in water-only exposures.
- Toxicity texts were also conducted with rainbow trout under similar test conditions to determine the relative sensitivity difference between white sturgeon and rainbow trout.

			EC20 (µg/L)			
	Exposures	**Age at initiation (dph)**	**Survival**	**Length**	**Dry weight**	**Biomass**
White Sturgeon	C1/CC 0-14d	2	>11	-	-	-
	C1/CC 0-25d	2	NR	-	-	-
	CC 0-53d	2	NR	6.3	5.4	NR

Dissolved Chronic at 100 mg/L: 0.42 µg/L

				C2 0-28d	27	5.9	8	6.3	3.2		
			Rainbow Trout	C1 0-21d	1	12	>12	>12	>12		
				CC 0-52d	1	5.3	>12	>12	5.6		
				C2 0-28d	26	3.2	>4.9	>4.9	1.9		

EPA's Conclusions: For white sturgeon, the chronic tests and endpoints had EC20s that were greater than 7.6 times the State's dissolved chronic cadmium criteria.

For rainbow trout, all the chronic tests and endpoints had EC20s that were greater than 4.5 times the State's dissolved chronic cadmium criteria.

Summary of Mussel Results from Existing Papers and Comparison to NC Criteria for Chromium VI

Green highlighting indicates 1) where 48 hour or 96 hour LC50 tests were greater than NC's acute criteria to demonstrate when toxicity levels were higher than the State's acute criterion or 2) longer term data toxicity results were greater than the State's chronic criterion. Other information that is relevant to showing effects but based on some other metric (EC50, NOEC or LOEC, etc) is highlighted in yellow as additional evidence considered in determining any potential effects from given exposure concentrations of chromium VI.

Chromium Paper provided by Tom A for mussels Listed by Author	Hardness	Results/Notes from Studies	Comparable NC chromium acute/chronic criterion based on similar hardness
Mussel Specific Information			
Keller, A. E., and Zam, S. G. (1991).	39-45 (range observed for soft water in this study)	• "Overall, mussels were found to be as sensitive to metals as zooplankton and more sensitive than commonly tested fish and aquatic insects." "In an effort to obtain basis experimental data, a series of acute toxicity (96 hr) tests were performed to determine whether juvenile mussels were sensitive to mercury, zinc, nickel, cadmium, copper, and chromium, the metals most toxic to other aquatic biota." • In soft water, the order of LC50 averages for juvenile A.imbecilis at 48hr was: Cd (0.057mg/L)> Cu (0.171 mg/L)>Hg (0.216mg/L)>Ni (0.240 mg/L)>Cr (0.295mg/L)>Zn (0.355mg/L) • In soft water, the order of LC50 averages for juvenile A.imbecilis at 96hr was: Cd (0.009mg/L) >Cr (0.039mg/L)> Cu (0.086 mg/L)>Hg (0.147mg/L)>Ni (0.190 mg/L)> Zn (0.268mg/L) ○ Cr and Cu increased tox much more than the other metals between 48 and 96 hrs • In moderately hard water, the order of LC50 averages for juvenile A.imbecilis at 48hr was: Cd (0.137mg/L)>Hg (0.233mg/L)> Cu (0.388 mg/L)>Ni (0.471 mg/L)>Zn (0.588mg/L)>Cr (1.187mg/L) • In moderately hard water, the order of LC50 averages for juvenile A.imbecilis at 96hr was: Cd (0.107mg/L)>Hg (0.171mg/L)> Cu (0.199 mg/L)>Ni (0.252 mg/L)>Zn (0.438mg/L)>Cr (0.618mg/L)	Acute at 25/50: 16/16 (since not hardness dependent)

		• Comparison of LC50 values for metals and ambient water quality guidelines established by the EPA indicates current standards may be adequate to protect mussels from acute exposures to metals. The 4 day average concentrations of all 6 metals tested are lower than the mussel 96 hr LC50 in soft water. However, sensitivity of A.imbecilis to Cr, Zn, and Ni is close enough to the WQS to bear further study.	
EPA's conclusion: In soft water, the average 48 hr LC50 value was 295 µg/L and the average 96 hr LC50 was 39 µg/L. In moderately hard water, the average 48 hr LC50 value was 1,187 µg/L and the average 96 hr LC50 was 618 µg/L. Since hardness is not applicable for chromium VI, the State criterion of 16 is used for comparison. Comparing the state concentrations against the lowest LC50 concentration in these studies (the 96 hr in soft water), the toxicity result is 2.4 times greater than the state's acute criterion. Chronic cadmium information was not available in this paper so it was not addressed in this conclusion box.			

Summary of Mussel and Fish Specific Results from Existing Copper Papers and Comparison to NC Criteria for Copper

Green highlighting indicates 1) where 48 hour or 96 hour LC50 tests were greater than NC's acute criteria to demonstrate when toxicity levels were higher than the State's acute criterion or 2) longer term data results were greater than the State's chronic criterion. Other information that is relevant to showing effects but based on some other metric (EC50, NOEC or LOEC, etc) is highlighted in yellow as additional evidence considered in determining any potential effects from given exposure concentrations to copper.

Copper Papers provided by Tom A for mussels Listed by Author	Hardness	Results/Notes from Studies	Comparable NC copper acute/chronic criterion based on similar hardness
Mussel Specific Information			
Augspurger, T.P., Wang, N., Kunz, J.L., and Ingersoll, C. G. (2014).	160-180	• Evaluation of habitat conditions for, and pollutant sensitivity of, the endangered Tar River spinymussel (TRS) • TRS was between median and bottom quartile of copper species sensitivity distributions for freshwater mussels based on 96 hr toxicity tests • Tested concentrations of copper of 0, 6.25, 12.5, 25, 50, and 100 µg copper/L. • Reference toxicant test (hardness at 160-180 mg/L): ○ EC50 from acute 4 day test for TRS 26 µg/L (22-31) ○ EC50 from acute 4 day test for notched rainbow 12 µg/L (9.6-15) and 39 µg/L (32-48) ○ EC50 from acute 4 day test for yellow lance 16 µg/L (13-20) and 16 µg/L (13-19) ○ EC50 from acute 4 day test for yellow lampmussel 46 µg/L (32-68) • When compared to previous study by Wang 2009 the SMAVs (normalized using BLM) for that and this study were noted. The notched rainbow and yellow lance would be suitable surrogates for TRS, but yellow lampmussel would not be.	Acute at 160/180: 20.9/23.4
EPA's conclusion: Depending on the mussel species, the EC50 values in this paper ranged between 12 and 46 µg/L, with 26 µg/L being the EC50 for the Tar River spinymussel, a species actually listed in North Carolina. Compared to the most stringent EC50 (12 µg/L) and the endangered TRS EC50 (26 µg/L), the toxicity levels are 57% of, or 1.2 times, the state's criterion (at hardness of 160) and 51% of, or 1.1 times, the state's acute criterion (at 180 hardness).			
Black (2001) *[Note: Originally included in cadmium reference list*		• Mussels: Glochidia, juveniles (acute and chronic), Other: *Ceriodaphnia dubia*	

but included here since study addressed copper also. See cadmium record papers for more information.]	80-88 mg/L	• "Overall acute toxicity tests with glochidia and juveniles of the three surrogate species yielded surprisingly similar results for most of the chemicals….The metals, copper and cadmium, have similar toxicities among the three taxa" • Results are all in µg/L • U. imbecilis gloc Copper LC50 average of 4 tests: 24 hr 54.63, 48 hr 23.29 (incl 1 control failure) • F. masoni gloc Copper LC50 average of 1 test: 6 hr 20.2, 12 hr 58.40, 24 hr control failure only • U. imbecilis juven Copper LC50 average of 3 tests: 48 hr 85.9, 96 hr 22.2 (incl 1 control failure) • L. subviridis juven Copper LC50 average of 3 tests: 48 hr 162.1, 96 hr 69.9 • C. daphnia Copper LC50 average of 3 tests: 24 hr 16.10, 48 hr 14.32	Acute at 50/100: 7/13.4
EPA's conclusion: The 48 hr LC50 values range from 14.32 to 162.1 µg/L and the 96 hr LC50 was 69.9 µg/L (not including testing with control failures). With a hardness between 50 and 100 mg/L, the comparable North Carolina criteria values would be 7-13.4 µg/L. Comparing the state concentrations against the lowest LC50 concentration of 14.32 µg/L, the toxicity results are ~1-2 times greater than the state's acute criteria. Chronic cadmium information was not available in this paper so it was not addressed in this conclusion box.			
Clearwater, S. J., Thompson, K.J., and Hickey, C.W. (2013). *[Note: Originally included in zinc reference list but included here since study addressed copper also. See zinc record papers for more information.]*	30	• COPPER (all values in µg/L) ○ 6 hr NOEC LOEC EC50 ○ Site 1 3.1 6.5 5.1 (4.3-6.0) ○ Site 2 4.6 7.4 6.9 (5.0-36.1) ○ Site 3 3.2 5.4 8.0 (7.4-8.9) ○ 24 hr ○ Site 1 2.2 3.1 2.9 (2.4-3.5) ○ Site 2 2.6 4.6 4.2 (3.8-4.5) ○ Site 3 1.1 3.2 3.8 (0.9-5.3) ○ 48 hr ○ Site 1 1.3 2.2 1.7 (1.4-2.0) ○ Site 2 2.6 4.6 3.4 (2.4-4.3) ○ Site 3 1.1 3.2 3.4 (2.5-5.8) • Geo mean of sites 1 &2…48 hr NOEC for copper: 1.8 • Geo mean of sites 1 &2…24 hr EC50 for copper: 3.5	Acute at 30: 4.3

		• Geo mean of sites 1 &2…48 hr EC50 for copper: 2.4 • Paper discusses use of BLM for calculating criteria for zinc and copper, proposed zinc update by Zinc association	
EPA's conclusion: When comparing the State's acute copper criterion against the most stringent site averaged endpoint value (an NOEC of 1.8 µg/L in the 48 hr test), the no effect concentration is ~42% of the adopted concentration. When compared to an actual effects based endpoint the difference between the criterion and the toxicity levels grows smaller.			
Clem S. A (1998) *[Note: Originally included in cadmium reference list but included here since study addressed copper also. See cadmium record papers for more information.]*	Used dechlorinated tap water (40-50) or moderately hard synthetic water (80-100)	Glochidial response of five species (L. fragilis, L.teres, P.purpuratus, P. occidentalis, and L. suborstrata) assessed using 24 hr acute tox tests with Al, Cd, Cu, Fe, Mn, Ni, and Zn. • LC50 values for copper ranged from 31 (for L. fragilis) to 246 µg/L (for L. teres) • Used dechlorinated tap water or moderately hard synthetic water	Acute at 40/50/80/100: 5.7/7/10.9/13.4
EPA's conclusion: The LC50 values ranged from 31 to 246 µg/L. With hardness between 40 and 100 mg/L, the North Carolina criteria values for comparison would range from 5.7-13.4 µg/L. Comparing the state concentrations against the lowest LC50 concentration (31 µg/L), the toxicity results are ~2.3-5.4 times greater than the state's criteria. Chronic cadmium information was not available in this paper so it was not addressed in this conclusion box.			
Conners, D.E. and Black, M.A. (2004).	85	• Study evaluated lethal and genotoxic effects of chemicals used in lawn care on an early life stage of freshwater mussels (Utterbackia imbecillis). • In acute tests, copper was the most toxic of all chemicals evaluated (LC50=37.4 µg/L). • Hardness of 85mg/L • To test genotoxicity, mussels were tested at ¼ and ½ of NOEC. NOEC for copper 12.62 µg/L. • In this study, weak genotoxic responses to chemicals were observed in mussel glochidia exposed singly to copper, atrazine, and diazinon.	Acute at 80/90: 10.9/12.2
EPA's conclusion: Based on the two endpoints provided, the LC50 of 37.4 µg/L is ~3.4-3 times greater than the state's acute criteria at a hardness of 80 and 90 mg/L and the NOEC of 12.62 µg/L is comparable to the criteria equivalents.			
Faria, M., Lopez, M.A., Fernandez-Sanjuan, M., Lacorte, S., and Barata, C. (2010).	200	• This study evaluated the impact of biocides and pollutants (including copper) on early developmental stages of native Spanish freshwater and invasive zebra mussels. • Copper EC50 for D. polymorpha (zebra mussel) was 1.25 µg/L • Copper EC50 for U. elongatulus (Naiad mussel) was 86.34 µg/L	Acute at 200: 25.8

<table>
<tr><td></td><td></td><td>• Embryos of zebra mussel more sensitive to pollutants than glochidia stages of naiad mussel, but sensitivities of naiad mussel similar to EC50s reported for North American species.</td><td></td></tr>
<tr><td colspan="4">EPA's conclusion: The two copper EC50s from this study varied greatly. The EC50 of the invasive species is just a fraction, ~5%, of the state's equivalent criterion whereas the EC50 of the native mussel is ~3.3 times greater than the state's equivalent acute criterion.</td></tr>
<tr><td>Gillis, P.L., McGeer, J.C., Mackie, G.L., Wilkie, M.P., and Ackerman, J.D. (2010).</td><td>84-284 mg/L</td><td>• The study examined the effect of DOC on Copper toxicity in glochidia
• An increase in DOC from 0.7 to 4.4 mg C/L resulted in a fourfold increase (36 - 150 µg Cu/L) in the 24hr EC50 and a significant linear relationship between the DOC concentration and the Cu EC50 of L. siliquoidea glochidia
• The tests demonstrate that DOC provides glochidia with significant protection from acute copper toxicity.
• Results DOC in mg C/L and copper results in µg/L:
<table>
<tr><td>Site</td><td>DOC</td><td>24 hr EC50</td><td>BLM predicted site specific CMC</td></tr>
<tr><td>Lake Huron</td><td>5.0</td><td>30.9</td><td>50.4</td></tr>
<tr><td>Lake Saint Clair</td><td>5.7</td><td>26.7</td><td>42.9</td></tr>
<tr><td>Cold Water River</td><td>6.4</td><td>32.1</td><td>67.7</td></tr>
<tr><td>Saugeen River</td><td>6.9</td><td>71.4</td><td>104.3</td></tr>
<tr><td>Thames River</td><td>9.4</td><td>90.9</td><td>105.8</td></tr>
<tr><td>Grand River</td><td>11.3</td><td>104.4</td><td>157.8</td></tr>
<tr><td>Sydenham River</td><td>14.7</td><td>110.9</td><td>209.1</td></tr>
<tr><td>Thames River 2</td><td>14.8</td><td>97.6</td><td>227.9</td></tr>
<tr><td>Soft water (SW)</td><td>0.7</td><td>36.1</td><td>2.7</td></tr>
<tr><td>SW + 0.5 DOC</td><td>1.2</td><td>42.1</td><td>3.4</td></tr>
<tr><td>SW + 1.0 DOC</td><td>2.0</td><td>63.7</td><td>6.3</td></tr>
<tr><td>SW + 2.5 DOC</td><td>3.3</td><td>106.5</td><td>16.4</td></tr>
<tr><td>SW + 3.75 DOC</td><td>4.4</td><td>150.2</td><td>16.9</td></tr>
</table></td><td>Acute at 80/280: 11/35.5</td></tr>
<tr><td colspan="4">EPA's conclusion: Since the study presented a large range in hardness values, but did not provide those specifically for each site shown above, the most stringent 24 hr EC50 will be compared to the equivalent acute criterion adopted by the state at a hardness of 80 to be the most conservative. The Lake Saint Clair 24 EC50 of 26.7 µg/L is ~2.4 times greater than the state's criterion of 11 µg/L. In contrast if the Lake Saint Clair was represented as the upper end of the hardness range provided, the Lake Saint Clair value is ~75% of the adopted criterion equivalent at a hardness of 280 mg/L. In this study, DOC also played an important role in effecting the level of acute copper toxicity experienced at a given site/scenario.</td></tr>
</table>

Gillis, P.L., Mitchell, R.J., Schwalb, A.N., McNichols, K.A., Mackie, G.L., Wood, C.M., and Ackerman, J.D. (2008).	40-48, 160-180	• Examined copper sensitivity in glochidia of both Canadian endangered and common species of mussels. Also assessed the effect of water hardness and DOC on acute toxicity of copper using glochidia from two of the endangered species (E.triquetra and L. fasciola). • There was significant variation in the copper sensitivity among mussel species, and in the majority of experiments control survival was above 90%. • Four exposures to copper (µg/L): Observed 24 hr EC50s BLM derived CMC ○ Soft water (DOC 0.2) 7.4-36.1 0.7-1.2 ○ Hard water (DOC 0.2) 17.6, 50.4 2.8-3.4 ○ Low DOC (DOC 0.3-0.6) 30.9, 44.5 3.2-4.4 ○ High DOC (DOC 1.6-1.7) 79.7, >800 11.6-12.4 • Soft water tests (40,48 mg/L), only results with 90+% survival shown (<90 shown as na) Common species results in µg/L) 24hr EC50 48hr EC50 ○ A. ligamentina 31.0 15.9 ○ L. siliquoidea 36.1 21.6 ○ L. recta 34.8 na Endangered species (results in µg/L) 24hr EC50 48hr EC50 ○ E. torulosa rangiana na na ○ E. triquetra na na ○ L. fasciola 17.6 12.5 ○ O. subrotunda 13.0 11.3 ○ P. fasciolaris (freed gochidia) 16.3 na ○ V. fabalis na na ○ P. fasciolaris (conglutinates) 72.6 54.4 • Mod hard water tests (165-166 mg/L), only results with 90+% survival shown Endangered species (results in µg/L) 24hr EC50 48hr EC50 ○ E. triquetra 17.6 na ○ L. fasciola 50.4 22.0 • Low DOC tests in soft water (40-42 mg/L), only results with 90+% survival shown Endangered species (results in µg/L) 24hr EC50 48hr EC50 ○ E. triquetra na na	Acute at 40/50/160/180: 5.7/7/20.9/23.4

		○ L. fasciola 44.5 40.8 • High DOC tests in soft water (40-42 mg/L), only results with 90+% survival shown Endangered species (results in µg/L) 24hr EC50 48hr EC50 ○ E. triquetra na na ○ L. fasciola >800 127.2 • Overall endangered species more sensitive than common species (based on 24 hr EC50s) • For both species copper EC50s in moderately hard water were significantly higher than those in soft water. The addition of DOC as humic acid also resulted in significant decreases in copper sensitivity in both species. • Acute copper toxicity testing in soft water revealed that glochidia of all species tested were sensitive to copper in the low microgram per liter range (7-36) and that endangered species were more sensitive than the three common species tested. • The BLM derived CMC would be protective for all species tested, although some of the endangered species with 24hr EC50s below 10µg/L (such as 7.4 and 6.9) protection would be marginal. • Paper concluded that although glochidia were extremely sensitive to copper when exposed in soft water, the BLM derived FAVs for the DOC exposures suggest that the complexity of most natural waters in Southern Ontario will provide protection from acute copper exposure.	
EPA's conclusion: General conclusions from the paper included glochidia toxicity results in the 7.4-36 µg/L range, and when considered in terms of the BLM derived CMC, would be protective of all species tested, although those species with 24 hr EC50s less than 10 µg/L would be less fully protected. The lower values in the range given for soft water (7.4-36 µg/L) are comparable to the state's adopted criteria of 5.7 and 7 µg/L at lower hardness values (40 and 50 mg/L), and the higher hardness criteria equivalents of 20.9 and 23.4 fall within the range of 17.6-50.4 µg/L noted in the study for moderately hard water tests.			
Hansten, C., Heino, M., and Pynnönen, K. (1996). *[Note: Originally included in cadmium reference list but included here since study addressed copper also. See cadmium record papers for more information.]*	25.7	• Looked at the effects of humic acid (200 mg Pt/l as color), EDTA (used in excessive amounts to achieve maximal chelation), Fe (1000 µg/L) and Mn (400 µg/L) on the toxicity of Cd, Cu, and Zn on glochidia. ○ Used concentrations which were non-toxic and matched maximums found in natural environments (values given above in parentheses). • Copper was the most toxic and Zinc was the least toxic. Toxicity increased with exposure time. ○ Copper 10, 20, 50, and 100 µg/L.	Acute at 25: 3.6 Chronic at 25: 2.7

		▪ After 24 hrs, Cu showed toxic effects at concentrations exceeding 20 µg/L ▪ Zero gloc viability approached after 144 hrs (6 days) when above 50 • Humic acid decreased toxicities of Cadmium and Copper, but increased Zinc toxicity. • EDTA and Fe decreased the toxicity of all three metals. • Manganese did not effect Cadmium and Copper, but increased toxicity of Zinc.	
EPA's conclusion: This study showed that levels exceeding 20 µg/L, resulted in toxic effects at 24 hours and that 50 µg/L resulted in zero viability after 144 hours (6 days). When comparing the short term exposure concentration of 20 µg/L to the North Carolina criteria value at 25 hardness (3.6 µg/L), the toxicity results are ~5.5 times greater than the state's acute criterion. When comparing the state's chronic criterion of 2.7 µg/L to the 6 day exposure, the toxicity endpoint was 18.5 times greater than the state's chronic criterion. While this study did not include typical durations of exposure, the information still provides some estimates by which to assess the state's criteria against for consultation purposes.			
Huebner, J. D. and Pynnonen, K. S. (1992). *[Note: Originally included in cadmium reference list but included here since study addressed copper also. See cadmium record papers for more information.]*	35	• EC50 for µg/L copper: 24 hr 17.7 (ranged 6.1-35.2), 48 hr 5.3 (ranged 2.0-9.4), 72 hr 2.1 (0.01-7.23) • Threshold concentration to cause significant decrease in gloc response for µg/L Copper: 24 hr 50, 48 hr 50, 72 hr 50 • The relative toxicities (based on 48 hr EC50s) of the metals to Anodonta cygnea gloc were Cu (5.3µg/L) > Cd (46.8µg/L) > Zn (69.1µg/L) > Al	Acute at 30/40: 4.3/5.7
EPA's conclusion: The average 48 hr EC50 value was 5.3 µg/L although it ranged from 2.0-9.4 µg/L and there was a significant decrease in response at 50 µg/L at the 48 hr mark. With hardness of 35 mg/L, the North Carolina criteria values are given at 30 and 40 hardness, 4.3-5.7 µg/L. Comparing the state concentrations against the 48 hr EC50 concentration, the toxicity results are 93% of and 1.2 times greater than the state's acute criteria. When compared to the threshold concentration at 48 hours, the differences increase. However, it should be noted this study used low pH (3-6.5) and simultaneously included exposure to other metals, so there could be confounding factors influencing these results. While this study did not include typical durations of exposure, the information still provides some estimates by which to assess the state's criteria against for consultation purposes. Chronic cadmium information was not available in this paper so it was not addressed in this conclusion box.			
Jacobson, P.J. (1990).		• Four life stages of freshwater mussels were tested for their sensitivity to copper and a metal containing effluent. • Little effect on glochidia was detected following 30 day artificial stream exposure of gravid adults to 19.1 µg/L copper and an effluent containing an average of 23.9 µg/L copper. • Isolated glochidia LC50s as low as 16 to 26 µg/L. • Encysted glochidia were resistant to exposures up to 400 µg/L copper.	

	170	• Juvenile mussels reduced their activity during 24 hr exposures to copper concentrations as low as 17 to 24 µg/L and concentrations of 30 to 42 µg/L caused mortality. • Juvenile mussels and glochidia within the marsupia are probably the two most sensitive life stages in the life cycle of mussels. • Copper pollution will have its greatest impact in the summer, during periods of high water temperature and low flow. • Isolated glochidia of all species were sensitive to copper. 24 hr LC50 values (all µg/L) ranged from 16 for Medionidus conradicus (although it ranged from 16 to 88 for this species) to 140 for Actinonaias pectorosa (although it ranged from 40 to 140 for this species). Lampsilis fasciola ranged from 26 to 48 and Villosa nebulosa ranged from 36 to 88. • Extending the exposure to 48 hours lowered the concentrations as to be expected with Medionidus conradicus going from 56 to 23, Actinonaias pectorosa going from 68 to 53, Lampsilis fasciola going from 45 to 43, and Villosa nebulosa going from 76 to 65 or 50 to 46 (depending on the test). • There was no apparent interspecies variation in sensitivity to copper or effluent among the five species tested. All species were affected by copper in the range of 20-80 µg/L and sensitivities increased with increasing temperature and hardness.	Acute at 170: 22.2
EPA's conclusion: The most stringent LC50 was the 48 hr test for the Medionidus conradicus glochidia (16 µg/L). The most stringent juvenile mortality data was about twice that level (30 µg/L). In comparing the LC50 of 16 µg/L to the state's criterion, a hardness of 170 was used based on the reported hardness for that particular test. Therefore, the toxicity results are associated with ~72% of the acute criterion concentration.			
Jacobson, P.J., Cherry, D.S., Farris, J.L., and Neves, R.J. (1993).	70 & 190 mg/L	• Two methods of assessing post exposure response were tested, visual examination and vital staining for two species. • V. iris tested at 190 hardness and A. grandis tested at 70 hardness • Both species responded to copper exposures, exhibiting valve closure at concentrations as low as 24 µg Cu/L for V. iris and 17 µg Cu/L for A. grandis. EC50 values of 27 µg Cu/L (V. iris) and 33 µg Cu/L (A. grandis) were calculated on the basis of the valve closure response. • LC50 values of 83 µg Cu/L (V. iris) and 44 µg Cu/L (A.grandis) were calculated from the results of vital staining.	Acute at 70/190: 9.6/24.6

EPA's conclusion: The LC50s for the two species were 83 and 44 µg/L. Using the most stringent LC50 of 44 µg/L and comparing it to the state's criterion at 70 mg/L hardness, the toxicity result was ~4.5 times the acute criterion. EC50 results while lower concentrations were still greater than the acute criterion.			

Jacobson, P.J., Neves, R.J., Cherry, D.S., and Farris, J.L. (1997).	50-170 mg/L (160 chosen for hardness associated with 26 µg/L 24 hr LC50)	• The sensitivity of glochidial stages of mussels was evaluated in a series of exposures to aqueous copper. Glochidia held within marsupia of gravid V. iris exhibited no observable effect following a 30 day copper exposure of levels up to 19.1 µg Cu/L.
		• Transformation of encapsulated glochidia of A. pectorosa and P. grandis to the juvenile stage was unaffected by 12 to 20 day exposures of largemouth bass at levels up to 200 µg Cu/L.
		• In contrast, released glochidia of all species were sensitive to copper at comparatively low concentrations.
		  ○ 24hr LC50 for L. fasciola ranged from 26 to 48 µg Cu/L (hardness ranged from 75-170), from 36 to 80 µg Cu/L for V. iris (hardness ranged from 50-190), from 37 to 81 µg Cu/L for M.conradicus (hardness ranged from 150-185), from 42 to 132 µg Cu/L for A. pectorosa (hardness ranged from 140-170), and from 46 to 347 µg Cu/L for P. grandis (hardness ranged from 50-170).
		• Comparison of copper sensitivity for life stages of two species in this study
		  ○ V. iris
		  ▪ Brooded glochidia 30 day artificial stream exposure >19 µg/L
		  ▪ Released glochidia 24hr LC50 36-80 µg/L
		  ▪ Encysted glochidia 20 day static exposure >400 µg/L
		  ○ P. grandis
		  ▪ Released glochidia 24hr LC50 46-347 µg/L
		  ▪ Encysted glochidia 12 day static exposure >200 µg/L
			Acute at 160: 20.9

EPA's conclusion: When comparing the 24 hr LC50s for the various species, the most stringent value was selected for comparison (26 µg/L, at a hardness of 160). The toxicity based value is about 1.2 times the acute criterion adopted by the state.			
Jorge, M.B., Loro, V.L., Bianchini, A., Wood, C.M., and Gillis, P.L. (2013).	86 mg/L	• Physiological effects of long-term exposure evaluated in juvenile (6 month) mussels (L. siliquoidea) • Mussels chronically exposed to 2 and 12 µg Cu/L showed significantly higher mortality than those held under control conditions. Mortality = 20.9, 69.9, and 12.5 % respectively.	Chronic at 80/90: 7/8

		• This indicated that juvenile L. siliquoidea is underprotected by EPA BLM derived chronic criterion (2.18µg/L) and hardness equation derived criterion (12.16µg/L).	
EPA's conclusion: Due the chronic exposure to 2 µg/L resulting in ~21% mortality, the study concluded that the juveniles tested in this study are underprotected when the hardness equation derived criteria are considered (although the concentration provided in the study is greater than the state's adopted equivalent chronic criterion). While this study points to concern with both the hardness and BLM based criteria it is difficult to make a generic comparison as has been done for most of the other studies with the information provided not being consistent with the format of the other studies.			
Keller, A. E., and Zam, S. G. (1991). *[Note: Originally included in cadmium reference list but included here since study addressed copper also. See cadmium record papers for more information.]*	39-45 (range observed for soft water in this study)	• "Overall, mussels were found to be as sensitive to metals as zooplankton and more sensitive than commonly tested fish and aquatic insects." "In an effort to obtain basis experimental data, a series of acute toxicity (96 hr) tests were performed to determine whether juvenile mussels were sensitive to mercury, zinc, nickel, cadmium, copper, and chromium, the metals most toxic to other aquatic biota." • In soft water, the order of LC50 averages for juvenile A.imbecilis at 48hr was: Cd (0.057mg/L)> Cu (0.171 mg/L)>Hg (0.216mg/L)>Ni (0.240 mg/L)>Cr (0.295mg/L)>Zn (0.355mg/L) • In soft water, the order of LC50 averages for juvenile A.imbecilis at 96hr was: Cd (0.009mg/L) >Cr (0.039mg/L)> Cu (0.086 mg/L)>Hg (0.147mg/L)>Ni (0.190 mg/L)> Zn (0.268mg/L) ○ Cr and Cu increased tox much more than the other metals between 48 and 96 hrs • In moderately hard water, the order of LC50 averages for juvenile A.imbecilis at 48hr was: Cd (0.137mg/L)>Hg (0.233mg/L)> Cu (0.388 mg/L)>Ni (0.471 mg/L)>Zn (0.588mg/L)>Cr (1.187mg/L) • In moderately hard water, the order of LC50 averages for juvenile A.imbecilis at 96hr was: Cd (0.107mg/L)>Hg (0.171mg/L)> Cu (0.199 mg/L)>Ni (0.252 mg/L)>Zn (0.438mg/L)>Cr (0.618mg/L) • Comparison of LC50 values for metals and ambient water quality guidelines established by the EPA indicates current standards may be adequate to protect mussels from acute exposures to metals. The 4 day average concentrations of all 6 metals tested are lower than the mussel 96 hr LC50 in soft water. However, sensitivity of A.imbecilis to Cr, Zn, and Ni is close enough to the WQS to bear further study.	Acute at 40/50: 5.7/7

EPA's conclusion: In soft water, the average 48 hr LC50 value was 171 µg/L and the average 96 hr LC50 was 86 µg/L. In moderately hard water, the average 48 hr LC50 value was 388 µg/L and the average 96 hr LC50 was 199 µg/L. With hardness of 39 mg/L, the North Carolina criteria values are given at 25 and 50 hardness, or 5.7 and 7 µg/L. Without details on what was characterized as "moderately hard water" the EPA chose to just compare using the 25 and 50 hardness range as described since this would be the most conservative assumption. Comparing the state concentrations against the lowest LC50 concentration in these studies (the 96 hr in soft water or 86 µg/L), the toxicity results are ~12-15 times greater than the state's acute criterion at a hardness of 40 and 50. Chronic cadmium information was not available in this paper so it was not addressed in this conclusion box.			
Klaine, S. J., Warren, L .W. and Summers, J. M. (1997). *[Note: Originally included in cadmium reference list but included here since study addressed copper also. See cadmium record papers for more information.]*	99-107	• Cadmium and copper concentrations ranged from 0-225 µg/L (acute juvenile mussels) and 0-90 µg/L (for glochidia), with mortality recorded at 24, 48, and 96 hours • Responses among age groups was similar for Cd but more variable for copper. • Copper results: 24 hr / 48 hr / 96 hr LC50 for mussels (in µg/L) ○ 2 day: 115 to 170 / 78-130 / 33-81 [MEAN 24 hr LC50 150 µg/L] ○ 9 day: >20 to 107 / 33-86 (one test had complete mortality) / 53 [MEAN 48 hr LC50 98.8 µg/L] ○ 16 day: >20 to >115 / >30 to 122 (one test had complete mortality) / >30 to 79 [MEAN 96 hr LC50 53.6 µg/L] • Paper also looked at in vivo vs in vitro LC50s	Acute at 100/110: 13.4/14.7
EPA's conclusion: Depending on the age group tested, the average 48 hr LC50 value was 53 µg/L, with lowest 48 hr LC50 being >30 µg/L. For the 96 hr LC50 the lowest value was >30 µg/L, with the 96 hr LC50 average noted as 53.6 µg/L. With a hardness concentration around 100 mg/L, the comparable North Carolina criteria values would be 13.4 and 14.7 µg/L. Comparing the acute state concentrations against the lowest LC50 concentration from all of the results (>30 µg/L), the toxicity results are ~2-2.2 times greater than the state's acute criterion at a hardness of 100 and 110 mg/L. Chronic cadmium information was not available in this paper so it was not addressed in this conclusion box.			
Kovats, N., Abdel-Hameid, N.A., Kavacs, K., and Paulovits, G. (2010). *[Note: Originally included in lead reference list but included here since study addressed copper also. See lead record papers for more information.]*	170 (noted as used in glochidia preparation, not otherwise discussed)	• Toxicity of lead, copper, and zinc based on 24 hr and 48 hr LC50s • Synergistics effects reported for copper+zinc and copper+lead • Additive effect reported for zinc+lead • Although some metals are essential for life (Engel and Sunda 1979) all metals are toxic at high concentrations and for some there is a narrow range of concentrations between what is essential and what is toxic. • COPPER 24hr LC50 / NOEC 48 hr LC50 / NOEC ○ A. anatina 31.2 (21.6-47.3) / 9 18.9 (10.0-31.1) / 8 ○ P. complanata 34.3 (29.9-39.4) / 12 29.3 (25.4-34.) / 10 ○ U. tumidus 26.8 (23.2-30.9) / 12 19.0 (16.2-22.0) / 8	Acute at 170: 22.2

		• Sensitivies of three species to copper fell in the same range. • Regarding Zn sensitivity, differences were much greater.	
EPA's conclusion: Using the assumption the tests were completed in sample with a hardness of 170 mg/L, the acute copper criterion was compared to the 48 hr LC50 of 18.9 µg/L (the most stringent of the species results). The toxicity level is about 85% of the adopted acute criterion. Caution should probably be used in including this paper without better resolution on the issue of hardness, as this greatly effects what the toxicity values are compared against.			
March, F.A, Dwyer, F.J, Augspurger, T., Ingersoll, C.G., Wang, N., Mebane, C.A. (2007).	n/a	• Study evaluated protection afforded by EPA hardness based 1996 copper WQC, 2007 BLM based WQC, and the 2005 Oklahoma copper WQC. Study tabulated tox data for glochidia and juveniles to calculate 20 species mean acute values for freshwater mussels. Generally, freshwater SMAVs were similar to those of the more sensitive species included in EPA's derivation database. Results indicate criteria may need to be revised to afford protection to freshwater mussels. • Database developed using journal articles, interim and final reports, and dissertations and theses that included tox information for native North American unionid species. • The final edited database, consistent with ASTM test acceptability requirements, was further modified to include only Oklahoma freshwater mussel species as identified in Mather. • At a hardness of 50 mg/L, the unionid recalculated Oklahoma WQS CMC was 5.418 µg/L and the corresponding CCC was 3.381 µg/L. These are about 50% of the current OK WQS.	n/a
EPA's conclusion: Without specific LC50 or other toxicity information, this study was not used in the EPA's analysis.			
McCann, M. (1993). *[Note: Originally included in zinc reference list but included here since study addressed copper also. See zinc record papers for more information.]*	40,50,140,150, and 160	• Copper was 5 to 15 times more toxic than zinc, with 48 hr LC50 values ranging from 52 to 156 µg/L copper and EC50 values ranging from 26 to 115 µg/L copper for juvenile A. pectorosa. • At certain concentrations, zinc seemingly had an antagonistic effect (less than additive) when mixed with copper. This effect was evidenced by reduced mortality of juveniles in copper solutions when zinc was added at concentrations of about 400 to 800 µg/L. • Paper notes that copper was lethal at concentrations as low as 25 µg/L under long term exposures (Havlik and Marking 1987).	Acute at 40/50/140/ 150/160: 7/8.3/18.5/ 19.7/20.9

		• Table 6: Copper and juveniles of Actinonaias pectorosa (pheasantshell)
		  ○ Tap water at 40 and 50 hardness:
		  ▪ 48 hr LC50 at 40 hardness was 52 µg/L
		  ▪ 48 hr LC50 at 50 hardness was 63 µg/L
		  ▪ 48 hr EC50 at 40 hardness was 26 µg/L
		  ▪ 48 hr EC50 at 50 hardness was 42 µg/L
		  ○ Powell River water at 140, 150, and 160 hardness:
		  ▪ 48 hr LC50 at 140 hardness was 112 µg/L
		  ▪ 48 hr LC50 at 150 hardness was 76 µg/L
		  ▪ 48 hr LC50 at 160 hardness was 156 µg/L
		  ▪ 48 hr EC50 at 140 hardness was 44 µg/L
		  ▪ 48 hr EC50 at 150 hardness was 39 µg/L
		  ▪ 48 hr EC50 at 160 hardness was 115 µg/L
		• Copper was 5.7 to 15.7 times more toxic than zinc with concentrations as low as 52 (at 40 hardness) to 76 (at 150 hardness) causing 50% mortality of juveniles exposed for 48 hours.	

EPA's conclusion: The most stringent 48 hr LC50 was 52 µg/L and the most stringent EC50 was 26 µg/L. Both of these values are from tests with a hardness of 40. Therefore, the comparison will be the state's criterion at a hardness of 40 (or 7 µg/L) to both these endpoints. The LC50 is ~7.5 times greater than the acute criterion and the EC50 is ~3.5 times greater than the acute criterion.			

Milam, C.D., Farris, J.L., Dwyer, F.J., and Hardesty, D.K. (2005).		• Acute 24 hr tox tests were used in this study to compare lethality responses in early life stages (glochidia) of 6 freshwater mussels (L. fragilis, U. imbecillis, L. cardium, L. siliquoidea, M. nervosa, and L. subrostrata) and two standard test organisms (C. dubia and D. magna).
		• No species was always the most sensitive and Daphnidae were generally protective of Uniondae.
		• Copper provided the most consistent LC50s across species responses; however, no single chemical provided consistent LC50s for all test organisms. Copper resulted in the lowest overall LC50s.
		• Average LC50s for mussels and standard test organisms exposed to copper **(results in mg/L)**
		  ○ L. fragilis 0.09 90 (converted to µg/L)
		  ○ L. cardium 0.21 210 (converted to µg/L)	

	162-178 mg/L	○ L. siliquoidea 0.13 130 (converted to µg/L) ○ M. nervosa 0.18 180 (converted to µg/L) ○ L. subrostrata 0.15 150 (converted to µg/L) ○ U. imbecillis 0.52 520 (converted to µg/L) ○ C. dubia 0.04 40 (converted to µg/L) ○ D. magna 0.12 120 (converted to µg/L) • Average NOECs for same species exposed to copper **(results in mg/L)** ○ C. dubia 0.18 180 (converted to µg/L) ○ D. magna 0.05 50 (converted to µg/L) ○ L. cardium 0.085 85(converted to µg/L) ○ L. siliquoidea <0.06 <60 (converted to µg/L) ○ L. subrostrata 0.06 60 (converted to µg/L) ○ L. fragilis 0.05 50 (converted to µg/L) ○ M. nervosa 0.06 60 (converted to µg/L) ○ U. imbecillis 0.145 145 (converted to µg/l) • Current WQC (freshwater) for the protection of aquatic life to copper (CMC=13 µg/L, CCC=9µg/L) should provide reasonable protection for these tested species, and recent modifications (i.e. BLM approach) should account for more specific sensitivities of these aquatic organisms.	Acute at 160/180: 20.1/23.4
EPA's conclusion: When comparing the most stringent average 24 hr LC50 (for C. dubia) of 40 µg/L, to the acute criteria equivalents at 160 and 180 hardness, the toxicity values are ~2-1.7 times the criteria values. When comparing the most stringent average NOEC (for D. magna and L. fragilis) of 50 µg/L, to the acute criteria equivalents at 160 and 180 hardness, the toxicity values are ~2.5-2 times the criteria equivalent values.			
Myers-Kinzie, M. L. (1998). *[Note: Originally included in zinc reference list but included here since study addressed copper also. See zinc record papers for more information.]*	204	• Acute toxicity testing was done with artificially cultured Lampsilis siliquoidea juveniles, and 48hr LC50 results indicated that the agricultural pollutants ammonia, nitrite, and potassium may be significantly toxic to young mussels. • The objectives of this research were to determine the acute toxicities of selected common pollutants to artificially cultured juvenile L. siliquiodea, including copper and zinc. • Of metals tested, copper (48 hr LC50 0.113 mg/L) was more toxic than zinc (48 hr LC50 0.463 mg/L). ○ 24 hr LC50s were higher concentrations: 0.159mg/L (copper) and 0.599 mg/L (zinc)	Acute at 200: 25.8

		• Previous studies of copper toxicity to juveniles were summarized: 24 hr LC50s ranged from 44 to > 400, 48 hr LC50s ranged from 99-388, and 96 hr LC50 was 199 (all values in µg/L, varying hardness) ○ Even with the same test species and similar water hardness, some variation in LC50 values is apparent. • For the water hardness of 204 mg/L in the present study, the calculated acute water quality for copper would be 35 µg/L and 214 µg/L for zinc. • The mean 48 hr LC50 for copper was 105 µg/L and for zinc 463 µg/L. Both of these values are considerably greater than EPA criteria, indicating these standards are probably protective of juvenile mussels.	
EPA's conclusion: In this study, the mean 48 hr LC50 was 105 µg/L (similar to the low end of previous studies) and when compared to the state's criterion at a hardness of 200, the LC50 value is ~4 times greater than the criterion.			
Pandolfo, T.J., Cope, W.G., and Arellano, C. (2010).	146-162 (average of 153.7) mg/L	• The purpose of this study was to determine the effect of sublethal copper concentration on the upper thermal tolerance of three specices, L. siliquoidea, P. alatus, and L. recta) of juvenile mussels in 48hr and 96hr tests. • Control survival at 20 degrees C, with 10 µg/L Cu in ASTM reconstituted hard water at 48hr and 96 hr was good, averaging 98.9 and 96.6% respectively. • Median copper levels in surface waters tend to be lower than the 10 µg/L concentration used in the present study, but maximum concentrations can be much higher. For example, in ~7% of sites in three North Carolina streams, copper concentrations exceeded 10 µg/L, ranging from 11 to 84 µg/L. 10 µg/L was picked based on published literature values to be nonacutely toxic to freshwater mussels so that temperature tolerance could be tested. • Even at the highest temperature (32 degrees C) in the presence of copper, mussel survival did not fall below 90% for any species. However, mortality occurred in the two higher acclimation temperature schemes, providing limited evidence for an interaction between sublethal exposure to copper and thermal stress in some instances.	Acute at 150: 19.7
EPA's conclusion: While this study was focused on thermal stress to three species of mussels, the value of 10 µg/L was given as a non-acutely toxic value for freshwater mussels, based on existing literature. When compared to the state's value at a hardness of 150, the value identified as not acutely toxic is about 50% of the state's adopted criterion.			

Pynnönen, K. (1995).	moderately hard water (35 mg/L Ca/L)	Did Not Use Study Due to inability to determine LC50, this paper is not directly helpful to BE effort. Maternal pre-exposure at low metal concentrations often increased resistance of gloc to metals, but exposure to higher concentrations decreased resistance. Order to toxicity: Cu>Cd>Zn	
EPA's conclusion: Did not use study due to lack of LC50 or other lethality related information.			
Wang, N., Ingersoll, C.G., Hardesty, D.K., Ivey, C.D., Kunz, J.L., May, T.W., Dwyer, F.J. Roberts, A.D., Augspurger, T., Kane, C.M., Neves, R.J., and Barnhart, M.C. (2007).		• Objective of study was to determine the acute toxicity of copper to larval (glochidia) and juvenile mussels using recently published ASTM guide. Tox tests were performed with glochidia (24 and 48hr exposures) and juveniles (96hr exposures) of up to 11 mussel species in reconstituted ASTM hard water and copper, among other chemicals. • Median EC50s for commonly tested species were >58 µg/L Cu (except 15 µg/L Cu for C. dubia) whereas the EC50s for mussels in most cases were <45 µg/L Cu and were often below criteria recommendations for copper. • Median EC50s for survival of glochidia in copper tests at 6hr/24hr/48hr (all µg/L) ○ Dwarf wedgemussel >100/>100/86 ○ Ellipse 18/10/8.6 ○ Fatmucket 43/36/23 ○ Fatmucket 55/29/15 ○ Fatmucket 77/42/28 ○ Fatmucket 42/31/20 ○ Fatmucket 87/38/31 ○ Fatmucket No value/41/23 ○ Fatmucket 48/33/17 ○ Mucket >100/59/23 ○ Mucket 83/35/20 ○ Mucket 62/66/32 ○ Mucket >100/53/31 ○ Neosho mucket >100/41/19	

	175-187	○ Oyster mussel 47/not reported/not reported ○ Oyster mussel 22/not reported/not reported ○ Pink mucket >100/34/13 ○ Pink papershell 65/14/13 ○ Rainbow mussel >100/37/22 ○ Scaleshell 21/not reported/- ○ Wavy rayed lampmussel >100/18/7.3 ○ Wavy rayed lampmussel 58/16/6.5 ○ MEAN ± STD DEVIATION 68±29/39±21/23±17 • Median EC50s for survival of juvenile mussels in copper tests at 2d/4d/10d (all µg/L) NEWLY TRANSFORMED JUVENILES ○ Fatmucket 29/18/8.1 ○ Fatmucket 35/20/- ○ Fatmucket 52/23/- ○ Fatmucket 34/21/- ○ Fatmucket 45/25/- ○ Neosho mucket 60/43/8.8 ○ Neosho mucket 37/23/8.7 ○ Oyster mussel 19/17/15 ○ Oyster mussel 10/6.8/5.9 ○ Rainbow mussel 37/17/12 ○ Scaleshell 29/22/14 ○ Wavy rayed lampmussel 56/21/6.7 ○ Wavy rayed lampmussel 73/25/4.8 ○ MEAN ± STD DEVIATION 40±17/22±8/9.3±3.6 2 MONTH OLD JUVENILES ○ Fatmucket 23/32/- ○ Fatmucket >100/60/32 ○ Pink mucket 38/37/14 ○ Rainbow mussel 45/33/13	Acute at 170/190: 22.2/24.6

		○ Rainbow mussel 20/24/8.6 ○ MEAN ± STD DEVIATION 45±32/37±14/17±10 • When normalized to water hardness of 50 mg/L the majority of the results of copper tox tests with freshwater mussels in the present study were within the range of EC50s for mussels reported by others. However, three species (ellipse, pink papershell, and oyster mussels) were much more sensitive to copper (GMAVs of 3.0-4.3 µg/L) compared to the other 17 species (GMAVs of 14-57µg/L)	
EPA's conclusion: With the exception of the C. dubia test, the median EC50 for commonly tested species was >58 µg/L and <45 µg/L for mussels. Both of these values are above the state's criterion at 170 or 190 hardness. If comparing to the most stringent (<45 µg/L), then the EC50 value is 2-1.8 times greater than the criterion. If the C. dubia result is considered (15 µg/L) then the EC50 is 68-61% of the adopted criterion.			
Wang, N., Augspurger, T., Barnhart, M.C., Bidwell, J.R., Cope, W.G., Dwyer, F.J., Geis, S., Greer, E., Ingersoll, C.G., Kane, C.M., May, T.W., Neves, R.J., Newton, T.J., Roberts, A.D., and Whites, D.W. (2007).	160-180mg/L (specifically ranged from 152-193 depending on life stage)	• This study evaluated the performance and variability in acute tox tests with glochidia and newly transformed juvenile mussels using ASTM methods. Multiple 48hr tox tests with glochidia and 96hr tests with juvenile mussels were conducted within a single laboratory and among five laboratories. All tests met acceptability requirements (≥90%).High completion success and overall low variability in test results indicate that the test methods have acceptable precision and can be performed routinely. • Intralaboratory variability of EC50s for copper in 48hr tests with glochidia and 96 hr tests with juvenile mucket Mean of Tests 1-4 with mucket glochidia: 24hr = 53µg/L 48hr = 26 µg/L Mean of Tests 1-7 with fatmucket glochidia: 24hr = 36µg/L 48hr = 22 µg/L Mean of Tests 1-5 with fatmucket juvenile: 48hr = 39µg/L 96hr = 21 µg/L • Interlaboratory variability of EC50s for copper in 48hr tests with fatmucket glochidia and 96 hr tests with newly transformed juvenile fatmucket Glochidia 24hr EC50/48hr EC50 EC50 / Juvenile mussels 48hr EC50/96hr Laboratory 1 29/13 29/18 Laboratory 2 33/24 48/28 Laboratory 3 27/26 47/41 Laboratory 4 38/21 34/21 Laboratory 5 32/20 36/19	Acute at 150: 19.7

		MEAN 32/21 39/23	
EPA's conclusion: The most stringent mean 24 hr EC50, 48 hr EC50, and 96 hr EC50 values were 32 µg/L, 21 µg/L, and 21 µg/L, respectively. The values of 21 µg/L correspond to glochidia and juvenile tests. If the most conservative hardness is used (150 mg/L) for comparison, the EC50 is practically equal to the state's acute criterion.			
Wang, N., Ingersoll, C.G., Greer, I.E., Hardesty, D.K., Ivey, C.D., Kunz, J.L., Brumbaugh, W.G., Dwyer, F.J. Roberts, A.D., Augspurger, T., Kane, C.M., Neves, R.J., and Barnhart, M.C. (2007).		• The objectives of the study were to develop methods for conducting chronic toxicity tests with juvenile mussels under flow-through conditions and to determine the chronic toxicity of copper to juvenile mussels using these methods. Multiple copper tox tests were conducted for 28 days starting with two month old mussels. Among copper tests with rainbow mussel, fatmucket, and oyster mussel (E.capsaeformis), chronic value (ChV), geo mean of the NOEC, and LOEC ranged from 8.5 to 9.8 µg/L Cu for survival from 4.6 to 8.5 µg/L for growth. Results indicate that tox tests with 2 month old mussels can be conducted for 28 days with >80% control survival; growth was frequently a more sensitive endpoint compared to survival; and the 1996 chronic copper WQC might not be adequately protective of the mussel species tested. However, recently revised 2007 chronic WQC for copper based on BLM may be more protective in the water tested. • Mean survival and growth of juveniles of three species at the end of 28 day copper tox tests, An asterisk indicates a significant reduction relative to control. Rainbow mussel — Mean concentration µg//L / Survival % / Length 0.9 / 88 / 1.31 4.1 / 96 / 1.34 6.4 / 68 / 1.13* 15 / 48* / - 21 / 13* / - 51 / 0* / - ChV survival=9.8, IC10=4.9, IC25=6.3 ChV length=5.1 Fatmucket — Mean concentration µg//L / Survival % / Length 1.0 / 98 / 1.15 3.1 / 80 / 1.30	

	160-180 mg/L		6.6	80	1.09	Chronic at 160/180: 13.4/14.8
			11	58	-	
			21	5	-	
			45	0*	-	
		ChV survival=8.5, IC10=<3.1, IC25=8.0		ChV length=8.5		
		Oyster Mussel	Mean concentration µg//L	Survival %	Length	
			1.3	100	1.11	
			3.1	88	1.05	
			6.7	88	0.97*	
			13	6.3*	-	
			23	0*	-	
			50	0*	-	
		ChV survival=9.3, IC10=<3.1, IC25=7.6		ChV length=4.6		
		• The EC50s for copper generally decreased over the exposure periods of 4, 10, 21, and 28 days. The 28 day ChVs for survival and growth typically were lower than 28 day EC50s for survival and were lower than the 1996 chronic WQC for copper. • Results indicate that the early life stages of freshwater mussels are chronically sensitive to copper and while earlier EPA WQC may not be adequately protective 2007 BLM based chronic WQC for copper may be more protective of chronic tox to mussels.				
EPA's conclusion: The ChV ranged from 8.5 to 9.8 µg/L Cu for survival from 4.6 to 8.5 µg/L for growth. Whether the comparison is made to the state's criterion at 160 or 180 hardness, the chronic values for survival and growth are more stringent than the criterion equivalents, with the values of 8.5 and 4.6 µg/L being ~60% and ~30% of the chronic equivalent values.						
Wang, N., Mebane, C.A., Kunz, J.L., Ingersoll, C.G., May, T.W., Arnold, W.R., Santore, R.C., Augspurger, T., Dwyer, F.J., and Barnhart, M.C. (2009).		• The influence of DOC and water composition on the toxicity of copper to juvenile fatmucket were evaluated in natural and reconstituted waters. Acute 96 hr tox tests for copper were conducted at four nominal DOC concentrations in dilutions of				

	Ranged from 42-297 mg/L	natural waters and ASTM soft, moderately hard, hard, and very hard reconstituted waters (hardness 45-300mg/L). • Results from 96 hr copper tox test with fatmucket juvenile mussel (EC50 in µg/L)	Acute at 40/50: 5.7/7

Test Site	DOC	Hardness	EC50	BLM-normalized EC50
Pond	0.9	138	27	6.1
	3.6	139	56	2.8
	5.6	141	56	1.7
	10.8	140	127	2.0
Eagle Bluffs	0.9	188	53	6.4
	3.1	192	113	4.0
	5.7	188	149	2.4
	9.5	186	298	3.3
Ditch#6	0.8	44	9.9	3.9
	2.8	42	58	7.7
	5.3	45	75	5.0
	9.8	42	144	4.4
Luther Marsh	0.3	215	44	18
	2.9	199	114	5.8
	5.9	215	187	3.6
	10.5	216	>396	5.3
Humic Acid	0.3	164	24	5.0
	1.3	166	66	3.0
	1.6	166	72	2.5
	2.3	167	133	3.6
	3.5	168	196	3.4
Variable Hardness	45 mg/L	52	21	24
	90 mg/L	87	30	26
	170 mg/L	176	26	11
	300 mg/L	297	30	6.9
Reference Test	Pond	175	31	15
	Eagle Bluffs	180	43	17
	Ditch#6	173	39	16

		• The results of the study indicate acute toxicity of copper to juvenile fatmucket was strongly influenced by DOC but negligibly influenced by water hardness, alkalinity, and pH. The BLM for copper reliably predicted acute copper toxicity to juvenile mussels across diverse water sources. However, uncertainty in BLM predictions is greater in reconstituted waters that contain low concentrations of DOC (i.e. 0.3 mg/L).
		• The SMAV for fatmucket would rank this mussel species among the four most sensitive species used in the derivation of the EPA acute WQC for copper.
		• Nearly 70% of the BLM normalized EC50s for fatmucket tested in natural waters were below the FAV used to derive the WQC, indicating that the acute WQC for copper might not be protective of this mussel species.
		• Table S3 of the paper provides following additional information:
		  ○ At hardness between 162-197, E.capsaeformis, L. fasciola, L. rafinesqueana, L. siliquoidea, L. leptodon, and V. iris had EC50s ranging from 6.8 to 44 µg/L. The BLM normalized EC50s ranged from 2.9 to 19 µg/L.
		  ○ At hardness between 84-103, L. subviridis and U. imbecillis had EC50s ranging from 19-93 µg/L. The BLM normalized EC50s ranged from 8.3 to 76 µg/L.	

EPA's conclusion: Of the site water tests, the most stringent EC50 was 9.9 µg/L (DOC, hardness 45 mg/L) and the least stringent was >396 µg/L (Luther Marsh, hardness 216 mg/L). When comparing the most stringent EC50 to the state's acute criterion at 40 and 50 hardness, the EC50 value was 1.7-1.4 times greater than the criterion. Of the variable hardness tests, the most stringent EC50 was 21 µg/L (45 mg/L DOC, hardness 52 mg/L) and the least stringent was 30 µg/L (90 and 300 mg/L DOC, hardness 87 and 297 mg/L). When comparing the most stringent EC50, in this subset of testing, to the state's acute criterion at 50 hardness, the EC50 value was 3 times greater than the criterion.			
Wang, N., Mebane, C.A., Kunz, J.L., Ingersoll, C.G., Brumbaugh, W.G., Santore, R.C., Gorsuch, J.W., and Arnold, W.R. (2011).	98-101 mg/L, with reference test hardness of 169 mg/L (mussel tests) 102-106 mg/L, with reference test hardness of 174 mg/L	• Acute and chronic toxicity of copper to a unionid mussel (V. iris) and a cladoceran (C. dubia) were determined in water exposures at four concentrations of DOC. • The acute and chronic values for the mussel were less than or about equal to values for the cladoceran. The BLM normalized acute EC50s and chronic EC20s for the mussel and BLM normalized chronic EC20s for the cladoceran in waters with DOC concentrations of 2.5 to 10 mg C/L were equal to or less than the FAV and FCV in the BLM based AWQC for copper, respectively, indicating that the copper AWQC might	Chronic at 100: 9

	(cladoceran tests)	not adequately protect the mussel from acute and chronic exposure and the cladoceran from chronic exposure.
		• Survival of rainbow mussel to copper over 28d test
		  ○ 0.5 mg/L DOC treatment
		  ▪ Concentration of copper and % survival:
		  • 0.3 µg/L and 100%
		  • 2.6 µg/L and 78%
		  • 4.9 µg/L and 100%
		  • 11 µg/L and 90%
		  • 23 µg/L and 0%
		  • 57 µg/L and 0%
		  • NOEC: 11 µg/L
		  • LOEC: 23 µg/L
		  ○ 2.5 mg/L DOC treatment
		  ▪ Concentration of copper and % survival:
		  • 1.7 µg/L and 100%
		  • 6.2 µg/L and 83%
		  • 11 µg/L and 95%
		  • 23 µg/L and 78%
		  • 46 µg/L and 23%
		  • 108 µg/L and 0%
		  • NOEC: 11 µg/L
		  • LOEC: 23 µg/L
		  ○ 10 mg/L DOC treatment
		  ▪ Concentration of copper and % survival:
		  • 8.9 µg/L and 88%
		  • 30 µg/L and 88%
		  • 51 µg/L and 78%
		  • 97 µg/L and 30%
		  • 212 µg/L and 0%
		  • 420 µg/L and 0%
		  • NOEC: 51 µg/L	

<table>
<tr><td></td><td></td><td>

- LOEC: 97 µg/L
- The results of the study indicate that acute and chronic tox of copper to rainbow mussel and cladoceran was influenced strongly by DOC. … The mussel was equally or more sensitive to copper compared to the cladoceran. The BLM based acute AWQC for copper seems to adequately protect the cladoceran, but might not protect the mussel. The chronic AWQC might not be protective of either.

</td><td></td></tr>
<tr><td colspan="4">EPA's conclusion: Assuming the 0.5 DOC treatment represents the most stringent result to capture the effect of copper on the mussel species, the resulting NOEC and LOEC values are 11 and 23 µg/L. When compared to the state's chronic criteria at 100 hardness, the toxicity values associated with no effect and the lowest effect concentration are 1.2 and 2.5 times the criterion value.</td></tr>
<tr><td colspan="4">Fish Specific Information</td></tr>
<tr><td>Besser, J., Mebane, C., Mount, D., Ivey, C., Kunz, J., Greer, E., May, T., and Ingersoll, C. (2007). [Note: Originally included in cadmium reference list but included here since study addressed copper also. See cadmium record papers for more information.]</td><td>100</td><td>

- Asterisks indicate estimated LC50s and target hardness during testing was 100 mg/L
- Table summary of all values, WQC calculated at 100 hardness and BLM standard conditions

<table>
<tr><td></td><td>MN sculpin</td><td>MO sculpin</td><td>Sculpin Species</td><td>Rainbow Trout</td><td>WQC</td></tr>
<tr><td>Copper</td><td colspan="5"></td></tr>
<tr><td>Acute LC50</td><td>61</td><td>16</td><td>31</td><td>59</td><td>13</td></tr>
<tr><td>BLM acute LC50</td><td>31</td><td>7.9</td><td>16</td><td>30</td><td>2.1</td></tr>
<tr><td>Chronic value</td><td>38</td><td>4.4</td><td>13</td><td>40</td><td>9.0</td></tr>
<tr><td>BLM chronic value</td><td>20</td><td>2.3</td><td>6.7</td><td>21</td><td>1.3</td></tr>
</table>

- Paper also discusses sensitivity relative to other taxa including comparison to mean tox values from WQC documents. Generally these species were close to most sensitive taxa

</td><td>Acute at 100: 13.4

Chronic at 100: 9</td></tr>
</table>

		• Results of study indicate WQC may be protective for rainbow trout but not mottled sculpins. For rainbow trout, all acute LC50s were at least two times greater than the acute WQC and all chronic values were greater than chronic WQC. Using BLM based copper criteria made the criteria protective of sculpins. Cadmium and zinc WQC provided marginal protection for sculpins,	
EPA's conclusions: When comparing the most stringent acute LC50 from the summarized table of values (16 for the Missouri sculpin) to the acute criteria at 100 hardness, the toxicity concentration is about 1.2 times the value adopted by the State. When comparing the most stringent BLM acute value (7.9 for the Missouri sculpin), the toxicity concentration is about 60% of the value adopted by the state. Similarly, when comparing the chronic criterion at 100 hardness, to the most stringent chronic value (4.4 for the Missouri sculpin), the toxicity concentration is about 50% of the value adopted by the state. When comparing the most stringent BLM chronic value (2.3 for the Missouri sculpin), the toxicity concentration is about 25% of the value adopted by the state. When compared to the least stringent acute, BLM acute, chronic, and BLM chronic values (61, 31, 40, and 21), the toxicity based values are ~4.5, 2.3, 4.4, and 2.3 times the values adopted by the state.			

Dwyer, F., Mayer, F., Sappington, L., Buckler, D., Bridges, C., Greer, I., Hardesty, D., Henke, C., Ingersoll, C., Kunz, J., Whites, D., Augspurger, T., Mount, D., Hattala, K., and Neuderfer, G. (2005).	160-180	• Hard water was used rather than soft water to minimize potential stress to listed species.
		• Of the five chemicals tested, copper is the only contained in NC's recent adoption.
		• Acute toxicity of copper to 18 fishes and 1 amphibian using 96 hr LC50s (reported in mg/L)
		  ○ Total range from >0.03 to 1.3 mg/L (desert pupfish not tested)
		  ▪ Note: this equates to 30 µg/L to 1,300µg/L
		  ○ Freshwater range from 0.06 to 0.47 mg/L
		  ○ Saltwater range from 0.63 to 1.3 mg/L
		• Of the listed species studied, the Atlantic and Shortnose sturgeon were two of the most sensitive species, LC50 of 0.06 and 0.08 mg/L, respectively. (ranked #1 and 2 out of total list for all chemicals)
		• Spotfin chub and Cape Fear shiner also studied…LC50s were 0.09 and 0.11 mg/L, respectively. (ranked #7 and 9 out of total list for all chemicals)
			Acute at 160/180: 20.9/23.4

EPA's conclusions: After converting the results from the four listed species that occur in NC waters to 60, 80, 90, and 100 µg/L and comparing against the acute criterion adopted by the State, it shows the LC50 values are ~2.8-4.8 times greater than the acute criterion at hardness of 160 and 2.5-4 times greater than the acute criterion at hardness of 180.			
Besser, J., Wang, N., Dwyer, F., Mayer Jr., F., and Ingersoll, C. (2005).	170	• Effect concentrations for chronic toxicity of copper to four fish species in early life stage toxicity tests • Survival NOEC-LOEC/chronic value/IC10 provided below:	Chronic at 170: 14.1

		○ Fountain darter 5.4 to 11/ 7.1 to 8.5/ 7.1 to <9.3 ○ Spotfin chub 23 to 42/ 31 / 32 ○ Fathead minnow 17 to 42/ 22 to 31/ 19 to 24 ○ Rainbow Trout 12 to 22/ 16 / 7 to 22 • Growth NOEC-LOEC/chronic value/IC10 provided below: ○ Fountain darter 5.4 to 11/ 7.1 to 8.5/ 12 ○ Spotfin chub 11 to 23/ 16 / 23 ○ Fathead minnow 1.9 to 23/ 2.9 to 16/ <4 to 16 ○ Rainbow Trout 6.2 to 22/ 8.6 to 16/ 8.4 to >22	
EPA's conclusions: The most stringent NOEC-LOEC for survival and growth was 5.4 to 11 µg/L. The most stringent chronic value for survival and growth was 7.1 µg/L. These values (5.4, 11, and 7.1) represent the following percentages of the adopted chronic criterion value: 38%, 78%, and 50%.			
Vardy, D.W., Oellers, J., Doering, J.A., Hollert, H., Giesy, J.P., Hecker, M. (2013).	65 mg/L	• Acute (96 hr) mortalities of white sturgeon early life stages due to exposure to copper under laboratory conditions are reported. • Two standard test species, rainbow trout and fathead minnow were exposed in parallel to determine relative sensitivity among species. Swim up larvae (15 days post hatch (dph)) and early juveniles (40-45 dph) of white sturgeon were more sensitive to copper (LC50= 10 µg/L and 9-17 µg/L respectively) than were yolk sac larvae (8dph; LC50=22 µg/L) and the later juvenile life stage (100 dph; LC50=54 µg/L). • White sturgeon were more sensitive to copper than rainbow trout and fathead minnow at all comparable life stages tested. • Previous work has indicated differences in sensitivity among early life stages of WS (Vardy et al. 2011), and studies of the effects of contaminants and life stage-specific sensitivities are important for making informed regulatory decisions. • LC50s were successfully calculated for all life stages of each species tested. Sturgeon were most sensitive to copper at 15 and 40 dph, followed by 45 and then 8 dph. Sturgeon exposed at a later life stage were more tolerant. • LC50s for sturgeon were lower than those for other fish species tested for all comparable life stages tested. • Early life stage Atlantic (Acipenser oxyrinchus), shortnose (Acipenser brevirostrum), and shovelnose (Scaphirhynchus platorynchus) sturgeon based on data from Dwyer et al. (2005) ranked in the 7th, 19th, and 30th centile, respectively. White sturgeon	Acute at 60/70: 8.3/9.6

		WS that were 8, 15, 40, 45, or 100 dph were ranked in the 14th, 1st, 2nd, 3rd, and 28th centile, respectively. • The WS life stage of greatest Cu sensitivity coincides with the beginning of active feeding and close association with sediment, possibly increasing risk. • Based on the findings of the study, early life stages of sturgeon appear to be among the most sensitive fishes to acute copper exposure….Similarly, all other early life stage sturgeon incorporated in the same SSD, including Atlantic, shortnose, and shovelnose sturgeon, were relatively sensitive and ranked in the 23rd centile or less.	
EPA's conclusions: Comparing the most stringent life stage LC50 (9 µg/L) to the state's acute criterion at 60 and 70 hardness, shows that the toxicity values are 1.1 times greater than and 94% of the acute criterion equivalents. The toxicity associated with the other life stages tested, specifically the larvae and later juveniles were greater than the acute values by up to 5.5-6.5 times.			
Vardy, D.W., Santore, R., Ryan, A., Giesy, J.P., Hecker, M. (2014).	54-66 mg/L	• Acute LC50s or early life stages of white sturgeon exposed to copper, cadmium, zinc, and lead in laboratory and site water • Copper 8dph lab/8dph site 40 dph lab/40 dph site Hardness 66/65 54/59 LC50 22/25 9/18 LC50 BLM normalized to site water 16/na 17/na LC50 BLM normalized to ref water 4.5/8.1 4.0/4.3 EPA WQC based on ref water 2.3/na • Sensitivity of early life stage white sturgeon to copper, cadmium, zinc, and lead appears to be more variable under acute exposures in comparison to trout and sculpins. • LC50s were greater than EPA recommendations for 8dph but bordered criteria for 40dph life stage • Further investigation warranted into site specific considerations….WERs were consistently >1 indicating metals were less toxic to white sturgeon exposed to site water than laboratory water.	Acute at 50/70: 7/9.6
EPA's conclusions: For the 8dph life stage of white sturgeon, the lab water based testing resulted in LC50s of 4.5-22 µg/L (with the lower values reflecting BLM normalized results and the upper end of the range reflecting the traditional LC50). For the 8dph life stage of white sturgeon, the site water based testing resulted in LC50s of 8.1 and 25 µg/L (with the lower value reflecting a BLM normalized result and the upper value reflecting the traditional LC50). In comparing the State's criteria at 50 and 70 hardness, the most stringent LC50 for lab water (4.5 µg/L) was ~47 to 64% of than the acute criterion. In comparing the State's criteria at 50 and 70 hardness, the most stringent LC50s for site water (8.1 µg/L) was 1.2 times greater than and ~84% of the acute criterion.			

For the 40dph life stage of white sturgeon, the lab water based testing resulted in LC50s of 4.0-17 µg/L (with the lower and upper values reflecting BLM normalized results and the middle of the range reflecting the traditional LC50). For the 40dph life stage of white sturgeon, the site water based testing resulted in LC50s of 4.3 and 18 µg/L (with the lower value reflecting a BLM normalized result and the upper value reflecting the traditional LC50). In comparing the State's criteria at 50 and 70 hardness, the most stringent LC50 for lab water (4 µg/L) was ~57-42% of the acute trout criterion. In comparing the State's criteria at 50 and 70 hardness, the most stringent LC50s for site water (4.3 µg/L) was ~61-45% than the acute trout criterion. Of the traditionally calculated LC50s, the toxicity values were comparable or greater than the state's adopted criteria equivalents of 7 and 9.6 µg/L.			
Vardy, D.W., Tompsett, A.R., Sigurdson, J.L., Doering, J.A., Zhang, X., Giesy, J.P., Hecker, M. (2011).	65-70 mg/L	• The study conducted to establish baseline toxicity data for the subchronic exposure of early life stages of white sturgeon to copper, cadmium, and zinc that can be used in metal-related risk assessment. Embryos, larvae, and fry were exposed to increasing concentrations of dissolved copper, cadmium, and zinc for 66 days using laboratory-based flow-through exposure systems. • Chronic lethal concentrations at which 20% mortality occurred (LC20s) for cadmium (1.5 µg/L), copper (5.5 µg/L), and zinc (112 µg/L) obtained for white sturgeon in present study were comparable to those of sensitive salmonid species. Based on LC20 values for 19 dph and 58dph white sturgeon, the US recommended criteria established for these three parameters protect white sturgeon early life stages. • For copper, cadmium, and zinc: Exposure of early life stages of white sturgeon resulted in concentration-dependent mortalities. Statistically significant greater mortalities relative to the reference group occurred at the two greatest concentrations of copper (36&217), cadmium (8.3&69), and zinc (198&1214). • LC20s Measured concentrations at: 19 dph 58 dph ○ Copper 3.4 µg/L 5.5 µg/L • LC50s Measured concentrations at: 19 dph 58 dph ○ Copper 9.9 µg/L 12.4 µg/L • Early life stages of white sturgeon appear to be relatively sensitive to copper, cadmium, and zinc relative to other aquatic species. The most sensitive LC20s determined in the present study were compared with chronic values outlined in EPA's chronic toxicity to freshwater organisms dataset in each metal's ambient WQC document. The LC20s (after adjustment to comparable hardness) were almost always within a factor of two of the chronic value of the most sensitive fish species. • Based on the LC values, the US criteria are protective of white sturgeon early life stages for cadmium, copper, and zinc.	Chronic at 50/100: 5/9

		• Further investigation is needed for sediment exposure potential.	
EPA's conclusions: While the overall conclusion of the study was that the current EPA criteria are protective of various early life stages of the white sturgeon, for comparison, a comparison of the most stringent LC50 value of 3.4 µg/L (the LC20 at 19 dph) shows that the LC20 is 38-68% of the State's chronic criterion at 100 and 50 hardness. In comparison, the LC20 identified in the study (LC20 at 58 dph) was 1.1 times the criterion at 50 hardness and ~60% of the criterion at 100 hardness. The LC50s reflect greater toxicity concentrations than the criterion at either hardness.			
Calfee, R.D. et al. (2014). *[Note: Also included in cadmium and zinc reference lists but included here since study addressed copper also. See cadmium and zinc record papers for more information.]*	100 mg/L	• The study was done to assess the acute sensitivity of white sturgeon and rainbow trout to copper, cadmium, and zinc.	Acute at 100: 13.4

White Sturgeon *(Acipenser transmontanus)*		**Rainbow Trout** *(Oncorhynchus mykiss)*	
Life Stage (dph)	**LC50 (µg/L)**	**Life Stage (dph)**	**LC50 (µg/L)**
2	>23.6	1	62.9
16	7.14	18	56.6
30	16.4	32	59.9
44	>49.8	46	59
61	<90	60	42.4
72	74	74	60.6
89	90	95	19.1

EPA's Conclusions: For the 16 dph life stage of white sturgeon (most sensitive), the lab water based testing resulted in LC50s of less than 7.14 µg/L. In comparing to the State's criteria at 100 hardness (same as the laboratory study), the most stringent LC50 for lab water (7.14) was 53% of the acute copper criterion. However, for the 95 dph rainbow trout (most sensitive stage), the lab water based testing resulted in an LC50 of 19.1 µg/L. In comparing to the State's criteria at 100 hardness (same as the laboratory study), the most stringent LC50 for lab water (19.1) was ~1.43 times greater than the acute copper criterion.			
Little et al. (2012)	81-119 mg/L	• The study examined acute toxicity of copper to early-life stage Kootenai River White Sturgeon (KRWS), Columbia River White Sturgeon (CRWS), and Rainbow Trout (RBT). • Tests were conducted with rainbow trout to assess the comparative sensitivity of the species as a surrogate for white sturgeon. • At 30 dph, sturgeon were highly sensitive to copper with LC50s ranging from 4.1 – 6.8 µg/L, compared to 36.5 µg/L for 30 dph rainbow trout.	Acute at various hardness levels shown in table to the left.

- White sturgeon at 123-167 dph were less sensitive to copper than rainbow trout with LC50 values ranging from 103.7-268.9 µg/L. Rainbow trout was more sensitive to copper at 160dph with an LC50 value of 30.9 µg/L.

Species	Life stage (dph)	Hardness (mg/L)	LC50 (µg/L)	NC Criteria (hardness-adjusted)
KRWS	38	93.1	4.1	12.56
CRWS	26	81.8	4.5	11.12
RBT	30	107.7	36.5	14.41
CRWS	123	109.8	268.9	14.67
RBT	160	108.0	30.9	14.44
KRWS	40	118.9	4.7	15.82
CRWS	27	119.1	6.8	15.84
KRWS	167	109.0	103.7	14.58

EPA's Conclusions: For sturgeon, the early life stages (26-40 dph) are most sensitive to copper with LC50s that are 29-43% of the NC hardness-based acute copper criteria. For other life stages (123-167 dph), the copper LC50s are 7.1-18.3 times higher than the NC hardness-based acute copper criteria.

For rainbow trout, the NC hardness-based acute copper criteria is 2.1-2.5 times higher than the NC hardness-based acute copper criteria.

Wang et al. (2014)

[Note: Also included in cadmium, lead, and zinc reference lists.]

100 mg/L

- The objective of the study was to evaluate the chronic toxicity of copper, cadmium, lead, or zinc to early life stages of white sturgeon in water-only exposures.
- Toxicity texts were also conducted with rainbow trout under similar test conditions to determine the relative sensitivity difference between white sturgeon and rainbow trout.

			EC20 (µg/L)			
	Exposures	**Age at initiation (dph)**	**Survival**	**Length**	**Dry weight**	**Biomass**
White Sturgeon	C1/CC 0-14d	2	2.2	-	-	-
	C1/CC 0-25d	2	NR	-	-	-
	CC 0-53d	2	NR	1.8	1.6	NR
	C1-R 0-24d	1	3	2.3	1.4	1.7
	C2 0-28d	27	4.2	4.4	2.9	2.7
	C1 0-21d	1	43	>60	>60	>60

Dissolved Chronic at 100 mg/L: 8.9 µg/L

			Rainbow Trout	CC 0-52d	1	36	>57	>57	32		
				C2 0-28d	26	39	>54	43	30		

EPA's Conclusions: For white sturgeon, the chronic tests and endpoints had EC20s that were 16-49% the State's dissolved chronic copper criteria.

For rainbow trout, all the chronic tests and endpoints had EC20s that were greater than 3.4 times the State's dissolved chronic copper criteria.

Summary of Mussel and Fish Results from Existing Lead Papers and Comparison to NC Criteria for Lead

Green highlighting indicates 1) where 48 hour or 96 hour LC50 tests were greater than NC's acute criteria to demonstrate when toxicity levels were higher than the State's acute criterion or 2) longer term data toxicity results were greater than the State's chronic criterion. Other information that is relevant to showing effects but based on some other metric (EC50, NOEC or LOEC, etc) is highlighted in yellow as additional evidence considered in determining any potential effects from given exposure concentrations of lead.

Lead Papers provided by Tom A for mussels Listed by Author	Hardness	Results/Notes from Studies	Comparable NC lead acute/chronic criterion based on similar hardness
Mussel Specific Information			
Kovats, N., Abdel-Hameid, N.A., Kavacs, K., and Paulovits, G. (2010).	170 (noted as used in glochidia preparation, not otherwise discussed)	• Toxicity of lead, copper, and zinc based on 24 hr and 48 hr LC50s • Although some metals are essential for life (Engel and Sunda 1979) all metals are toxic at high concentrations and for some there is a narrow range of concentrations between what is essential and what is toxic. • LEAD (µg/L) 24hr LC50 / NOEC 48 hr LC50 / NOEC P. complanata 374.6 (321.0-440.1) / 32 260.8 (226.0-300.5) / 29	Acute at 170: 114.5
EPA's conclusions: Using the assumption the tests were completed in sample with a hardness of 170 mg/L, the acute lead criterion was compared to the average 48 hr LC50 of 260.8. The toxicity level therefore, represents ~2.3 times the adopted acute criterion. For comparison, if the State's criterion using a hardness of 25µg/L was used (which would be 14 µg/L), the difference would be much greater between the criterion and the 48 hr LC50, and would also be more stringent than the concentrations associated with no effect. By looking at this range of interpretations, the EPA finds that the general conclusion would support that the toxicity information indicates higher levels than those adopted by the State.			
Mosher, S., Cope, W.G., Weber, F.X., Kwak, T.J., Shea, D. (2012).	42 (ranged 40-44)	• Conducted a 28 day laboratory toxicity test with Pb and adult Eastern Elliptio mussels to determine uptake kinetics and to assess several potential non-lethal biomarkers of Pb exposure. • Exposed to 1 to 251 µg/L (as lead nitrate) as a static renewal test.(specific concentrations of 0.9, 1.3, 3.2, 6.4, 10.5, 25.9, 66.3, and 250.8) • No mussels died during the test. • Average lead concentration in mussel tissue at the end of 28 d study was strongly correlated to exposure concentration (R2=.98, $p < 0.0001$)	Chronic at 40: 0.92

		• Lead was accumulated extremely rapidly by ventilation across the gills. • The mussels appear to accumulate lead in a concentration dependent manner and begin to actively regulate lead uptake by day 14 of exposure based on hemolyph concentrations. • The lowest exposure (0.9) for 28 d resulted in an average tissue concentration of 1.5 µg/g dry weight, which is similar to average tissue concentration of 1.6 µg/g dry weight measured in Elliptio complanata (n=240) sampled from natural populations at 40 stream sites across North Carolina (Mosher 2008).	
EPA's conclusions: Although no specific LC50s were identified in this study, the study looked at a range of exposure concentrations and found that no mussels died during the test. Further, the lowest exposure (0.9), which is equivalent to the state's adopted chronic lead criterion, was identified as resulting in a comparable tissue concentration as tissue concentrations from natural Elliptio complanata populations in the state.			

Wang, N., Ingersoll, C. G., Ivey, C. D., Hardesty, D. K., May, T. W., Augspurger, T., Roberts, A. D., van Genderen, E., and Barnhart, M. C. (2010).	reconstituted soft water (hardness 40-48mg/L)	• 24 hr EC50 for 2 hr old fatmucket gloc: >299 µg/L to 400 Pb, 96 hr EC50 for fatmucket 2 month juvenile: >426 µg/L Pb, 96 hr EC50 for newly transformed (5 day) fatmucket 142 and 298 µg/L Pb and Neosho mucket 188 µg/L Pb
		• 28 day chronic values for fat mucket was 10 µg/L Pb from ACR 22 and EC50 of 220
		• EC50s for survival of juvenile fatmucket : >83µg//L(4 day), >83 µg/L(10 day), 29µg/L(21 day), and 20 (28 day)
		• When mussel data from this study was added to EPA's database, mussel GMAVs were in the lower percentiles of the sensitivity distribution of all freshwater mussels for Pb (26th percentile). The mussel lampsilis GMCV was lowest ever reported for Pb (9th percentile). Therefore, mussels relatively sensitive to acute toxicity of Pb and chronic toxicity of Pb.
		• Survival % for Lead at end of 28 day test:
		  ○ Concentration 0.04 µg/L: 100 % survival
		  ○ Concentration 2.9 µg/L: 100 % survival
		  ○ Concentration 6.1 µg/L: 98 % survival
		  ○ Concentration 17 µg/L: 78 % survival
		  ○ Concentration 36 µg/L: 2.5 % survival
		  ○ Concentration 83 µg/L: 0 % survival
		• Other info from 28 day test:
		  ○ NOEC = 6.1µg/L
		  ○ LOEC = 17µg/L
			Acute at 25/50: 14/30
			
			Chronic at 25/50: 0.54/1.17

		• The results indicate that the current EPA acute and chronic WQC are protective of the tested freshwater mussels from Pb or Cd exposure, but may not be adequately protective for Zn exposure. Paper discusses BLM for Zn.	
EPA's conclusions: When comparing the most stringent acute EC50 provided (96 hr juvenile fat mucket, 83 µg/l), the toxicity value represents a value 6 and 2.8 times the adopted acute criterion at 25 and 50 hardness respectively. In comparing the chronic criterion of 0.54 and 1.17 µg/L (representing hardness of 25 and 50), the 28 day chronic value was 10 µg/L which is 18.5 and 8.5 times greater than the chronic criteria adopted by the State. When looking at percent survival (and NOEC/LOEC) at the end of the 28 day test, both chronic criterion equivalents (0.54 and 1.17) equate to 100% survival concentrations and are less than the NOEC of 6.1µg/L (NOEC is 5-11 times higher than the chronic equivalents).			
Fish Specific Information			
Vardy, D.W., Santore, R., Ryan, A., Giesy, J.P., Hecker, M. (2014). *[Note: Originally included in copper reference list but included here since study addressed lead also. See copper record papers for more information.]*	53-59 mg/L	• Acute LC50s or early life stages of white sturgeon exposed to copper, cadmium, zinc, and lead in laboratory and site water • Lead site Hardness 59/57 53/58 LC50 177/>410 528/1,556 LC50 BLM normalized to site water 244/na 917/na LC50 BLM normalized to ref water 98/>219 600/1,087 EPA WQC based on ref water 54/na • In current study, LC50s for white sturgeon exposed to lead in lab water were significantly less than average LC50s for rainbow trout and less than or equal to cutthroat trout. However, for cadmium, an opposite trend was observed whereby early life state white sturgeon exposed to cadmium in lab water were less sensitive than rainbow trout, bull trout, cutthroat trout, shorthead sculpins, and mottled sculpins, all of which exhibited LC50s that ranged between 1.7 µg/L and 3.5 µg/L. Thresholds for mortality to zinc were more consistent with rainbow, bull, and mottled sculpins (range between 114 and 251 µg/L) and approximately three times less than those of cutthroat trout and shorthead sclupins (494 and 528 µg/L respectively). • Sensitivity of early life stage white sturgeon to copper, cadmium, zinc, and lead appears to be more variable under acute exposures in comparison to trout and sculpins. • LC50s were greater than EPA recommendations for 8dph but bordered criteria for 40dph life stage	Acute at 50: 30

		• Further investigation warranted into site specific considerations….WERs were consistently >1 indicating metals were less toxic to white sturgeon exposed to site water than laboratory water.	

EPA's conclusions: For the 8dph life stage of white sturgeon, the lab water based testing resulted in LC50s of 98-244 µg/L (with the lower and upper values reflecting BLM normalized results and the middle of the range reflecting the traditional LC50). For the 8dph life stage of white sturgeon, the site water based testing resulted in LC50s of >219 and >410 µg/L (with the lower value reflecting a BLM normalized result and the upper end of the range reflecting the traditional LC50). In comparing the State's criteria at 50 hardness, the most stringent LC50 for lab water (98 µg/L) was ~3.3 times greater than the acute trout criterion. In comparing the State's criteria at 50 hardness, the most stringent LC50s for site water (219 µg/L) was ~7.3 times greater than the acute trout criterion.

For the 40dph life stage of white sturgeon, the lab water based testing resulted in LC50s of 528-917 µg/L (with the upper values reflecting BLM normalized results and the low end of the range reflecting the traditional LC50). For the 40dph life stage of white sturgeon, the site water based testing resulted in LC50s of 1,087 and 1,556 µg/L (with the lower value reflecting a BLM normalized result and the upper value reflecting the traditional LC50). In comparing the State's criteria at 50 hardness, the most stringent LC50 for lab water (528 µg/L) was 17.6 times greater than the acute trout criterion. In comparing the State's criteria at 50 and 100 hardness, the most stringent LC50s for site water (1,087 µg/L), were ~36 times greater than the acute trout criterion.

Fish Specific Information

Wang et al. (2014)

[Note: Also included in cadmium, copper and zinc reference lists.]

100 mg/L

- The objective of the study was to evaluate the chronic toxicity of copper, cadmium, lead, or zinc to early life stages of white sturgeon in water-only exposures.
- Toxicity texts were also conducted with rainbow trout under similar test conditions to determine the relative sensitivity difference between white sturgeon and rainbow trout.

			EC20 (µg/L)			
	Exposures	**Age at initiation (dph)**	**Survival**	**Length**	**Dry weight**	**Biomass**
White Sturgeon	C1/CC 0-14d	2	>56	-	-	-
	C1/CC 0-25d	2	NR	-	-	-
	CC 0-53d	2	NR	>27	>27	NR
	C2 0-28d	27	>60	>60	>60	>60
Rainbow Trout	C1 0-21d	1	>128	>128	>128	>128
	CC 0-52d	1	>126	>126	>126	>126
	C2 0-28d	26	>128	>128	>128	>128

Dissolved Chronic at 100 mg/L: 2.5 µg/L

EPA's Conclusions: For white sturgeon, all the chronic tests and endpoints had EC20s that were greater than 10.8 times the State's dissolved chronic lead criteria.

For rainbow trout, all the chronic tests and endpoints had EC20s that were greater than 50 times the State's dissolved chronic lead criteria.

Summary of Mussel Results from Existing Nickel Papers and Comparison to NC Criteria for Nickel

Green highlighting indicates 1) where 48 hour or 96 hour LC50 tests were greater than NC's acute criteria to demonstrate when toxicity levels were higher than the State's acute criterion or 2) longer term data results were greater than the State's chronic criterion. Other information that is relevant to showing effects but based on some other metric (EC50, NOEC or LOEC, etc) is highlighted in yellow as additional evidence considered in determining any potential effects from given exposure concentrations of nickel.

Nickel Papers provided by Tom A for mussels Listed by Author	Hardness	Results/Notes from Studies	Comparable NC nickel acute/chronic criterion based on similar hardness
Mussel Specific Information			
Besser, J.M., Brumbaugh, W.G., Kemble, N.E., Ivey, C.D., Kunz, J.L., Ingersoll, C.G., and Rudel, David. (2011).	100	• Study included information on the toxicity and bioavailability of nickel in nickel-spiked freshwater sediments. • Task 2 evaluated the relative sensitivity of invertebrate taxa to toxic effects of two nickel spiked sediments, one from Spring River, MO (which had low concentrations of metal binding components) and one from West Bearskin Lake, MN (which had high concentrations of metal binding components like TOC and AVS) • Tests lasted 28 days and included multiple chronic toxicity endpoints including survival, growth, and biomass for 8 taxa (two amphipods, two midges, two oligochaetes, one mussel, and one mayfly)) ○ The taxa most sensitive to toxicity of nickel spiked sediments were Hyalella, Gammarus, and Hexagenia. • Water replacement treatments strongly affected nickel concentrations in overlying water during toxicity tests. At the lowest water replacement rate (2 times), mean overlying water nickel in several spike treatments exceeded the chronic WQC for nickel (52µg/L at 100 hardness) with means as high as 120 µg/L indicating a substantial risk of toxicity from nickel in overlying water. • Responses of invertebrates to nickel-spiked sediments differed between sample locations and among species and endpoints.	Chronic at 100: 52

		○ In spiked Spring River sediments, the mussel and 4 other species, has no statistically different reductions of any endpoint, relative to the controls. ○ In spiked Bearskin Lake sediments, all species except the mussel and one oligochaete had statistically significant toxic effects. • Lampsilis siliqouidea endpoints: ○ Survival: NOEC >71 µg/L, LOEC no value, EC10 no value, EC20 no value ○ Growth: NOEC 25 µg/L, LOEC 71 µg/L, EC10 41 µg/L, EC20 65 µg/L ○ Biomass: NOEC 25 µg/L, LOEC 71 µg/L, EC10 32 µg/L, EC20 46 µg/L	
EPA's conclusions: The state's chronic criterion of 52 µg/L (at 100 hardness) was less than the level of 71µg/L indicated as NOEC for survival, LOEC for growth, and LOEC for biomass, all of which are 1.3 times the chronic criterion. All though not an LC50 based endpoint, the EC10s (and one EC20) reflected concentrations which were more stringent than the chronic criterion adopted by the state, 62%-88% of the chronic criterion equivalent, when compared to the most stringent EC10 and 20.			
Besser, J.M., Ingersoll, C.G., Brumbaugh, W.G., Kemble, May, T.W., Wang, N., MacDonald, D.D., and Roberts, A.D. (2015).	100 and 200	• Sediment toxicity tests compared chronic effects (28 day test) on survival, growth, and biomass of juvenile freshwater mussels to the responses of standard test organisms – amphipods. • Sediments were contaminated with lead, zinc, and cadmium. • The frequency of highly toxic responses (reduced by 10% or more relative to reference sites) in Tri State sediments was greatest for amphipod survival and midge biomass (25% and 20%) and 14% for mussel survival. For SE Missouri sediments, the frequency was greatest for mussel biomass (25%) and amphipod biomass (13%).	n/a
EPA's conclusions: Did not use study due to lack of specific concentration information for comparison to North Carolina's chronic criteria.			
Clem S. A (1998) *[Note: Originally included in cadmium reference list but included here since study addressed nickel also. See cadmium record papers for more information.]*	Used dechlorinated tap water (40-50) or moderately hard synthetic water (80-100)	• Glochidial response of five species (L. fragilis, L.teres, P.purpuratus, P. occidentalis, and L. subrostrata) assessed using 24 hr acute tox tests with Al, Cd, Cu, Fe, Mn, Ni, and Zn. • LC50 values for nickel ranged from 339 (for L. teres) to 918 µg/L (for L. subrostrata) • Used dechlorinated tap water or moderately hard synthetic water • Order of sensitivity: L. teres > L. fragilis > P.purpuratus > P. occidentalis > L. suborstrata • Order of toxicity: Cu > Cd > Zn > Ni > Mn > Fe > Al • In vivo and in vitro results are also discussed in the paper.	Acute at 50/100: 260/468
EPA's conclusion: The LC50 values ranged from 339 to 918 µg/L. With hardness between 40 and 100 mg/L, the North Carolina criteria values are given at 50 and 100 hardness, or 260 and 468 µg/L for the acute criterion equivalents. Comparing the state concentrations against the lowest 24 hr LC50 concentration in			

these studies (339 µg/L), the toxicity results are ~ 1.3 times greater than and ~72% of the state's acute criteria at a hardness of 50 and 100 respectively. Chronic cadmium information was not available in this paper so it was not addressed in this conclusion box.			
Keller, A. E., and Zam, S. G. (1991). *[Note: Originally included in cadmium reference list but included here since study addressed nickel also. See cadmium record papers for more information.]*	39-45 (range observed for soft water in this study)	• "Overall, mussels were found to be as sensitive to metals as zooplankton and more sensitive than commonly tested fish and aquatic insects." "In an effort to obtain basis experimental data, a series of acute toxicity (96 hr) tests were performed to determine whether juvenile mussels were sensitive to mercury, zinc, nickel, cadmium, copper, and chromium, the metals most toxic to other aquatic biota." • In soft water, the order of LC50 averages for juvenile A.imbecilis at 48hr was: Cd (0.057mg/L)> Cu (0.171 mg/L)>Hg (0.216mg/L)>Ni (0.240 mg/L)>Cr (0.295mg/L)>Zn (0.355mg/L) • In soft water, the order of LC50 averages for juvenile A.imbecilis at 96hr was: Cd (0.009mg/L) >Cr (0.039mg/L)> Cu (0.086 mg/L)>Hg (0.147mg/L)>Ni (0.190 mg/L)> Zn (0.268mg/L) ○ Cr and Cu increased tox much more than the other metals between 48 and 96 hrs • In moderately hard water, the order of LC50 averages for juvenile A.imbecilis at 48hr was: Cd (0.137mg/L)>Hg (0.233mg/L)> Cu (0.388 mg/L)>Ni (0.471 mg/L)>Zn (0.588mg/L)>Cr (1.187mg/L) • In moderately hard water, the order of LC50 averages for juvenile A.imbecilis at 96hr was: Cd (0.107mg/L)>Hg (0.171mg/L)> Cu (0.199 mg/L)>Ni (0.252 mg/L)>Zn (0.438mg/L)>Cr (0.618mg/L) Comparison of LC50 values for metals and ambient water quality guidelines established by the EPA indicates current standards may be adequate to protect mussels from acute exposures to metals. The 4 day average concentrations of all 6 metals tested are lower than the mussel 96 hr LC50 in soft water. However, sensitivity of A.imbecilis to Cr, Zn, and Ni is close enough to the WQS to bear further study.	Acute at 25/50: 140/260
EPA's conclusions: EPA's conclusion: In soft water, the average 48 hr LC50 value was 240 µg/L and the average 96 hr LC50 was 190 µg/L. In moderately hard water, the average 48 hr LC50 value was 471 µg/L and the average 96 hr LC50 was 252 µg/L. With hardness of 39-45 mg/L, the North Carolina criteria values are given at 25 and 50 hardness, or 140 and 260 µg/L. Without details on what was characterized as "moderately hard water" the EPA chose to just compare using the 25 and 50 hardness range as described since this would be the most conservative assumption. Comparing the state concentrations against the lowest LC50 concentration in these studies (the 96 hr in soft water, or 190 µg/L), the toxicity results are 1.4 times greater than and 75% of the state's acute criteria at hardness of 25 and 50 respectively. Chronic nickel information was not available in this paper so it was not addressed in this conclusion box.			

Summary of Mussel and Fish Results from Existing Zinc Papers and Comparison to NC Criteria for Zinc

Green highlighting indicates 1) where 48 hour or 96 hour LC50 tests were greater than NC's acute criteria to demonstrate when toxicity levels were higher than the State's acute criterion or 2) longer term data results were greater than the State's chronic criterion. Other information that is relevant to showing effects but based on some other metric (EC50, NOEC or LOEC, etc) is highlighted in yellow as additional evidence considered in determining any potential effects from given exposure concentrations of zinc.

Zinc Papers provided by Tom A for mussels Listed by Author	Hardness	Results/Notes from Studies	Comparable NC zinc acute/chronic criterion based on similar hardness
Mussel Specific Information			
Clearwater, S. J., Thompson, K.J., and Hickey, C.W. (2013).	30	• ZINC NOEC / LOEC / EC50 (all measurements in µg/l) ○ 6 hr ○ Site 1 1,655 >1655 >1655 ○ Site 2 620 >620 >620 ○ Site 3 593 >593 >593 ○ 24 hr ○ Site 1 240 370 346 (313-377) ○ Site 2 373 493 557 (528-593) ○ Site 3 161 230 202 (117-158) ○ 48 hr ○ Site 1 128 240 229 (204-263) ○ Site 2 240 307 337 (299-368) ○ Site 3 <161 161 128 (55-202) • Geo mean of sites 1 &2…48 hr NOEC for zinc: 175.3 • Geo mean of sites 1 &2…24 hr EC50 for zinc: 439 • Geo mean of sites 1 &2…48 hr EC 50 for zinc: 277 • Paper discusses use of BLM for calculating criteria for zinc and copper, proposed zinc update by Zinc association.	Acute at 25: 36

EPA's Conclusions: When comparing the State's acute zinc criterion against the most stringent value determined in this paper (an NOEC of 128 µg/L in the 48 hr test), the no effect concentration is 3.5 times greater than the adopted concentration. Even if compared at a hardness of 50, the criterion (which would be 65 µg/L) is still only half of the concentration associated with no effect.			
Clem S. A (1998) *[Note: Originally included in cadmium reference list but included here since study addressed zinc also. See cadmium record papers for more information.]*	Used dechlorinated tap water (40-50) or moderately hard synthetic water (80-100)	• Glochidial response of five species (L. fragilis, L.teres, P.purpuratus, P. occidentalis, and L. suborstrata) assessed using 24 hr acute tox tests with Al, Cd, Cu, Fe, Mn, Ni, and Zn. • LC50 values for zinc ranged from 249 (for P.purpuratus) to 663 µg/L (for L. fragilis) • Used dechlorinated tap water or moderately hard synthetic water • Order of sensitivity: L. teres > L. fragilis > P.purpuratus > P. occidentalis > L. suborstrata • Order of toxicity: Cu > Cd > Zn > Ni > Mn > Fe > Al • In vivo and in vitro results are also discussed in the paper.	Acute at 50/100: 65/117
EPA's Conclusions: When comparing the most stringent 24 hr LC50 for zinc against the state's criterion at a hardness of 50 and 100, the toxicity results indicate a level which is 5 and 2.5 times greater than the adopted acute criterion.			

Hansten, C., Heino, M., and Pynnönen, K. (1996).
[Note: Originally included in cadmium reference list but included here since study addressed zinc also. See cadmium record papers for more information.]
	25.7	• Looked at the effects of humic acid (200 mg Pt/l as color), EDTA (used in excessive amounts to achieve maximal chelation), Fe (1000 µg/L) and Mn (400 µg/L) on the toxicity of Cd, Cu, and Zn on glochidia.
		  ○ Used concentrations which were non-toxic and matched maximums found in natural environments (values given above in parentheses).
		• Copper was the most toxic and Zinc was the least toxic. Toxicity increased with exposure time.
		• Metals concentrations were:
		  ○ Zinc 100, 200, 500, 1000, and 5000 µg/L
		  ▪ After 24 hrs, Zn showed toxic effects at concentrations exceeding 500 µg/L
		  ▪ Zero gloc viability reached after 144 hrs when above 500
		• Humic acid decreased toxicities of Cadmium and Copper, but increased Zinc toxicity.
		• EDTA and Fe decreased the toxicity of all three metals.
		• Manganese did not effect Cadmium and Copper, but increased toxicity of Zinc.
			Acute at 25: 36
			
			Chronic at 25: 37

EPA's Conclusions: This study showed that levels exceeding 500 µg/L, resulted in toxic effects at 24 hours and that 500 µg/L resulted in zero viability after 144 hours (6 days). When comparing the short term and longer term exposure concentration of 500 µg/L to the North Carolina criteria values at 25 hardness, the criteria should be compared to the state's acute and chronic criteria of 36 µg/L and 37 µg/L, respectively. Comparing the state's acute concentration against the 500 µg/L, the toxicity results were ~14 times greater than the state's acute criteria. When compared to the same value (although reflecting a longer term exposure), the toxicity endpoint was 13.5 times greater than the state's chronic criterion. While this study did not include typical durations of exposure, the information still provides some estimates by which to assess the state's criteria against for consultation purposes.			
Huebner, J. D. and Pynnonen, K. S. (1992). *[Note: Originally included in cadmium reference list but included here since study addressed zinc also. See cadmium record papers for more information.]*	35	• pH is important • exposed to 5 to 30000 µg/L zinc • EC50 for µg/L zinc: 24 hr 197.9 (confidence limits 63.1-480), 48 hr 69.1 (confidence limits 22.5-173.8), 72 hr 45.8 (confidence limits 17.8-98.1) • Threshold concentration to cause significant decrease in gloc response for µg/L Zinc: 24 hr 500, 48 hr 500, 72 hr 500 • The relative toxicities (based on 48 hr EC50s) of the metals to Anodonta cygnea gloc were Cu (5.3µg/L) > Cd (46.8µg/L) > Zn (69.1µg/L) > Al	Acute at 25/50: 36/50
EPA's Conclusions: The average 48 hr EC50 value was 69.1 µg/L. With hardness of 35 mg/L, the North Carolina criteria values are given at 25 and 50 hardness, 36 and 50 µg/L. Comparing the state concentrations against the lowest LC50 concentration in these studies, the toxicity results are ~1.4-1.9 times greater than the state's acute criterion. However, it should be noted this study used low pH (3-6.5) and simultaneously included exposure to other metals, including aluminum and copper so there could be confounding factors influencing these results. While this study did not include typical durations of exposure, the information still provides some estimates by which to assess the state's criteria against for consultation purposes. Chronic cadmium information was not available in this paper so it was not addressed in this conclusion box.			
Keller, A. E., and Zam, S. G. (1991). *[Note: Originally included in cadmium reference listed but included here since study addressed zinc also. See cadmium record papers for more information.]*	39-45 (range observed for soft water in this study)	• "Overall, mussels were found to be as sensitive to metals as zooplankton and more sensitive than commonly tested fish and aquatic insects." • "In an effort to obtain basis experimental data, a series of acute toxicity (96 hr) tests were performed to determine whether juvenile mussels were sensitive to mercury, zinc, nickel, cadmium, copper, and chromium, the metals most toxic to other aquatic biota." Also looked at mixtures and comparability of mussel and C. dubia response. • In soft water, the order of LC50 averages for juvenile A.imbecilis at 48hr was: Cd (0.057mg/L)> Cu (0.171 mg/L)>Hg (0.216mg/L)>Ni (0.240 mg/L)>Cr (0.295mg/L)>Zn (0.355mg/L) • In soft water, the order of LC50 averages for juvenile A.imbecilis at 96hr was: Cd (0.009mg/L) >Cr (0.039mg/L)> Cu (0.086 mg/L)>Hg (0.147mg/L)>Ni (0.190 mg/L)> Zn (0.268mg/L)	Acute at 25/50: 36/65

		○ Cr and Cu increased tox much more than the other metals between 48 and 96 hrs • In moderately hard water, the order of LC50 averages for juvenile A.imbecilis at 48hr was: Cd (0.137mg/L)>Hg (0.233mg/L)> Cu (0.388 mg/L)>Ni (0.471 mg/L)>Zn (0.588mg/L)>Cr (1.187mg/L) • In moderately hard water, the order of LC50 averages for juvenile A.imbecilis at 96hr was: Cd (0.107mg/L)>Hg (0.171mg/L)> Cu (0.199 mg/L)>Ni (0.252 mg/L)>Zn (0.438mg/L)>Cr (0.618mg/L) • Toxicities of all metals but mercury were significantly lower in moderately hard water than they were in soft water. • Hardness ranged from 39 (for Cd, Cr, Cu, Ni, and Zn) to 45 (for Hg) (associated with soft water labeling in paper) • Comparison of LC50 values for metals and ambient water quality guidelines established by the EPA indicates current standards may be adequate to protect mussels from acute exposures to metals. The 4 day average concentrations of all 6 metals tested are lower than the mussel 96 hr LC50 in soft water. However, sensitivity of A.imbecilis to Cr, Zn, and Ni is close enough to the WQS to bear further study.	
EPA's Conclusions: Relative to other pollutants, zinc was usually the parameter with the least sensitivity or the next to least sensitivity. Of the soft water LC50s the most stringent LC50 (96 hr) was 0.268mg/L, or 268 µg/L. When comparing against the state's criterion at 25 and 50 hardness, the LC50 is ~7.5 and 4 times greater than the corresponding criterion concentrations of 36 and 65 µg/L. In addition, the paper did note that additional study should be considered for chromium, zinc, and nickel.			
Kovats, N., Abdel-Hameid, N.A., Kavacs, K., and Paulovits, G. (2010). *[Note: Originally included in lead reference list but included here since study addressed zinc also. See lead record papers for more information.]*	170 (noted as used in glochidia preparation, not otherwise discussed)	• Toxicity of lead, copper, and zinc based on 24 hr and 48 hr LC50s • Synergistic effects reported for copper+zinc and copper+lead • Additive effect reported for zinc+lead • Although some metals are essential for life (Engel and Sunda 1979) all metals are toxic at high concentrations and for some there is a narrow range of concentrations between what is essential and what is toxic. • ZINC (µg/L) 24hr LC50 / NOEC 48 hr LC50 / NOEC ○ A. anatina 361.1 (314.9-415.5) / 90 233.5 (199.8-271.9) / 60 ○ P. complanata 262.5 (230.5-298.9) / 70 201.6 (175.5-230.5) / 55 ○ U. tumidus 180.6 (55.4-208.3) / 60 134.2 (16.1-153.5) / 50 • Sensitivities of three species to copper fell in the same range.	Acute at 170: 183.7

		• Regarding Zn sensitivity, differences were much greater.	
EPA's Conclusions: Using the assumption the tests were completed in sample with a hardness of 170 mg/L, the acute lead criterion was compared to the most stringent LC50 of 134.2 µg/L µg/L (48 hr test). At that hardness, the toxicity level is about 73% of the adopted acute criterion. For comparison, considering the lowest end range of hardness typically used in testing, such as a hardness of 25µg/L which would be 36 µg/L, the difference would be that the toxicity levels are ~3.7 times greater than the acute criterion. If compared to the NOEC values given in this study, the state's criterion at 170 hardness is higher than any of the NOEC values and at 25 hardness is less than all the NOEC values. Caution should probably be used in including this paper without better resolution on the issue of hardness, as this greatly effects what the toxicity values are compared against.			
McCann, M. (1993).	40, 50, 140, 150, and 160	• Table 1: Zinc and glochidia for A. pectorosa (pheasantshell) ○ Tap water at 50 hardness: ▪ 24 hr LC50 at 50 hardness ranged from 392-721 µg/L ▪ 48 hr LC50 at 50 hardness ranged from 273-525 µg/L ○ Powell River water at 150 and 160 hardness: ▪ 24 hr LC50 at 150 hardness was 2009 µg/L ▪ 24 hr LC50 at 160 hardness ranged from 1154-2886 µg/L ▪ 48 hr LC50 at 150 hardness was 1134 µg/L ▪ 48 hr LC50 at 160 hardness ranged from 665-1049 µg/L • Table 2: Zinc and glochidia for Villosa iris (rainbow) ○ Tap water at 40 and 50 hardness: ▪ 24 hr LC50 at 40 hardness ranged from 1620-1908 µg/L ▪ 24 hr LC50 at 50 hardness ranged from 739-1765 µg/L ▪ 48 hr LC50 at 40 hardness ranged from 1155-1173 µg/L ▪ 48 hr LC50 at 50 hardness ranged from 577-1202 µg/L ○ Powell River water at 140 and 160 hardness: ▪ 24 hr LC50 at 140 hardness ranged from 1331-3087 µg/L ▪ 24 hr LC50 at 160 hardness ranged from 1004- 4123 µg/L ▪ 48 hr LC50 at 140 hardness ranged from 1042-1775 µg/L ▪ 48 hr LC50 at 160 hardness ranged from 836- 1230 µg/L • Table 3: Zinc and glochidia and Medionidus conradicus (Cumberland moccasinshell) ○ Tap water at 40 and 60 hardness: ▪ 48 hr LC50 at 40 hardness was 726 µg/L ▪ 48 hr LC50 at 60 hardness was 492 µg/L ○ Powell River water at 140 and 160 hardness:	Acute at 40/160: 54/175

		▪ 24 hr LC50 at 140 hardness was 549 µg/L ▪ 24 hr LC50 at 160 hardness was 423 µg/L • Table 4: Zinc and juveniles for A. pectorosa (pheasantshell) ○ Tap water at 40 hardness: ▪ 48 hr LC50 at 40 hardness ranged from 361-411 µg/L ▪ 96 hr LC50 at 40 hardness ranged from 211-274 µg/L ▪ 48 hr EC50 at 40 hardness ranged from 201-247 µg/L ▪ 96 hr EC50 at 40 hardness ranged from 158-183 µg/L ○ Powell River water at 160 hardness: ▪ 48 hr LC50 at 160 hardness ranged from 1060-1885 µg/L ▪ 96 hr LC50 at 160 hardness was 413 µg/L ▪ 48 hr EC50 at 160 hardness ranged from 664-1222 µg/L • Table 5: Zinc and juveniles of Villosa iris (rainbow) ○ Tap water at 50 hardness: ▪ 48 hr LC50 at 50 hardness was 339 µg/L ▪ 96 hr LC50 at 50 hardness ranged from 236-354 µg/L ▪ 48 hr EC50 at 50 hardness ranged from 229-298 µg/L ▪ 96 hr EC50 at 50 hardness ranged from 209-295 µg/L ○ Powell River water at 140 and 160 hardness: ▪ 96 hr LC50 at 140 hardness ranged from 418-877 µg/L ▪ 48 hr EC50 at 140 hardness ranged from 498-827 µg/L ▪ 96 hr EC50 at 140 hardness ranged from 288-530 µg/L ▪ 48 hr LC50 at 160 hardness was 1122 µg/L ▪ 48 hr EC50 at 160 hardness was 1026 µg/L • Glochidia and juveniles of the species tested in this paper exhibited about the same sensitivity as those ranked as the 6 most sensitive species used by EPA to determine Zn WQC.	
EPA's Conclusions: Given the numerous combinations of hardness tested, the EPA selected the most stringent 24 hr, 48 hr, and 96 hr LC50 results, or 392 µg/L (at a hardness of 50), 201 µg/L (at a hardness of 40), and 158 µg/L (at a hardness of 40), respectively. The most stringent of the three results was the 158 µg/L concentration at 40 hardness. Therefore, EPA compared the state's criterion at 40 hardness (54 µg/L) to the most stringent LC50 documented in the study. The most stringent toxicity level is ~3 times greater than the comparable acute criterion adopted by the state.			

Since a lot of the data represents testing at higher hardness values as well, the values associated with a hardness of 160 were also considered. At a hardness of 160, the State's criterion would be 175 µg/L. Results of the most stringent 24 hr glochidia, 48 hr glochidia and juvenile, and 96 hr juvenile tests at a hardness of 160 were: 423 µg/L (glochidia), 665 µg/L (glochidia) and 664 µg/L (juvenile), 413 µg/L (juvenile), with the values representing approximately 2.4, 3.8, and 2.4 times the comparable State's criterion at hardness of 160.			
Myers-Minzie, M. L. (1998).	204	• Of metals tested, copper (48 hr LC50 0.113 mg/L) was more toxic than zinc (48 hr LC50 0.463 mg/L). ○ 24 hr LC50s were higher concentrations: 0.159mg/L (copper) and 0.599 mg/L (zinc) • Previous studies of zinc toxicity to juveniles were summarized: 48 hr LC50s ranged from 588 to 1186 and 96 hr LC50s ranged from 364 to 578 (all values in µg/L, varying hardness) • For the water hardness of 204 mg/L in the present study, the calculated acute water quality for copper would be 35 µg/L and 214 µg/L for zinc. • The mean 48 hr LC50 for copper was 105 µg/L and for zinc 463 µg/L. Both of these values are considerably greater than EPA criteria, indicating these standards are probably protective of juvenile mussels.	Acute at 200: 211
EPA's Conclusions: Comparing the 48 hr LC50 of 463 µg/L to the comparable State equivalent of 211 µg/L, results in a value that is approximately 2 times the acute criterion adopted by the state.			
Pynnönen, K. (1995). *[Note: Originally included in cadmium reference list but included here since study addressed zinc also. See cadmium record papers for more information.]*	moderately hard water (35 mg/L Ca/L)	Did Not Use Study Due to inability to determine LC50, this paper is not directly helpful to BE effort. • Maternal pre-exposure at low metal concentrations often increased resistance of gloc to metals, but exposure to higher concentrations decreased resistance. Order to toxicity: Cu>Cd>Zn • Due to inability to determine LC50, this paper is not directly helpful to BE effort.	n/a
EPA's Conclusions: Did not use study due to lack of LC50 or other lethality related information.			
Wang, N., Ingersoll, C. G., Ivey, C. D., Hardesty, D. K., May, T. W., Augspurger, T., Roberts, A. D., van Genderen, E., and Barnhart, M. C. (2010).	reconstituted soft water (hardness 40-48mg/L)	• 24 hr EC50 for 2 hr old fatmucket gloc: >200 to 2,685 µg/L Zn, 96 hr EC50 for fatmucket 2 and 6 month juvenile: >471 and 1,700 µg/L Zn, 96 hr EC50 for newly transformed (5 day) fatmucket 151 and 175 µg/L Zn and Neosho mucket 145 µg/L Zn • 28 day chronic values for fat mucket was 66 µg/L Zn from ACR 2.5 and EC50 of 163 • EC50s for survival of juvenile fatmucket : >415 and >450 µg//L(4 day), >415 and >450 µg/L(10 day), >415 and >450 µg/L(21 day), and 228 and 333 (28 day)	Acute at 25/50: 36/65 Chronic at 25/50: 37/66

<table>
<tr>
<td>[Note: Originally included in cadmium reference list but included here since study addressed zinc also. See cadmium record papers for more information.]</td>
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When mussel data from this study was added to EPA's database, mussel GMAVs were in the lower percentiles of the sensitivity distribution of all freshwater mussels for Zn (12th to 21st percentile). The mussel lampsilis GMCV were middle of sensitivity for Zn (44th percentile). Therefore, mussels relatively sensitive to acute toxicity of Pb and chronic toxicity of Pb.
The ASTM reconstituted soft water (hardness 40-48mg/L) was used as test water to represent the lower range of water hardness of the Ozark Plateau.
Survival % for Zinc after 28 day test:

Concentration 3.1 µg/L: 100 % survival
Concentration 21 µg/L: 100 % survival
Concentration 45 µg/L: 100 % survival
Concentration 87 µg/L: 100 % survival
Concentration 179 µg/L: 76 % survival
Concentration 415 µg/L: 40 % survival

Other info for 28 day test:

NOEC = 87µg/L
LOEC = 179µg/L

The results indicate that the current EPA acute and chronic WQC are protective of the tested freshwater mussels from Pb or Cd exposure, but may not be adequately protective for Zn exposure. Paper discusses BLM for Zn.
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<tr>
<td colspan="4">EPA's Conclusions: When comparing the criteria against the most stringent acute toxicity result of 145 µg/L (5 day 96 hr EC50 for the Neosho mucket), the acute toxicity results were 4 and 2 times greater than the state's adopted acute values at a hardness of 25 and 50 respectively. When comparing to the chronic criterion equivalents at 25 and 50 hardness, the chronic NOEC of 87 µg/L would be 2.3 and 1.3 times greater than the chronic criteria.</td>
</tr>
<tr>
<td colspan="4">Fish Specific Information</td>
</tr>
<tr>
<td>Besser, J., Mebane, C., Mount, D., Ivey, C., Kunz, J., Greer, E., May, T., and Ingersoll, C. (2007). [Note: Originally included in cadmium reference list but included here since study addressed zinc also. See cadmium record papers for more information.]</td>
<td>100</td>
<td>

Table summary of all values, WQC calculated at 100 hardness

<table>
<tr><td></td><td>MN sculpin</td><td>MO sculpin</td><td>Sculpin Species</td><td>Rainbow Trout</td><td>WQC</td></tr>
<tr><td>Zinc</td><td colspan="5"></td></tr>
<tr><td>Acute LC50</td><td>107</td><td>245</td><td>162</td><td>290</td><td>118</td></tr>
</table>
</td>
<td>Acute at 100: 117

Chronic at 100: 118</td>
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Chronic Value	75	219	128	219	117		

- Paper also discusses sensitivity relative to other taxa including comparison to mean tox values from WQC documents. Generally these species were close to most sensitive taxa
- Results of study indicate WQC may be protective for rainbow trout but not mottled sculpins. For rainbow trout, all acute LC50s were at least two times greater than the acute WQC and all chronic values were greater than chronic WQC. Using BLM based copper criteria made the criteria protective of sculpins. Cadmium and zinc WQC provided marginal protection for sculpins.

EPA's Conclusions: When comparing the most stringent acute LC50 from the summarized table of values (107 for the Minnesota sculpin) to the acute criteria at 100 hardness, the toxicity concentration is about 91% of the value adopted by the State. Similarly, when comparing the chronic criterion at 100 hardness, to the most stringent chronic value (75 for the Minnesota sculpin), the toxicity concentration is about 64% of the value adopted by the state. When compared to the least stringent acute and chronic values (290 and 219), the toxicity based values are ~2.5 times and 2 times the values adopted by the state.

Vardy, D.W., Santore, R., Ryan, A., Giesy, J.P., Hecker, M. (2014).

[Note: Originally included in copper reference list but included here since study addressed zinc also. See copper record papers for more information.]

72-76 mg/L

- Study reports results for 96hr tox tests for copper, cadmium, zinc, and lead from parallel studies that were conducted in laboratory water and in the field with Columbia River water.
- Zinc

	8dph lab/8dph site
Hardness	76/72
LC50	150/625
LC50 BLM normalized to site water	130/na
LC50 BLM normalized to ref water	100/945
EPA WQC based on ref water	102/na

- In current study, LC50s for white sturgeon exposed to lead in lab water were significantly less than average LC50s for rainbow trout and less than or equal to cutthroat trout. However, for cadmium, an opposite trend was observed whereby early life state white sturgeon exposed to cadmium in lab water were less sensitive than rainbow trout, bull trout, cutthroat trout, shorthead sculpins, and mottled sculpins, all of which exhibited LC50s that ranged between 1.7 µg/L and 3.5 µg/L. Thresholds for mortality to zinc were more consistent with rainbow, bull, and mottled sculpins (range between 114 and 251 µg/L) and approximately three times less than those of cutthroat trout and shorthead sculpins (494 and 528 µg/L respectively).

Acute at 50/100: 65/117

		• Sensitivity of early life stage white sturgeon to copper, cadmium, zinc, and lead appears to be more variable under acute exposures in comparison to trout and sculpins. • LC50s were greater than EPA recommendations for 8dph but bordered criteria for 40dph life stage • Further investigation warranted into site specific considerations….WERs were consistently >1 indicating metals were less toxic to white sturgeon exposed to site water than laboratory water.	
EPA's Conclusions: For the 8dph life stage of white sturgeon, the lab water based testing resulted in LC50s of 100-150 µg/L (with the lower values reflecting BLM normalized results and the upper end of the range reflecting the traditional LC50). For the 8dph life stage of white sturgeon, the site water based testing resulted in LC50s of 625-945 µg/L (with the lower value reflecting the traditional LC50 and the higher value reflecting a BLM normalized result). In comparing the State's criteria at 50 and 100 hardness, the most stringent LC50 for lab water (100 µg/L) was ~1.5 times greater than and ~85% of the acute criterion, respectively. In comparing the State's criteria at 50 and 100 hardness, the most stringent LC50s for site water (625 µg/L) was ~5-9.5 times greater than the acute criterion.			
Vardy, D.W., Tompsett, A.R., Sigurdson, J.L., Doering, J.A., Zhang, X., Giesy, J.P., Hecker, M. (2011). *[Note: Originally included in copper reference list but included here since study addressed zinc also. See copper record papers for more information.]*	65-70 mg/L	• The study conducted to establish baseline toxicity data for the subchronic exposure of early life stages of white sturgeon to copper, cadmium, and zinc that can be used in metal-related risk assessment. Embryos, larvae, and fry were exposed to increasing concentrations of dissolved copper, cadmium, and zinc for 66 days using laboratory-based flow-through exposure systems. • Chronic lethal concentrations at which 20% mortality occurred (LC20s) for cadmium (1.5 µg/L), copper (5.5 µg/L), and zinc (112 µg/L) obtained for white sturgeon in present study were comparable to those of sensitive salmonid species. Based on LC20 values for 19 dph and 58dph white sturgeon, the US recommended criteria established for these three parameters protect white sturgeon early life stages. • Target hardness of 65 to 70 mg/L and DOC 2 to 3 mg/L (average hardness 70±9.8) • For copper, cadmium, and zinc: Exposure of early life stages of white sturgeon resulted in concentration-dependent mortalities. Statistically significant greater mortalities relative to the reference group occurred at the two greatest concentrations of copper (36&217), cadmium (8.3&69), and zinc (198&1214). • LC20s Measured concentrations at: 19 dph 58 dph ○ Zinc 102 µg/L 112 µg/L • LC50s Measured concentrations at: 19 dph 58 dph CCC	Chronic at 50/100: 66/118

		○ Zinc 340 µg/L 250 µg/L 87 • Early life stages of white sturgeon appear to be relatively sensitive to copper, cadmium, and zinc relative to other aquatic species. The most sensitive LC20s determined in the present study were compared with chronic values outlined in EPA's chronic toxicity to freshwater organisms dataset in each metal's ambient WQC document. The LC20s (after adjustment to comparable hardness) were almost always within a factor of two of the chronic value of the most sensitive fish species. • Based on the LC values, the US criteria are protective of white sturgeon early life stages for cadmium, copper, and zinc. • Further investigation is needed for sediment exposure potential.	
EPA's Conclusions: While the overall conclusion of the study was that the current EPA criteria are protective of various early life stages of the white sturgeon, for comparison, a comparison of the most stringent value of 102 µg/L (the LC20 at 19 dph) to the State's chronic criterion at 50-100 hardness corresponds to a toxicity value of ~1.5 times greater than and 86% of the state's adopted chronic criterion.			
Calfee, R.D. et al. (2014). *[Note: Also included in copper and cadmium reference lists but included here since study addressed zinc also. See copper and cadmium record papers for more information.]*	100 mg/L	• The study was done to assess the acute sensitivity of white sturgeon and rainbow trout to copper, cadmium, and zinc. • In this study, rainbow trout are more sensitive to cadmium than white sturgeon across all life stages.	Acute at 100: 117 µg/L

White Sturgeon *(Acipenser transmontanus)*		**Rainbow Trout** *(Oncorhynchus mykiss)*	
Life Stage (dph)	**LC50 (µg/L)**	**Life Stage (dph)**	**LC50 (µg/L)**
2	>634	1	>571
16	>1575	18	253.2
30	3109	32	448.9
44	>2610	46	282
61	<253	60	268.5
72	<391	74	345.9
89	<9330	95	227.9

EPA's Conclusions: For the 61 dph life stage of white sturgeon (most sensitive), the lab water based testing resulted in LC50s of less than 253 µg/L. It is difficult to make a quantitative comparison to the State's criteria at 100 hardness, given that the value is <253 µg/L and not an exact value. The criteria at 100 hardness is 117 µg/L.

However, for the 95 dph rainbow trout (most sensitive stage), the lab water based testing resulted in an LC50 of 227.9 µg/L. In comparing to the State's criteria at 100 hardness (same as the laboratory study), the most stringent LC50 for lab water (227.9) was 1.94 times greater than the acute zinc criterion.

Wang et al. (2014)

[Note: Also included in cadmium, copper and lead reference lists.]

100 mg/L

- The objective of the study was to evaluate the chronic toxicity of copper, cadmium, lead, or zinc to early life stages of white sturgeon in water-only exposures.
- Toxicity texts were also conducted with rainbow trout under similar test conditions to determine the relative sensitivity difference between white sturgeon and rainbow trout.

			EC20 (µg/L)			
	Exposures	**Age at initiation (dph)**	**Survival**	**Length**	**Dry weight**	**Biomass**
White Sturgeon	C1/CC 0-14d	2	>369	-	-	-
	C1/CC 0-25d	2	NR	-	-	-
	CC 0-53d	2	NR	332	99	NR
	C2 0-28d	27	248	356	239	203
Rainbow Trout	C1 0-21d	1	>753	>753	>753	>753
	CC 0-52d	1	>755	>755	>755	>755
	C2 0-28d	26	169	>755	>755	201

Chronic at 100 mg/L: 117 µg/L

EPA's Conclusions: For white sturgeon, the most sensitive chronic test resulted in an EC20 that is 1.72 times the State's chronic zinc criteria. The other chronic endpoints resulted in EC20s that are 2 times to greater than 3 times the State's chronic zinc criteria.

For rainbow trout, the most sensitive chronic test resulted in an EC20 that is 1.48 times the State's chronic zinc criteria. The other chronic end points resulted in EC20s that are 1.7 to greater than 6 times the State's chronic zinc criteria.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

MAY 26 2016

Ms. Cathy Tortorici
Chief, ESA Interagency Cooperation Division
Office of Protected Resources
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
1315 East-West Highway
Silver Spring, Maryland 20910

Subject: Transmittal of the Endangered Species Act Section 7(a) Biological Evaluation for the EPA's Clean Water Act, Section 303(c) Approval Action for North Carolina's Triennial Review of the State's Water Quality Standards

Dear Ms. Tortorici:

The U.S. Environmental Protection Agency is obligated under Section 7(a)(2) of the Endangered Species Act (ESA), 16 U.S.C. § 1536(a)(2) to insure that any action it approves is not likely to jeopardize the continued existence of any threatened or endangered species or result in the destruction or adverse modification of critical habitat. The EPA therefore requests that the National Marine Fisheries Service (Service) review the enclosed biological evaluation (BE) for the EPA's approval of revisions to specific provisions of the State of North Carolina's Water Quality Standards (WQS), pursuant to Section 303(c) of the Clean Water Act, 33 U.S.C. § 1313(c).

These revisions are described in the enclosed BE, as are the EPA's effect determinations for threatened and endangered species in North Carolina. The EPA is submitting this request under the informal consultation provision of the ESA regulations at 50 C.F.R. § 402.13, and has made determinations of "no effect" or "may effect, but not likely to adversely affect" for all aquatic and aquatic-dependent species within statewide waters as detailed within the enclosed BE. The EPA reviewed and approved the new and revised WQS for the State of North Carolina on April 6, 2016. Enclosed please find a copy of our final decision document that provides the technical rationale for EPA's CWA 303(c) approval or disapproval for each revision to WQS.

The Memorandum of Agreement signed by the Service and the EPA regarding enhanced coordination under the CWA and ESA, provision V.B.6., requests that the EPA notify the Service in writing when making a "may effect, not likely to adversely affect" determination. Additionally, the Service will respond in writing within 30 days of receipt of such a determination, unless extended by mutual agreement. The response will state whether the Service concurs or does not concur. If the Service does not concur, it will provide a written explanation that includes the species of concern, the perceived adverse effects, supporting information, and a basic rationale. 66 Fed. Reg. 11,202-11,210 (Feb. 22, 2001).

Please contact Ms. Cecelia Harper at (404) 562-9418 or harper.cecelia@epa.gov should you have questions regarding the enclosed BE.

Sincerely,

Joanne Benante

Joanne Benante, Chief
Water Quality Planning Branch

Enclosure

cc: Ms. Pat Allen-Shaw, NMFS, Ph.D., Silver Spring, MD (electronic only)
Ms. Harriet Nash, NMFS, Ph.D., Silver Spring, MD (electronic only)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
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MAY 26 2016

Mr. Pete Benjamin
Field Office Supervisor
U.S. Fish and Wildlife Service
Raleigh Field Office
P.O. Box 33726
Raleigh, North Carolina 27636-3726

Subject: Transmittal of the Endangered Species Act Section 7(a) Biological Evaluation for the EPA's Clean Water Act, Section 303(c) Approval Action for North Carolina's Triennial Review of the State's Water Quality Standards

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Please contact Ms. Cecelia Harper at (404) 562-9418 or harper.cecelia@epa.gov should you have questions regarding the enclosed BE.

Sincerely,

Joanne Benante

Joanne Benante, Chief
Water Quality Planning Branch

Enclosure

cc: Mr. Bryan Tompkins, FWS, Asheville, NC (electronic only)
Mr. Tom Augspurger, FWS, Raleigh, NC (electronic only)
Mr. Jerry Ziewitz, FWS, Tallahassee, FL (electronic only)
Mr. Leopoldo Miranda, FWS, Atlanta, GA (electronic only)

BIOLOGICAL EVALUATION FOR THE ENDANGERED SPECIES ACT SECTION 7 CONSULTATION FOR NORTH CAROLINA'S WATER QUALITY STANDARDS REVISIONS FOR THE U.S. NATIONAL MARINE FISHERIES SERVICE

Prepared by EPA Region 4

May 2016

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Overview

The focus of this Biological Evaluation (BE) is the effects which may occur to threatened and endangered species and/or designated critical habitat from the revisions to water quality standards (WQS) contained in North Carolina's 2007-2014 Triennial Review as approved by the U.S. Environmental Protection Agency (EPA) on April 6, 2016, pursuant to section 303(c) of the Clean Water Act (CWA). The majority of the changes to the State's rule language, incorporate updated scientific information pertaining to metals criteria for fresh and salt waters. Other revisions are generically related to the application and implementation of North Carolina's water quality standards and will be addressed in this BE as needed, based on the EPA's effects determinations for those provisions. A detailed analysis of the EPA's technical basis for the CWA section 303(c) action can be found in Attachment D.

Description of Federal Action:

Under section 303(c) of the CWA and 40 CFR § 131, States and authorized tribes have primary responsibility to develop and adopt WQS to protect their waters. As required by section 303(c) of the CWA and 40 CFR § 131, the EPA reviews new and revised WQS that have been adopted by States and authorized tribes. State and Tribal WQS are not considered effective under the CWA until approved by the EPA.

The Federal action being evaluated is the EPA approval of several revised WQS rule provisions as it relates to the protection of aquatic life use as set forth in the North Carolina Department of Environmental Quality, Rule 15A NCAC 02B.

Section 303(c)(3) of the CWA states in part: If the Administrator, within sixty days after the date of submission of the revised or new standard, determines that such standard meets the requirements of this Act, such standard shall thereafter be the water quality standard for the applicable waters of the State…

A. History of ESA Consultation for this CWA Action

Section 7(a)(2) of the Endangered Species Act (ESA) requires the EPA, in consultation with the U.S. Fish and Wildlife Service (FWS) and/or the National Marine Fisheries Service (NMFS), to ensure that any action authorized by the agency is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of designated critical habitat for such species. As provided in the Memorandum of Agreement between the EPA, the FWS, and the NMFS regarding enhanced coordination of CWA and ESA obligations, the EPA uses a BE to analyze whether a new or revised water quality standard may affect federally-listed species or designated critical habitat. This BE has been prepared to determine whether the EPA's approval of specific aspects of North Carolina's surface water quality standards may affect federally listed endangered or threatened species or the designated critical habitat of such species. If the EPA determines that approval may affect listed species or critical habitat but is not likely to adversely affect listed species or habitat, then formal consultation with the FWS is not required if the EPA obtains concurrence on the "may effect, not likely to adversely affect" finding from the FWS.

The EPA carried out early coordination and initiated consultation with the NMFS for this change to WQS on February 2, 2015, through informal conversations with several NMFS staff regarding the species location and critical habitat within state waters. On March 9, 2015, through a written request for technical assistance, the EPA requested verification of the current species list. On March 31, 2015, in an email from Karla Reece, NMFS, to Lauren Petter, EPA Region 4, the NMFS confirmed the species list provided on March 9, 2015, as accurate for North Carolina waters. Prior to the completion of the EPA's action to approve the above referenced rules, the EPA coordinated with staff located at the NMFS Headquarters office via conference calls to further discuss the EPA's review of the revision to North Carolina's WQS and subsequent analyses in support of the interim BE. On January 6, 2016, Karla Reece, confirmed in an email to Cecelia Harper, EPA, that there were no changes to the species list verified in March 2015. Finally, the EPA completed an ESA section 7(d) memo "To the File" with a supporting interim BE dated March 15, 2016 in anticipation of the EPA 303(c) decision document being signed. Lastly, in an email dated March 30, 2016, the FWS confirmed that there were no additional proposed or listed species to add to this final BE. Lastly, in an email dated April 1, 2016, the NMFS confirmed that there were no additional proposed or listed species to add to this final BE.

B. Overview of Water Quality Standards

The CWA provides the statutory basis for the water quality standards program and defines broad water quality goals.

Section 101(a)(2) of the CWA sets out a national goal that wherever attainable, waters achieve a level of quality that provides for the protection and propagation of fish, shellfish, and wildlife, and for recreation in and on the water ("fishable/swimmable"). Section 303(c) of the CWA requires that all states adopt water quality standards and that the EPA review and approve these standards. In addition to adopting water quality standards, states are required to review those standards every three years and to then revise the standards, as necessary. This public process, commonly referred to as the triennial review, allows for new technical and scientific data to be considered in order to update the standards. The regulatory requirements governing water quality standards are established at 40 CFR § 131.

The purpose of the CWA, 33 U.S.C.S. § 1251(a), is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. Consistent with the CWA, as part of their water quality standards, states must designate the uses for which their waters are to be protected, such as fishing and swimming, and identify water quality criteria to protect the uses for pollutants that could reasonably be expected to interfere with the designated uses. In addition, states' water quality standards must include an antidegradation policy and implementation procedures that are consistent with the EPA's policy to protect existing uses, high quality waters, and water quality in waters identified by the state as outstanding national resource waters. Id. § 1313(c)(2)(A) (Supp. 1993); 40 C.F.R. § 131. Under section 303 of the CWA, states must submit new and revised water quality standards to the EPA for review and approval. When a state submits its water quality standards to EPA for review, the standards must include: (1) the designated uses for each body of water; (2) what methods were used and analyses conducted to support the revisions to state water quality standards; (3) water quality criteria, which protect the designated uses for each water body and which may be

expressed as either a narrative standard or a numeric concentration level; and (4) an antidegradation policy to protect existing uses of bodies of water and high-quality waters. 40 C.F.R. §§ 131.3(i), 131.3, 131.6, 2131.12.

Description of Specific Provisions Considered by the EPA for the Endangered Species Act (ESA) Section 7 Consultation

15A NCAC 02B .0206 Flow Design for Effluent Limitations

The majority of the revisions to 15A NCAC 02B .0206 were editorial in nature and are shown in their entirety in Attachment A. The EPA has determined that such editorial changes will have No Effect on listed species or their critical habitat. With regard to 15A NCAC 02B .0206, the EPA will only be consulting on the addition of a 1Q10 flow for protection of aquatic life from acute toxicity.

15A NCAC 02B .0211 Fresh Surface Water Quality Standards for Class C Waters

Many of the revisions to 15A NCAC 02B .0211 were editorial in nature and are shown in their entirety in Attachment A. The EPA has determined that such editorial changes will have No Effect on listed species or their critical habitat. With regard to 15A NCAC 02B .0211, the EPA will be consulting on the addition of acute and revised chronic values for the following non-hardness dependent metals: arsenic, beryllium, and chromium VI; the revision of the chronic silver criterion; the equations associated with hardness based equations for the following acute and chronic metals: cadmium, chromium III, copper, lead, nickel, and zinc; the equations associated with hardness based equations for an acute trout water specific cadmium and an acute silver criterion; and the incorporation of provisions pertaining to the use of Water Effects Ratios, Recalculation Procedure, and Resident Species Procedure for all metals and the Biotic Ligand Model (BLM) for copper.

15A NCAC 02B .0212-.0218 Fresh Surface WQS for Class WS-1 Through WS-V Waters

The revisions to 15A NCAC 02B .0212, .0214, .0215, .0216, and .0218 (pertaining to Class Water Supply I, II, III, IV, and V designations) were primarily editorial in nature and are shown in their entirety in Attachment A. The EPA has determined that editorial changes will have No Effect on listed species or their critical habitat and changes which are human health related are considered to be No Discretion. This is because the EPA's discretion to act on a State submission, is limited to determining whether the criteria ensure the protection of designated uses upon which the criteria are based. The EPA has no discretion to revise an otherwise approvable human health criteria to benefit listed species.

15A NCAC 02B .0220 Tidal Salt Water Quality Standards for Class SC

The majority of the revisions to 15A NCAC 02B .0220 were editorial in nature and are shown in their entirety in Attachment A. The EPA has determined that such editorial changes will have No Effect on listed species or their critical habitat. With regard to non-editorial changes within 15A NCAC 02B .0220, the EPA will be consulting on the addition of acute and revised chronic values for arsenic, cadmium, copper, lead, nickel, silver, and zinc; the addition of acute and chronic values for chromium VI; and the incorporation of provisions pertaining to the use of Water Effects Ratios, Recalculation Procedure, and Resident Species Procedure for all metals.

Description of the Geographic Area That May Be Affected by the Action

The action area for this BE includes all salt waters within the State of North Carolina to which these criteria apply, except where noted otherwise to address the portion of the Atlantic and shortnose sturgeon lifecycles that occur in fresh water. The relevant species that occur in fresh waters which are under the jurisdiction of the FWS will be addressed in a BE for to FWS.

Summary of Species Present in North Carolina

Table 1 provides a list of all threatened and endangered species located in the State of North Carolina under the jurisdiction of the NMFS, information on species' specific designated critical habitats (where applicable), species current status, and the EPA's final ESA section 7 determination of no effect or may affect, not likely to adversely affect (NLAA) with either discountable or insignificant effects.

Table 1. Threatened and Endangered Species Under the Jurisdiction of National Marine Fisheries Service.

	Scientific Name	Status	ESA Determination
Marine Mammals			
blue whale	*Balaenoptera musculus*	Endangered	May affect, NLAA-discountable
finback whale	*Balaenoptera physalus*	Endangered	May affect, NLAA-discountable
humpback whale	*Megaptera novaeangliae*	Endangered	May affect, NLAA-discountable
North Atlantic right whale	*Eubalaena glacialis*	Endangered	May affect, NLAA-discountable
sei whale	*Balaenoptera borealis*	Endangered	May affect, NLAA-discountable
sperm whale	*Physeter macrocephalus*	Endangered	May affect, NLAA-discountable
Turtles			
green sea turtle	*Chelonia mydas*	Threatened[1]	May affect, NLAA-discountable
hawksbill sea turtle	*Eretmochelys imbricata*	Endangered	May affect, NLAA-discountable
Kemp's ridley sea turtle	*Lepidochelys kempii*	Endangered	May affect, NLAA-discountable
leatherback sea turtle	*Dermochelys coriacea*	Endangered	May affect, NLAA-discountable
loggerhead sea turtle	*Caretta caretta*	Threatened[2]	May affect, NLAA-discountable
The Critical Habitat Primary Constituent Elements for Loggerhead are: Nearshore Reproductive Habitat • Nearshore waters directly off the highest density nesting beaches and their adjacent beaches as identified in 50 C.F.R. § 17.95(c) to 1.6 km (1 mile) offshore; • Waters sufficiently free of obstructions or artificial lighting to allow transit through the surf zone and outward toward open water.			

• Waters with minimal manmade structures that could promote predators (i.e., nearshore predator concentration caused by submerged and emergent offshore structures), disrupt wave patterns necessary for orientation, and/or create excessive longshore currents. Winter Habitat • Water temperatures above 10° C from • November through April; • Continental shelf waters in proximity to the western boundary of the Gulf Stream; and • Water depths between 20 and 100 m. Breeding Habitat • High densities of reproductive male and female loggerheads; • Proximity to primary Florida migratory corridor; and • Proximity to Florida nesting grounds. Migratory Habitat • Constricted continental shelf area relative to nearby continental shelf waters that concentrate migratory pathways; and • Passage conditions to allow for migration to and from nesting, breeding, and/or foraging areas. Sargassum Habitat • Convergence zones, surface-water downwelling areas, the margins of major boundary currents (Gulf Stream), and other locations where there are concentrated components of the Sargassum community in water temperatures suitable for the optimal growth of Sargassum and inhabitance of loggerheads; • Sargassum in concentrations that support adequate prey abundance and cover; • Available prey and other material associated with Sargassum habitat including, but not limited to, plants and cyanobacteria and animals native to the Sargassum community such as hydroids and copepods; and • Sufficient water depth and proximity to available currents to ensure offshore transport (out of the surf zone), and foraging and cover requirements by Sargassum for post-hatchling loggerheads, i.e., >10 m depth.			
Fish			
Atlantic sturgeon	*Acipenser oxyrhynchus oxyrhynchus*	Endangered[3]	
shortnose sturgeon	*Acipenser brevirostrum*	Endangered	

[1] Green turtles are listed as threatened, except for breeding populations of green turtles in Florida and on the Pacific Coast of Mexico, which are listed as endangered.
[2] Northwest Atlantic Ocean (NWA) Distinct Population Segment (DPS) was listed as threatened. NMFS and USFWS issued a final rule changing the listing of loggerhead sea turtles from a single, threatened species to nine DPSs listed as either threatened or endangered in 2012 (76 Fed. Reg. 58,868).
[3] NMFS listed two Atlantic sturgeon DPSs that spawn in the southeast (the Carolina and the South Atlantic) (77 Fed. Reg. 5919). There are an additional three Atlantic sturgeon DPSs in the northeast that spawn in the northeast (the Gulf of Maine, New York Bight, and Chesapeake) (77 Fed. Reg. 5,880). Depending on the project area, a combination of DPSs may be present, particularly in marine waters. Please see Federal Register Notices for additional information.

Species of Interest for ESA Consultation

According to the Endangered Species Consultation Handbook, in order for EPA to determine that a proposed action is a may affect, but NLAA action for threatened and endangered species or designated critical habitat, all of the effects of that action must be expected to be discountable, insignificant, or completely beneficial. Discountable effects are those that are extremely unlikely to occur and, based on best judgment, cannot be meaningfully measured, detected, or evaluated. Insignificant effects relate to the size of the impact and should never reach the scale where taking of a species (take) occurs. Beneficial effects are contemporaneous positive effects without any adverse effects to the species or designated critical habitat. As explained later in this document, the EPA concluded that the revisions to North Carolina's water quality standards will not have an adverse effect on any listed species or their designated critical habitats. Therefore, the EPA considered the three distinctions within the may affect, NLAA determination in its analysis of the State's revisions to their water quality standards. As detailed below, the EPA found that its action for each specific revision falls into one of the following categories: may affect, NLAA-discountable; may affect, NLAA-insignificant; or no effect.

In addition, according to the Draft Framework for Conducting Biological Evaluations of Aquatic Life Criteria Methods Manual, there are three different types of species: "aquatic" which have at least one of their life stages spent as a water-breathing organism or plants that are submerged or emergent; "aquatic dependent" which are not water-breathing organisms, but a meaningful amount of their diet includes aquatic organisms; and "terrestrial" which has only limited amount of exposure to "waters of the U.S.".

As a result of the EPA's consideration of the species specific information, there are some listed species that will not be the primary focus of this consultation as the EPA actions will have either no effect or a may affect, NLAA-discountable effect on these species.

- Revisions with no effect determination: Where the EPA has reviewed editorial and non-substantive changes as part of its CWA 303(c) action and approves those revisions, the EPA considers those revisions to have no effect on any of the listed species or their designated critical habitat and therefore are not covered further in this BE. For reference, a summary of these changes can be found at the end of this document, with all of the other conclusions described above.

- Revisions with may affect, NLAA-discountable effects determination: For several species, the EPA found that any effect to species relative to the revisions adopted by the State will be discountable.

    - With regard to four of the six whales identified in the table above, the EPA expects the State's revisions will have may affect, NLAA-discountable effects on these species (blue whale, finback whale, sei whale, and sperm whale) because they do not frequent shallow coastal waters.[1] With regard to the humpback whale and North Atlantic right whale, the EPA expects the State's revisions will have may affect, NLAA-discountable effects due to limited exposure to the metals through possible consumption of prey species and plants. Therefore, all six whale species were not considered further by the EPA in its evaluation because they will not be directly or indirectly affected to any significant

[1] Based on information contained in excerpts from the 2015 MSGP provided by Pat Shaw-Allen, Ecotoxicologist, NMFS.

degree by actions related to the approval of these new and revised water quality standards.

- Based on communications with Pat Shaw-Allen, NMFS, regarding the potential to exposure through dietary ingestion of salt water in addition to the ingestion of prey species. The EPA has concluded that the five listed turtles may be exposed to the parameters addressed by the State's new and revised water quality standards; however, the revisions would likely range between may affect, NLAA-discountable effects, due to limited exposure associated with spending much of the life span away from near shore sources of pollution to possible may affect, NLAA-insignificant effects due to limited exposure because of diluted concentrations of metals when ingesting water, prey, and plants. With only general information from the recovery plans indicating that certain parameters can be present in the tissue of the subject turtle species and a lack of additional information on specific toxicity results, the EPA concluded the effect of the revisions would be may affect, NLAA-discountable when considering the limited amount of time the turtle species spend near shore. Therefore, the five turtle species are not considered further by the EPA in its evaluation.

Therefore, the EPA focuses the remainder of its BE on the considerations of possible impacts to the two sturgeon species in North Carolina waters which have contact with salt water: the Atlantic sturgeon and shortnose sturgeon. For these two species, in addition to considering the revisions for salt water, the revisions for fresh water will also be considered since sturgeon spend time in both types of waters depending on their life stage. Additionally, based on conversations with Pat Shaw-Allen, NMFS, it was noted that exposure of contaminants from the sediment should also be taken into account when considering any potential to affect the Atlantic and shortnose sturgeon species. For these species, the EPA has determined that the effects, while not discountable, would still be insignificant and would not reach the scale where take occurs. To support this conclusion, additional analyses were completed related to known toxicity levels associated with exposures to certain parameters. To supplement the fresh water analysis further, additional information contained in the NMFS biological opinion (BO) for the adoption of salt water criteria in Oregon was considered. Prior to discussing those analyses, a short summary of the pertinent information about life history and habitat for the two sturgeon species, pulled from information on the Raleigh FWS Field Office and NatureServe websites, is given.

Life History and Habitat Summaries – Fish

Shortnose Sturgeon (*Acipenser brevirostrum*)

Status:
The status of the shortnose sturgeon (*Acipenser brevirostrum*) is endangered. The species was listed as endangered on March 11, 1967 (32 Fed. Reg. 4,001).

Location:
Shortnose sturgeon spawn in the coastal rivers along the east coast of North America from the St. John River in Canada to the St. Johns River in Florida. They prefer the nearshore marine, estuarine, and riverine habitat of large river systems. Shortnose sturgeon, unlike other anadromous species in the region such as shad or salmon, do not appear to make long distance offshore migrations. They are "benthic" feeders, eating crustaceans, mollusks, and insects. Data are lacking for the rivers of North Carolina.

Habitat and Diet:
Shortnose sturgeon are typically large, long-lived fish that inhabit a great diversity of riverine habitat, from the fast-moving freshwater riverine environment downstream and, for some species, into the offshore marine environment of the continental shelf.

Threats:
Decline was due mainly to damming, which cut off upriver spawning areas and altered stream flow and temperature, and water pollution. Habitat degradation remains a threat. Other factors in the decline include siltation, habitat disruption from dredging, and overharvest (Burkhead and Jenkins 1991). Additionally, the long life span and benthic predator life style predisposes the species to the effects of bioaccumulation of heavy metals, pesticides, polychlorinated aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs).

References (Accessed on May 11 and 12, 2015):
http://www.nmfs.noaa.gov/pr/species/fish/shortnosesturgeon.htm
http://explorer.natureserve.org/servlet/NatureServe

Atlantic Sturgeon (*Acipenser oxyrinchus*)

Status:
The status of the Atlantic sturgeon (*Acipenser oxyrinchus*) is endangered. The species was listed as endangered on March 11, 1967 (32 Fed. Reg. 4,001).

Location:
Historically, Atlantic sturgeon were present in approximately 38 rivers in the United States from St. Croix, Maine, to the Saint Johns River, Florida, of which 35 rivers have been confirmed to have had a historical spawning population. Atlantic sturgeon are currently present in approximately 32 of these rivers, and spawning occurs in at least 20 of them.

In a fact sheet for the Carolina Distinct Population Segment for the Atlantic Sturgeon, the numbers of Atlantic sturgeon in the Carolina distinct population segment are further described as extremely low compared to historic levels and have remained so for the past 100 years. The riverine spawning populations in the Carolina distinct population segment are estimated to be at less than three percent of their historic levels. Currently, the existing spawning populations in each of the rivers in the Carolina distinct population segment have less than 300 adults spawning each year.

Habitat and Diet:
Atlantic sturgeon are typically long-lived, estuarine dependent, anadromous fish. Spawning occurs in flowing water between the salt front and fall line of large rivers. They are "benthic" feeders and typically forage on crustaceans, worms, and mollusks.

Threats:
Threats include "bycatch" of sturgeon in fisheries targeting other species, habitat degradation and loss from various human activities such as dredging, dams, water withdrawals, and other development, as well as, habitat impediments including locks and dams (e.g., Cape Fear and Santee-Cooper Rivers).

References (Accessed on May 11 and 12, 2015):
http://www.nmfs.noaa.gov/pr/species/fish/atlanticsturgeon.htm
http://www.nmfs.noaa.gov/pr/pdfs/species/atlanticsturgeon_carolina_dps.pdf

Effects of the Action on Species of Interest for ESA Consultation

This section sets out the basis for the EPA's conclusions that the revisions to North Carolina water quality standards are not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of designated critical habitat. This is because the EPA has determined that this action will have may affect, NLAA-insignificant impacts on the above-described species. These conclusions presume any effects are small relative to the size of the impact and should never reach the scale where "take" to listed species occurs. Therefore, such conclusions would support may affect, NLAA determinations for the two sturgeon species, and any respective designated critical habitat, as listed in Table 1.

Non-Substantive Revisions or Detailed ESA Analysis Not Needed

Before proceeding with the main substance of the EPA's review of the revisions contained in 15A NCAC 02B .0211, Fresh Surface Water Quality Standards for Class C Waters, and 15A NCAC 02B .0220 Tidal Salt Surface Water Quality Standards for Class SC Waters, the following discussion documents the EPA's consultation considerations related to conclusions for all of the other revisions described above in the section titled "Description of Specific Provisions Considered by EPA for ESA Consultation," which the EPA considers to be non-substantive or not needing additional consideration with regard to this consultation, as further described below.

- With regard to the substantive revision in 15A NCAC 02B .0206, Flow Design for Effluent Limitations, the addition of a 1Q10 flow for protection of aquatic life from acute toxicity is a recommended and approvable revision by the EPA and is a method for determining design flows for calculating water quality based effluent limits for National Pollutant Discharge Elimination System permits. Since this provision did not exist in North Carolina's water quality standards prior to these revisions, these provisions do ultimately effect the species of interest for this ESA consultation. However, because this provision is intended to protect the designated uses of a waterbody including protection of aquatic life, the EPA concluded this revision may affect, NLAA – insignificant for any of the listed species or designated critical habitat in North Carolina. Further information regarding the technical basis for approving this provision can be found in Attachment D.

- Further detailed in the EPA's decision document at the beginning of the section titled "15A NCAC 02B .0211 Fresh Surface Water Quality Standards for Class C Waters General paragraph and Subparagraphs (1) through (9)"are a number of revisions which the EPA is approving but are considered non-substantive due to the nature of the revisions. Revisions that are considered non-substantive in this section include changes such as improving readability or adding introductory text, removing regulation sections which no longer exist, and reordering and renumbering due to alphabetizing. Such changes are articulated fully in the decision document and the EPA has concluded such revisions will have no effect on any of the listed species or designated critical habitat in North Carolina as they are editorial in nature and do not affect the applicable water quality criteria of the state.

- In the EPA's review of the state's revisions, the EPA is approving the removal of the action level for iron from 15A NCAC 02B .0211(22). In the absence of the action level, the State has indicated that designated uses will continue to be protected by the narrative criterion at 15A NCAC .0211(12), "[o]ils, deleterious substances, colored, or other wastes: only such amounts as shall not render the waters injurious to public health, secondary recreation, or to aquatic life and wildlife, or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated uses." The EPA's consideration for consultation is focused only on the removal of the action level for iron, as that is the only change subject to the EPA's current CWA 303(c) review, but the EPA does note that the narrative standard continues to provide an option for regulating anthropogenic sources of iron. The State provided information indicating that iron occurs at naturally high levels in the state, often above the numeric value of 1 mg/L (value of the action level that is being deleted), and the EPA's scientific review found the revision to be defensible. Since this provision is changing the applicable water quality standard from an action level of 1 mg/L to the narrative criterion that takes into account naturally high iron levels in the state, these provisions do ultimately effect the species of interest for this ESA consultation. However, since this provision will protect the designated uses of a waterbody including protection of indigenous aquatic life where naturally high iron levels are appropriate, the EPA concluded this revision is a may affect, NLAA-insignificant effect for listed species or their designated critical habitat. Further information regarding the technical basis for approving this provision can be found in Attachment D.

- As noted above, there are revisions to 15A NCAC 02B .0212-.0218, Fresh Surface WQS for Class WS-1 through WS-V Waters. The revisions are located in section (h) of each of the five water supply designated use classifications and remove the manganese numeric criterion and revise the 2, 4 Dichlorophenoxyacetic acid (2, 4 D) numeric criterion. Since both of these criteria are located within a designated use which is related to human uses, the EPA's concluded there is no discretion to consult further on these revisions. This is because the EPA's discretion to act on a State submission, is limited to determining whether the criteria ensure the protection of designated uses upon which the criteria are based. The EPA has no discretion to revise an otherwise approvable human health criteria to benefit listed species.

- Portions of 15A NCAC 02B .0212-.0218 were modified for clarification, grammar, and reorganization. Such changes are articulated fully in the decision document (Attachment D) and the EPA has concluded such revisions will have no effect on any of the listed species or designated critical habitat in North Carolina as they are editorial in nature and do not affect the applicable water quality criteria of the state.

- As further detailed in the EPA's decision document when discussing non-substantive changes for 15A NCAC 02B .0220 Tidal Salt Surface Water Quality Standards for Class SC Waters, there were a number of revisions which the EPA is approving but are considered non-substantive due to the nature of the revisions. Revisions that are considered non-substantive in this section include: changes such as improving readability or adding introductory text, and renumbering due to alphabetizing. Such changes are articulated fully in the decision document and the EPA has concluded such revisions will have no effect on any of the listed species or their designated critical habitat in North Carolina as they are editorial in nature and do not affect the applicable water quality criteria of the state.

Research Strategy to Supplement Existing Data/Literature for Remaining Provisions

As part of the informal ESA consultation, Tom Augspurger with the FWS, Raleigh, North Carolina Field Office provided a data research strategy on June 9, 2015, with regard to the species which are present in fresh waters, to which the EPA agreed. The strategy defined the approach in which the agencies could work together to request and obtain the best scientific and commercial data available for use in this consultation.

The first step was to complete database retrievals, which was coordinated with EPA Headquarters regarding available data sets compiled as part of the EPA's development of recommended ambient water quality criteria (AWQC). Discussions with Wade Lehmann (EPA HQ) regarding available databases/datasets relating to AWQC, concluded that chromium III, chromium VI, and copper were most recently addressed in the BE of Oregon's Water Quality Criteria for Toxics dated January 2008, data for arsenic, cadmium, copper could be obtained from the Idaho Water Quality Standards for Toxic Substances Biological Opinion (BO) prepared by the NMFS dated May 2014, and data for cadmium was obtained from the California Toxics Rule (CTR) BO. There was no recent data updates for beryllium, lead, nickel, silver or zinc. More recent work at EPA Headquarters is in progress for cadmium and copper, but is not yet complete.

The EPA considered the suggested BE and BO developed as part of the EPA actions in other regions relating to the same criteria adopted by North Carolina, with the assumption that they reflected a more recent compilation of relevant best available scientific data for the toxics that this consultation addresses. In reviewing these historical documents, it became clear that, while they contained a great amount of useful information, the results may not be completely transferable, in the absence of other supplementary information, for reasons detailed later in the EPA's analysis.

In addition, the EPA asked EPA Headquarters and other regional offices for any recent data synthesis efforts or other consultations. The result of the EPA's inquiries generally pointed back to the existing BE and BO that had been completed for specific consultations. Also, due to the concurrent consultation effort with NMFS, the EPA also inquired and received more information related to existing BOs and other data sources. Similarly, the FWS contacted other sources of potential information (such as other regional FWS offices, ORD labs, science centers, etc.) that might have additional data to aid in the consultation effort. In response to part of the FWS's efforts in this step, Tom Augspurger provided the EPA staff with an extensive amount of journal articles for five of the subject parameters: cadmium, copper, lead, nickel, and zinc, based on files already available for his use and information others provided to supplement those files.

After reviewing the articles Mr. Augspurger provided, the EPA determined many of these papers provided information that could be used as a supplement to the existing BE and BO, and therefore, serve to address gaps that may exist had the EPA solely relied on the results of the existing BE and BO.

A third component of the strategy included asking numerous metals industry groups what was available in their databases. Mr. Augspurger provided the files he received to the EPA and they were evaluated to determine if they could supplement the existing data set.

Finally, the EPA Region 4 staff completed an advanced database query of the ECOTOXicology database (ECOTOX) which is a source for locating single chemical toxicity data for aquatic life, terrestrial plants and wildlife. ECOTOX was created and is maintained by the U.S. EPA, Office of

Research and Development and the National Health and Environmental Effects Research Laboratory's Mid-Continent Ecology Division. ECOTOX integrates three previously independent databases - AQUIRE, PHYTOTOX, and TERRETOX - into a unique system which includes toxicity data derived predominately from the peer-reviewed literature, for aquatic life, terrestrial plants, and terrestrial wildlife, respectively. An advanced database query was completed for each chemical using the predefined chemical groups search key to ensure all metal compounds were included. Other search parameters were defined as follows:

Taxonomic Selection

Genus/Species Name(s) to be searched on:
Acipenser brevirostrum – Shortnose sturgeon
Acipenser oxyrhynchus – Atlantic sturgeon

Test Results Selection

Endpoint(s) to be searched on :
Concentration Based Endpoint(s):
LC/LD xx (all % values)
LC50
LD50

EC/ED xx (all % values)
EC50/ED50

LOEC/LOEL
NOEC/NOEL

Effect Measurement(s) to be searched on :
Behavior Group
Avoidance
Behavior
Feeding Behavior

Growth Group
Developmental
Growth
Morphological

Reproduction Group
Reproduction
Avian/Reptilian Egg

Test Conditions Selection
Test Location(s) to be searched on :
All Field Tests
Field, Artificial
Field, Natural
Field, Undeterminable
Lab

Exposure Media to be searched on :
Water - Fresh Water
Water - Salt Water

Exposure Type(s) to be searched on :

Environmental
Flow-through
Lentic
Lotic
Renewal
Static
Tidal

Control Type(s) to be searched on :
Baseline(B)
Concurrent(C)
Historical(H)

Chemical Analysis Method(s) to be searched on :
Measured

Publication/Updates Selection

Publication Year(s) to be searched on :
Starting Year: One year prior to publication year of 304(a) criteria document
Ending Year: *2016*
All **Authors** to be searched
All **Test Number(s)** to be searched
All **Reference Number(s)** to be searched
All **Independently Compiled Data Sets** to be searched
All **Recent Modification/Updates** to be searched

The advanced database query ECOTOX search, yielded no additional information that was not already included in the previous interim BE prepared to support the ESA section 7(d) memorandum.

Discussion of Expected Improvements in Water Quality in North Carolina

Although only the shortnose sturgeon is specifically identified as threatened by heavy metal pollution, water pollution could potentially be a threat to the Atlantic sturgeon, in addition to the more significant threats identified. It is the EPA's determination that implementation of the new and revised metals criteria will reduce these listed species' exposure to metals. Reducing the allowable level of metals in state waters is a critical step in attaining and/or maintaining the goal of the CWA to restore and maintain the chemical, physical, and biological integrity of the Nation's waters (also referred to as "fishable/swimmable") through the improvement of water quality. It is also the goal of the ESA to conserve listed species and their designated critical habitat in the state of North Carolina. The following table compares North Carolina's previous metals criteria with the new or revised criteria and with EPA's recommended criteria.

Non-Hardness Dependent Metals for Freshwaters				
Metal (all values are dissolved)	**NCDWR's Previous Criteria (ug/l)**	**NCDWR New/Revised Criteria (ug/l)**	**EPA's Recommended Criteria (ug/l)**	**EPA's Reference for Recommended Criteria**
Arsenic (acute)	--	340	340	*1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water* (EPA 1995)
Arsenic (chronic)	50 ug/l	150	150	
Beryllium (acute)	--	65	--	N/A
Beryllium (chronic)	6.5	6.5	--	
Chromium VI (acute)	--	16	16	EPA 1995
Chromium VI (chronic)	--	11	11	
Silver (chronic)	0.06 Action Level only	0.06	--	N/A

Hardness Dependent Metals for Freshwaters				
Metal (all values are dissolved)	**NCDWR's Previous Criteria (ug/l)**	**NCDWR's Criteria calculated at a hardness of 25 (ug/l)**	**EPA's Nationally Recommended criteria calculated at a hardness of 25 (ug/l)**	**EPA's Reference for Recommended Criteria**
Cadmium (acute)	--	0.82	0.52	*(EPA 2000)*
Cadmium (acute, trout waters)	--	0.51	0.52	
Cadmium (chronic)	0.4 ug/l trout waters 2.0 ug/l non-trout waters	0.15	0.09	
Chromium III (acute)	-	180	183.07	*(EPA 1995)* *(EPA 1999)*
Chromium III (chronic)	-	24	23.81	
Copper (acute)	-	3.6	N/A	*(EPA 2007)* *(EPA 1999)*
Copper (chronic)	Action Level 7.0	2.7	N/A	
Lead (acute)	-	14	13.88	*Ambient Water Quality for Lead – 1984; (EPA 1984)*
Lead (chronic)	25	0.54	0.54	
Nickel (acute)	-	140	144.92	*(EPA 1999)*
Nickel (chronic)	8.3	16	16	
Silver (acute)	-	0.30	0.3	*Ambient Water Quality Criteria for Silver;* *(EPA 1980)*
Zinc (acute)	-	36	36	*(EPA 1999)*
Zinc (chronic)	Action Level 50	36	36	

Metals for Salt Water (Dissolved Fraction)			
Metal (all values are dissolved)	**NCDWR's Previous Criteria (ug/l)**	**NCDWR's Criteria** (all values ug/l)	**EPA's Nationally Recommended criteria** (all values ug/l)
Arsenic (acute)	--	69	69
Arsenic (chronic)	50	36	36
Cadmium (acute)	--	40	40
Cadmium (chronic)	5.0	8.8	8.8
Chromium VI (acute)	--	1100	1100
Chromium VI (chronic)	--	50	50
Copper (acute)	--	4.8	4.8
Copper (chronic)	Action Level 3	3.1	3.1
Lead (acute)	--	210	210
Lead (chronic)	25	8.1	8.1
Nickel (acute)	--	74	74
Nickel (chronic)	8.3	8.2	8.2
Silver (acute)	--	1.9	1.9
Silver (chronic)	Action Level 0.1	0.1	--
Zinc (acute)	--	90	90
Zinc (chronic)	Action Level 86	81	81

Discussion of Recovery Plans and Exposure Pathways by Species of Concern

The EPA has provided an excerpt from the species-specific recovery plan developed by the FWS and/or NMFS along with a conclusion regarding risks to the species and potential exposure pathways for each species of concern.

Shortnose Sturgeon

In the recovery plan for the shortnose sturgeon (dated Dec. 17, 1998), it is clear there is not as much information on the effects of toxics as is the case for some of the other threats in which the shortnose sturgeon is susceptible. As noted in the recovery plan, "heavy metals and organochlorine compounds are known to accumulate in fat tissues of sturgeon, but their long term effects are not yet known (Ruelle and Henry 1992; Ruelle and Keenlyne 1993)." Further, since point-source discharges may also contribute to impacts stemming from poor water quality, several of the recovery action items reflect an interest in completing additional research including the "effects of contaminants (using realistic levels) on shortnose sturgeon growth, survival, and reproduction" and that contaminants should be reduced, and if possible, removed.

Therefore, the EPA determined that regulating the amount of pollutants that could result in potential exposure to the shortnose sturgeon is an important consideration in the EPA's determination of any potential for effect to this listed species. Based on the available information at the time this BE was prepared, the shortnose sturgeon is present in 15 counties (Anson, Bertie, Bladen, Brunswick, Camden, Carteret, Columbus, Currituck, Dare, New Hanover, Onslow, Pamlico, Pasquotank, Pender, and Richmond) in North Carolina.

Atlantic Sturgeon

There does not appear to be a recovery plan for the population of Atlantic sturgeon associated with North Carolina waters. The EPA considered that any actions needed to support the recovery of the species, particularly as it relates to chemical water quality, would likely be very similar to the shortnose sturgeon. This conclusion is based on the fact the two species have a similar range, habitat, and feed on a similar diet (crustaceans, mollusks). Furthermore, the two species are also listed to have similar threats to the populations and are in the same genus, which would suggest additional similarities as well.

Therefore, the EPA determined that regulating the amount of pollutants that could result in potential exposure to the Atlantic sturgeon is an important consideration in the EPA's determination of any potential for effect to this listed species. Based on the available information at the time this BE was prepared, the Atlantic sturgeon is present in 28 counties (Anson, Beaufort, Bertie, Bladen, Brunswick, Camden, Carteret, Chowan, Columbus, Craven, Currituck, Dare, Gates, Halifax, Hertford, Hyde, Martin, New Hanover, North Hampton, Onslow, Pamlico, Pasquotank, Pender, Perquimans, Pitt, Richmond, Tyrell, and Washington) in North Carolina.

Consideration of Best Available Scientific and Commercial Data Discussion of Existing Biological Opinions and Comparison of Other Data to North Carolina's Revised Water Quality Criteria

As required by the ESA, the EPA has considered and analyzed the best available scientific and commercial data, including historic BEs and BOs from recent ESA section 7 consultations conducted for CWA 303(c) actions with the FWS and NMFS. These BEs and BOs considered the possible effects of the same parameters (often at the same concentrations) that are being considered by the EPA in this review. The findings of those BOs are included in Attachment B. In addition, the EPA also analyzed the best available scientific and commercial data specific to sturgeon that were considered to be more comparable to the species located in North Carolina's waters than the primarily salmonid-focused conclusions of the existing BOs. The more regionally relevant information associated with sturgeon specific information is contained in Attachment C along with freshwater species, and summarized by parameter as part of Attachment B that contains both freshwater and salt water species. The overall findings from these two Attachments are discussed below.

By considering the differences, or in many cases, the similarities between the historical BO analyses to the criteria adopted by North Carolina, the EPA determined whether the North Carolina criteria values had been previously determined to be protective or not, of the western state species. The EPA concluded that when compared to the water quality criteria adopted by North Carolina, many of the historic BOs prepared by FWS and NMFS concluded that an equivalent or more stringent concentration would be unlikely to jeopardize the continued existence of listed species or adversely modify critical habitat. When the conclusion was the North Carolina's criteria were less stringent or that the historic BO had made an adverse finding, additional discussion and analysis, such as that in Attachments B and C, was provided to document the EPA's review. Additional details of the findings, including the specifics of species and critical habitat conclusions, for each BO can be found in the footnotes and general content contained in Attachment B. Attachment B presents a color-coded row for each acute and chronic numeric criteria value by parameter, further discusses the EPA's analyses for all types of findings from the respective historic BOs, and discusses how it relates to the equivalent concentrations that were adopted by North Carolina and are the subject of this BE. The following table depicts how the EPA characterized the Services' conclusions from the BOs within Attachment B:

Services' Conclusion	Cell Color
May affect, NLAA or No Effect	Green Highlighted Cells
May affect, Likely to Adversely Affect (LTAA), but implementation of the Services' RPA, would render the conclusion no longer adverse	Orange Highlighted Cells
Some Effect Finding – Did not rise to level of LTAA and no RPA was identified	Yellow Highlighted Cells

To supplement the EPA's analysis of historical BOs, the EPA compiled the information in Attachment C from papers provided by Tom Augspurger (herein referred to as "supplemental papers"). For each parameter in Attachment B, there is a section titled "EPA's Conclusion for…" in which the EPA has summarized the results of the analyses of the supplemental papers documented in greater detail in Attachment C. It should be noted that EPA's review of the historical BOs addressed the following parameters: arsenic, cadmium, chromium III, chromium VI, copper, lead, nickel, silver, and zinc. As noted above, the BO related information was also supplemented with the results of the EPA's analyses of the supplemental papers for the following parameters: cadmium, chromium VI, copper, lead, nickel, and zinc. Beryllium was not discussed in any of the BOs or supplemental papers.

Since the two sturgeon species reside in both fresh waters and salt waters of the State, this section breaks down the EPA's analysis by water type. Before providing a summary of the quantified results of the EPA's analyses of the more localized or relative species comparisons for the six parameters addressed in the supplemental papers, the EPA provides the following discussion regarding its interpretations of the ranges found in the papers:

> In some instances, the supplemental papers provided significant ranges in toxicity values for a given parameter. There are a number of reasons why this range may exist. Differences may be due, in part, to differences in the endpoints studied within a paper (i.e., median lethal concentration of a toxicant with 50% survival rate [LC50] vs. no observed effect concentration [NOEC]), the use of different species within each mussel or fish tests and their resulting sensitivity differences, the range in hardness values used in each tests (although the EPA attempted to correct for this through comparisons of a most comparable hardness for each test). The goal was also to select the most sensitive result of the study, which could have the effect of providing a potentially less comparable species to those species present in North Carolina.
>
> Based on information in the 1985 Aquatic Life Criteria Guidelines and the generally accepted calculation that an acute value (LC50) divided by 2 results in an LC1 or LC0 value, the EPA determined that any study that has an acute value that is $\geq$2 times the criteria should build our case of the criteria being protective of listed species, or at a minimum results in an insignificant effect or exposure to the species. Therefore, additional commentary will be provided for values that reflect results which indicate toxicity is occurring at an equivalent or lower concentration than the adopted criterion value, or more specifically for those studies where the value is <2.

Discussion of Freshwater

Although more detail can be found in Attachments B and C, the following summarizes the findings and additional commentary discussing values <2 following the EPA's review of the supplemental papers obtained by the call for data carried out by the FWS:

- Cadmium
    - In the one paper available for acute cadmium effects on sturgeon (Calfee et al. 2014), the lab water based testing resulted in LC50s of less than 34.4 µg/L for 61 dph life stage of white sturgeon (most sensitive life stage). It is difficult to make a quantitative comparison to the State's criteria at 100 hardness, given that the value is <34.4 µg/L. The criteria at 100 hardness is 2.74 µg/L. Wang et al. (2014) examined the chronic effects of cadmium on white sturgeon, chronic endpoints had EC20s that were greater than 7.6 times the State's dissolved chronic cadmium criteria.

- Chromium VI
    - No studies related to fish and Chromium VI were located and reviewed.

- Copper
    - For sturgeon, the range in acute values were 29 to 64% of (all in the Calfee et al. 2014, Little et al. 2012, and Vardy et al. studies – 2011, 2013, 2014), to ~3.5 times greater than (Dwyer et al. 2005), the appropriate hardness-based acute criterion. For the fish chronic criterion comparison, values ranged from 16% (based on EC20 for sturgeon in Wang et al. 2014) to 95% of the chronic criterion (based on an LC20) using the results of the most sensitive fish species tested.
        - North Carolina has two listed sturgeon species: shortnose and Atlantic sturgeon. One study examines shortnose and Atlantic sturgeon (Dwyer et al. 2005) and demonstrates the acute criteria are protective of both listed species of sturgeon in North Carolina. The studies which indicate sturgeon toxicity (acute and chronic) occurs below the appropriate hardness-calculated criteria were studies that examined white sturgeon (Calfee et al. 2014, Little et al. 2012, and Vardy et al. studies). There is not adequate data to indicate the appropriateness of white sturgeon as a surrogate species for shortnose or Atlantic sturgeon (WebICE, http://www3.epa.gov/ceampubl/fchain/webice/). In addition, the ranges of a white sturgeon are geographically different (west coast of the U.S.) from shortnose or Atlantic sturgeon (east coast of the U.S.). These ranges result in potential differences in water quality parameters, such as hardness, pH, and DOC that could affect copper toxicity. The mechanism of copper toxicity is influenced by copper complexation with ions and DOC in site waters. In addition, cation competition for gill-binding sites (with hardness ions Ca^{+2} and Mg^{+2}) greatly affects copper toxicity. Recent studies have indicated that further investigation into site specific considerations is important in determining copper toxicity to white sturgeon. Water effect ratios in the Columbia River study were consistently >1 indicating metals were less toxic to white sturgeon exposed to site water than laboratory water (Vardy et al. 2014). North Carolina has adopted Water Effect Ratios (WERs) and the Biotic Ligand model as part of their criteria. A quantitative comparison of BLM criteria to the laboratory studies discussed above was

not possible, because the multiple input water quality parameters for the BLM were not always reported in the studies. Thus, application of a BLM standard or a WER, which consider site-specific water quality parameters, would likely be more protective of sturgeon.

- Lead
    - Acute LC50s of early life stages of white sturgeon exposed to lead in lab and site water were evaluated in Vardy et al. 2014.
        - LC50s for white sturgeon exposed to lead in lab water were significantly less than average LC50s for rainbow trout and less than or equal to cutthroat trout.
        - LC50s were ~3-36 times the State's acute lead criteria.
    - Chronic effects of lead on the early life stages of white sturgeon were evaluated in Wang et al. 2014. All of the chronic tests and endpoints had EC20s that were greater than 10.8 times the State's chronic lead criteria.

- Nickel
    - No supplemental papers on Nickel effects on fish were evaluated.

- Zinc
        - The ~1.3 times greater than the chronic criterion result reflects the most stringent value and is an LC20.

There were no supplemental papers evaluated for chromium VI and nickel. The results of the lead, zinc, and cadmium analysis indicated values greater than the two times greater threshold discussed earlier. The copper data had a range of values above and below the threshold of two times greater. Based on the additional commentary provided above, the EPA considered that some results less than the threshold should be given less weight for the reasons provided with each result. The EPA considered that the most relevant study results were typically the most sensitive endpoint that could be compared to either the acute or chronic values (or both, where the study contained multiple endpoints) and reflected the most sensitive species or life stage for a species from the study, when that information was articulated. Additionally, the EPA expects that, for less sensitive species or life stages, the risk of exposure to adverse amounts of the pollutant is even less.

In conclusion, the EPA's overall determination was that most of the results were greater than two times the equivalent criterion and, by using these sources of information, the EPA has determined that the amount of exposure to pollutants that would be allowed by North Carolina's revised water quality standards may effect, NLAA-insignificant and is therefore not likely to jeopardize the continued existence of the seven listed mussel species and the six listed fish species or result in the destruction or adverse modification of their designated critical habitat.

        - The ~1.3 times greater than the chronic criterion result reflects the most stringent value and is an LC20.

The results of the chromium VI and lead analysis indicated values greater than the two times greater threshold discussed earlier. The other four parameters, cadmium, copper, nickel, and zinc, had a range of values above and below the threshold of two times greater. Based on the additional commentary

provided above, the EPA considered that some results less than the threshold should be given less weight for the reasons provided with each result. The EPA considered that the most relevant study results were typically the most sensitive endpoint that could be compared to either the acute or chronic values (or both, where the study contained multiple endpoints) and reflected the most sensitive species from the study, when that information was articulated. Additionally, the EPA expects that, for less sensitive species, the risk of exposure to adverse amounts of the pollutant is even less.

In conclusion, the EPA's overall determination was that most of the results were greater than two times the equivalent criterion and by using these sources of information, the EPA has determined that the amount of exposure to pollutants that would be allowed by North Carolina's revised water quality standards may effect, NLAA-insignificant and is therefore not likely to jeopardize the continued existence of the shortnose or Atlantic sturgeon.

Discussion of Salt Water

In addition to the information provided above from the freshwater analyses, the EPA considered the salt water related information contained in the NMFS Oregon BO, dated August 14, 2012, because the acute and chronic salt water criteria adopted by North Carolina are the same criteria adopted by Oregon. As summarized in Attachment B, the BO concluded that it was some of the freshwater criteria revisions which were likely to adversely affect (LAA) certain species, including several species/populations of salmon and steelhead, green sturgeon, eulachon, and killer whales as well as result in destruction or adverse modification of designated critical habitats for the same species (less the LCR coho salmon and killer whale). Additional detail summarizing the findings relative to the salt water criteria adopted by Oregon was contained in an Excel spreadsheet provided by Pat Shaw Allen, NMFS. In the spreadsheet, there are a number of toxicity endpoints considered by the Services in the BO, including, but not limited to mortality, growth, behavioral, sublethal, and reproductive attributes. For the parameters listed below, with the corresponding criteria concentrations, none of the parameters were found to have "high intensity increase in toxicity effects on listed species that affect[ed] one or more population attributes," the description associated with a LAA finding. Based on the NMFS's analyses, and as shown in Table 2 below, the attributes fell into one of three other categories described in the final column. As a result of the parameters not being considered LAA in the Oregon BO, the EPA determined this information provides a line of evidence in consideration of the North Carolina revisions also being determined to be NLAA.

Table 2. Summarized information based on biological opinion data contained in Pat Shaw Allen's spreadsheet contained in the email to Lauren Petter, dated May 28, 2015.

Parameter	Acute Salt Water Criterion	Chronic Salt Water Criterion	Analysis Results
Arsenic	69 µg/L	36 µg/L	For 3 of 10 attributes: Moderate intensity increase in toxicity effects on listed species at the scale of individuals or groups of individuals For 1 of 10 attributes: Moderately-High-intensity increase in toxicity effects on listed species at the scale of individuals or groups of individuals, but not at the scale of any population

			For 6 of 10 attributes: No increase in toxicity noted
Cadmium	40 µg/L	8.8 µg/L	For 3 of 10 attributes: Moderate intensity increase in toxicity effects on listed species at the scale of individuals or groups of individuals For 1 of 10 attributes: Moderately-High-intensity increase in toxicity effects on listed species at the scale of individuals or groups of individuals, but not at the scale of any population For 6 of 10 attributes: No increase in toxicity noted
Chromium VI	1100 µg/L	50 µg/L	For 2 of 10 attributes: Moderate intensity increase in toxicity effects on listed species at the scale of individuals or groups of individuals For 2 of 10 attributes: Moderately-High-intensity increase in toxicity effects on listed species at the scale of individuals or groups of individuals, but not at the scale of any population For 6 of 10 attributes: No increase in toxicity noted
Copper	4.8 µg/L	3.1 µg/L	For 3 of 10 attributes: Moderate intensity increase in toxicity effects on listed species at the scale of individuals or groups of individuals For 1 of 10 attributes: Moderately-High-intensity increase in toxicity effects on listed species at the scale of individuals or groups of individuals, but not at the scale of any population For 6 of 10 attributes: No increase in toxicity noted
Lead	210 µg/L	8.1 µg/L	For 1 of 10 attributes: Low intensity increase in toxicity effects on listed species at the scale of individuals or groups of individuals For 1 of 10 attributes: Moderate intensity increase in toxicity effects on listed species at the scale of individuals or groups of individuals For 3 of 10 attributes: Moderately-High-intensity increase in toxicity effects on listed species at the scale of individuals or groups of individuals, but not at the scale of any population For 5 of 10 attributes: No increase in toxicity noted

Nickel	74 µg/L	8.2 µg/L	For 3 of 10 attributes: Moderate intensity increase in toxicity effects on listed species at the scale of individuals or groups of individuals For 1 of 10 attributes: Moderately-High-intensity increase in toxicity effects on listed species at the scale of individuals or groups of individuals, but not at the scale of any population For 6 of 10 attributes: No increase in toxicity noted
Silver	1.9 µg/L	n/a	For 2 of 10 attributes: Moderate intensity increase in toxicity effects on listed species at the scale of individuals or groups of individuals For 1 of 10 attributes: Moderately-High-intensity increase in toxicity effects on listed species at the scale of individuals or groups of individuals, but not at the scale of any population For 7 of 10 attributes: No increase in toxicity noted
Zinc	90 µg/L	81 µg/L	For 3 of 10 attributes: Moderate intensity increase in toxicity effects on listed species at the scale of individuals or groups of individuals For 1 of 10 attributes: Moderately-High-intensity increase in toxicity effects on listed species at the scale of individuals or groups of individuals, but not at the scale of any population For 6 of 10 attributes: No increase in toxicity noted

Although the EPA did not find additional papers for the effects of the adopted revisions for salt water, on October 26, 2015, Pat Allen-Shaw with NMFS, provided the EPA with additional information contained in the 2012 Vessel General Permit (VGP) BO and 2015 Multi Sector General Permit (MSGP) BO in an email to Lauren Petter, EPA. While there were portions of the BOs that spoke to toxic levels of these same parameters, it was determined that the actions that were both related to general permits, were not as comparable as the information contained in the Oregon BO, which was for an action pertaining to approval of a state's water quality standards.

Lastly, the EPA considered that the most sensitive life stages of the sturgeon occur in freshwater and that the analyses provided above for freshwater is a critical consideration in the overall potential of exposure and impact to the shortnose and Atlantic sturgeon species. Therefore, the EPA determined that since most of the information available to assess impacts to the species considered the most sensitive life stage, and what information was available for the salt water revisions, was determined to protect the less sensitive salt water life stages, the EPA's approval of the salt water revisions would have no additional level and/or route of toxicity exposure.

Summary

By using these sources of information, the EPA determined that the level and route of exposure to pollutants that would be allowed by North Carolina's revised fresh and salt water quality standards is likely to be insignificant and not likely to jeopardize the continued existence of the shortnose and Atlantic sturgeon species. Based on the available information, this action is may affect, not likely to adversely affect the listed species.

Discussion of the Implementation of Water Effect Ratios, Recalculation Procedure, and Resident Species Procedure, Hardness Dependent Equations, and Biotic Ligand Model for Copper

Water Effect Ratios, Recalculation Procedure, and Resident Species Procedure (Applies to Both Fresh and Salt Waters)

New subparagraphs that were added in both the freshwater and salt water provisions, allows North Carolina the ability to conduct either a WER, Recalculation Procedure, or Resident Species Procedure. The new language clarifies the State's expectations for these types of site specific criteria studies consistent with EPA guidance. Further technical information regarding these provisions can be found in the final decision document for this action provided as Attachment D to this BE. Such clarification was determined to have no effect on federally listed species or their designated critical habitats for the Recalculation Procedure and Resident Species Procedure because use of these provisions will ultimately result in new or revised water quality standards that will require a federal action by the EPA and an ESA section 7 consultation with FWS.

WERs are also processes that allow the State to put site specific water quality criterion in place; however, this is accomplished through modified permit limits for individual dischargers and does not result in a new or revised water quality criterion. The EPA considers a WER as a performance-based standard implemented through NPDES permits. The purpose of a WER is to allow for site-specific water quality characteristics, which may affect metal bioavailability and toxicity, to be considered in the applicable criterion. The EPA found that use of the WER provision by the state, would result in the same level of bioavailability of metals to species of concern as that found in the results of the toxicity tests for the WER[4]. For ESA consultation purposes, the EPA considers this a programmatic consultation defined as a consultation that addresses multiple actions on a program, regional or other basis. Based on the EPA's analysis of this provision, it was concluded that the WER provision is may affect, NLAA – insignificant to designated critical habitat and species of concern.

Hardness Based Equations (Applies to Fresh Waters Only)

A new table, Table A, was added under the freshwater section .02 11(d) to show the new and revised criteria for hardness dependent metals, including the respective equations. Additionally, as noted in the decision document, North Carolina has chosen to also adopt the Aquatic Life Ambient Freshwater Quality Criteria—Copper 2007 Revision (EPA-822-R-07-001) for calculating acute or chronic freshwater copper values using the Biotic Ligand Model. The BLM criteria, which is discussed further in the next section, is written as a supplement to the EPA's previously published recommendations for copper. With regard to the consultation for the addition of hardness based equations to the State's

[4] EPA, 1994, Interim Guidance on the Determination and Use of Water-Effect Ratios for Metals, EPA-823-B-94-001, U.S. Environmental Protection Agency, Office of Water, Washington, DC.

regulations, the EPA concludes the substance of its review is addressed in the previous discussion regarding the criteria concentrations themselves that result from the use of the equations. Therefore, for this provision, the EPA has concluded a may affect, NLAA effect-insignificant determination for listed species or their designated critical habitat based on the EPA's review of the historical BOs and species specific toxicity information as discussed above.

Biotic Ligand Model Based Criterion for Copper (Applies to Fresh Waters Only)

The BLM is a model used for freshwaters that uses receiving water body characteristics to develop site-specific water quality criteria using the best available science to determine the bioavailability of copper. The BLM requires that ten waterbody specific parameters be input into the model, including temperature, pH, dissolved organic carbon, calcium, magnesium, sodium, potassium, sulfate, chloride, and alkalinity rather than just the hardness of a waterbody as required for the hardness-based equation. However, North Carolina determined that the BLM was often not practical to implement when resources or data were not available for the collection or use of all ten parameters and therefore caveated the adoption to note that it will be used where "sufficient data is available". When sufficient data is not available, North Carolina has chosen to utilize the EPA's previously published hardness based equation for copper in order to ensure state wide implementation of copper criteria.

The implementation of the BLM can result in two outcomes: 1) a change to permit limits similar to the implementation of a WER, or 2) a new site specific water quality criterion. No ESA consultation would be required for the first outcome because there is no change to the underlying water quality criterion. This scenario, was therefore determined to have no effect on federally listed species or their designated critical habitats. The use of the BLM to develop a site specific criterion for copper is a process that clarifies the ability of the State to have a revised water quality criterion to support the designated use(s). Such clarification was determined to have no effect on federally listed species or their designated critical habitats. When use of the BLM results in the adoption of a revised water quality criterion, the EPA would evaluate at that time whether or not an ESA section 7 consultation was necessary.

Summary of EPA's Conclusions by Provision

Based on the above information, the EPA concluded that for those species not previously identified as having no effect based on their habitat relative to the subject action or a may effect, NLAA-discountable effect, the following determinations were made on a revision specific basis. Even though some species were located in the action area and/or had the potential for exposure, some revisions were still determined to have no effect on the species due to the nature of the revision. Where this was the case, as well as where the EPA expects the effect to be insignificant, those conclusions have been summarized for each of the revised provisions within North Carolina's regulations for which the EPA is taking an approval action. In conclusion, the EPA has determined that its analysis supports a conclusion that the revisions the EPA's CWA 303(c) action addresses are may affect, NLAA-insignificant, no effect, or no discretion.

Section	Provision	EPA's ESA Determination
15A NCAC 02B.0206 – Flow Design for Effluent Limitations	Addition of a 1Q10 flow for protection of aquatic life from acute toxicity	May affect, NLAA – insignificant

Section	Provision	EPA's ESA Determination
	Editorial Changes shown in Attachment A	No effect
15A NCAC 02B .0211 - Fresh Surface Water Quality Standards for Class C Waters	Addition of Acute/Revised Criteria for Chronic Arsenic	May affect, NLAA – insignificant
	Addition of Acute Beryllium	May affect, NLAA – insignificant
	Addition of Acute and Chronic Chromium VI	May affect, NLAA – insignificant
	Revision of Chronic Silver	May affect, NLAA – insignificant
	Revised Criteria for Chronic Cadmium	May affect, NLAA – insignificant
	Addition of Acute Criteria for Cadmium in Trout and Non-Trout Waters	May affect, NLAA – insignificant
	Addition of Acute and Chronic Criteria for Chromium III	May affect, NLAA – insignificant
	Revised Acute and Chronic Criteria for Copper	May affect, NLAA – insignificant
	Revised Acute and Chronic Criteria for Lead	May affect, NLAA – insignificant
	Revised Acute and Chronic Criteria for Nickel	May affect, NLAA – insignificant
	Revised Acute and Chronic Criteria for Zinc	May affect, NLAA – insignificant
	Addition of Acute Silver Criterion	May affect, NLAA – insignificant
	Removal of Iron Action Level	No effect
	Use of hardness based equations	May effect, NLAA – insignificant (except the low end hardness cap component of the

Section	Provision	EPA's ESA Determination
		hardness equation was disapproved under CWA 303(c) – ESA section 7 consultation not required.)
	Use of WERs, Recalculation Procedure, and Resident Species Procedure	May affect, NLAA – insignificant No effect or determine if future ESA section 7 consultation is required.
	Use of BLM for copper	No effect or determine if future ESA section 7 consultation is required
	Editorial Changes shown in Attachment A	No effect
15A NCAC 02B .0212 - Fresh Surface WQS for Class WS-I Waters	Editorial Changes shown in Attachment A	No effect
	Removal of Manganese Numeric Criterion and Revision of 2, 4 D Numeric Criterion	No discretion – human health
15A NCAC 02B .0214 - Fresh Surface WQS for Class WS-II Waters	Editorial Changes shown in Attachment A	No effect
	Removal of Manganese Numeric Criterion and Revision of 2, 4 D Numeric Criterion	No discretion – human health
15A NCAC 02B .0215 - Fresh Surface WQS for Class WS-III Waters	Editorial Changes shown in Attachment A	No effect
	Removal of Manganese Numeric Criterion and Revision of 2, 4 D Numeric Criterion	No discretion – human health

Section	Provision	EPA's ESA Determination
15A NCAC 02B .0216 - Fresh Surface WQS for Class WS-IV Waters	Editorial Changes shown in Attachment A	No effect
	Removal of Manganese Numeric Criterion and Revision of 2, 4 D Numeric Criterion	No discretion – human health
15A NCAC 02B .0218 - Fresh Surface WQS for Class WS-V Waters	Editorial Changes shown in Attachment A	No effect
	Removal of Manganese Numeric Criterion and Revision of 2, 4 D Numeric Criterion	No discretion – human health
15A NCAC 02B .0220 - Tidal Salt Water Quality Standards for Class SC Waters	Addition of Acute/Revised Criteria for Chronic Arsenic	May affect, NLAA – insignificant
	Addition of Acute and Chronic Chromium VI	May affect, NLAA – insignificant
	Addition of Acute/Revised Chronic Criteria for Silver	May affect, NLAA – insignificant
	Addition of Acute/Revised Criteria for Chronic Cadmium	May affect, NLAA – insignificant
	Addition of Acute/Revised Chronic Criteria for Copper	May affect, NLAA – insignificant
	Addition of Acute/Revised Chronic Criteria for Lead	May affect, NLAA – insignificant
	Addition of Acute/Revised Chronic Criteria for Nickel	May affect, NLAA – insignificant
	Addition of Acute/Revised	May affect, NLAA – insignificant

Section	Provision	EPA's ESA Determination
	Chronic Criteria for Zinc	
	Use of WERs, Recalculation Procedure, and Resident Species Procedure	May affect, NLAA – insignificant
	Editorial Changes shown in Attachment A	No effect

BIOLOGICAL EVALUATION FOR THE ENDANGERED SPECIES ACT SECTION 7 CONSULTATION FOR NORTH CAROLINA'S WATER QUALITY STANDARDS REVISIONS FOR THE U.S. FISH AND WILDLIFE SERVICE

Prepared by EPA Region 4
May 2016

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Overview

The focus of this Biological Evaluation (BE) is the effects which may occur to threatened and endangered species and/or designated critical habitat from the revisions to water quality standards (WQS) contained in North Carolina's 2007-2014 Triennial Review as approved by the U.S. Environmental Protection Agency (EPA) on April 6, 2016, pursuant to section 303(c) of the Clean Water Act (CWA). The majority of the changes to the State's rule language, incorporate updated scientific information pertaining to metals criteria for fresh and salt waters. Other revisions are generically related to the application and implementation of North Carolina's water quality standards and will be addressed in this BE as needed, based on the EPA's effects determinations for those provisions. A detailed analysis of the EPA's technical basis for the CWA section 303(c) action can be found in Attachment D.

Description of Federal Action:

Under section 303(c) of the CWA and 40 CFR § 131, States and authorized tribes have primary responsibility to develop and adopt WQS to protect their waters. As required by section 303(c) of the CWA and 40 CFR § 131, the EPA reviews new and revised WQS that have been adopted by States and authorized tribes. State and Tribal WQS are not considered effective under the CWA until approved by the EPA.

The Federal action being evaluated is the EPA approval of several revised WQS rule provisions as it relates to the protection of aquatic life use as set forth in the North Carolina Department of Environmental Quality, Rule 15A NCAC 02B.

Section 303(c)(3) of the CWA states in part: If the Administrator, within sixty days after the date of submission of the revised or new standard, determines that such standard meets the requirements of this Act, such standard shall thereafter be the water quality standard for the applicable waters of the State…

A. History of ESA Consultation for this CWA Action

Section 7(a)(2) of the Endangered Species Act (ESA) requires the EPA, in consultation with the U.S. Fish and Wildlife Service (FWS) and/or the National Marine Fisheries Service (NMFS), to ensure that any action authorized by the agency is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of designated critical habitat for such species. As provided in the Memorandum of Agreement between the EPA, the FWS, and the NMFS regarding enhanced coordination of CWA and ESA obligations, the EPA uses a BE to analyze whether a new or revised water quality standard may affect federally-listed species or designated critical habitat. This BE has been prepared to determine whether the EPA's approval of specific aspects of North Carolina's surface water quality standards may affect federally listed endangered or threatened species or the designated critical habitat of such species. If the EPA determines that approval may affect listed species or critical habitat but is not likely to adversely affect listed species or habitat, then formal consultation with the FWS is not required if the EPA obtains concurrence on the "may effect, not likely to adversely affect" finding from the FWS.

Early coordination began on February 13, 2015, with a phone call between Tom Augspurger of the Raleigh FWS field office. The EPA initiated consultation with the FWS on March 23, 2015, through a written request for technical assistance, whereby the EPA requested verification of the current species list. On April 23, 2015, in a letter from Pete Benjamin, Field Supervisor, to Annie Godfrey, Chief of EPA Region 4, Water Quality Standards Section, the FWS provided a revised file reflecting the updated species and critical habitat information for the EPA to use in the development of its interim and final BEs. Over the next nine months and prior to the completion of the EPA's action to approve the revision to North Carolina's water quality standards, the EPA coordinated with FWS staff located at the Raleigh and Asheville Field Offices via numerous conference calls to develop a data search strategy and to complete a data call from various technical organizations further detailed below. The FWS verified the species list was still accurate via emails dated January 11, 2016, for the interim BE and again on March 30, 2016, for the final BE. The EPA completed an ESA section 7(d) memo "To the File" with a supporting interim BE dated March 15, 2016, for the EPA CWA 303(c) decision document. Lastly, in an email dated March 30, 2016, the FWS confirmed that there were no additional proposed or listed species to add to this final BE.

B. Overview of Water Quality Standards

The CWA provides the statutory basis for the water quality standards program and defines broad water quality goals.

Section 101(a)(2) of the CWA sets out a national goal that wherever attainable, waters achieve a level of quality that provides for the protection and propagation of fish, shellfish, and wildlife, and for recreation in and on the water ("fishable/swimmable"). Section 303(c) of the CWA requires that all states adopt water quality standards and that the EPA review and approve these standards. In addition to adopting water quality standards, states are required to review those standards every three years and to then revise the standards, as necessary. This public process, commonly referred to as the triennial review, allows for new technical and scientific data to be considered in order to update the standards. The regulatory requirements governing water quality standards are established at 40 CFR § 131.

The purpose of the CWA, 33 U.S.C.S. § 1251(a), is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. Consistent with the CWA, as part of their water quality standards, states must designate the uses for which their waters are to be protected, such as fishing and swimming, and identify water quality criteria to protect the uses for pollutants that could reasonably be expected to interfere with the designated uses. In addition, states' water quality standards must include an antidegradation policy and implementation procedures that are consistent with the EPA's policy to protect existing uses, high quality waters, and water quality in waters identified by the state as outstanding national resource waters. Id. § 1313(c)(2)(A) (Supp. 1993); 40 C.F.R. § 131. Under section 303 of the CWA, states must submit new and revised water quality standards to the EPA for review and approval. When a state submits its water quality standards to EPA for review, the standards must include: (1) the designated uses for each body of water; (2) what methods were used and analyses conducted to support the revisions to state water quality standards; (3) water

quality criteria, which protect the designated uses for each water body and which may be expressed as either a narrative standard or a numeric concentration level; and (4) an antidegradation policy to protect existing uses of bodies of water and high-quality waters. 40 C.F.R. §§ 131.3(i), 131.3, 131.6, 2131.12.

Description of Specific Provisions Considered by the EPA for the Endangered Species Act (ESA) Section 7 Consultation

15A NCAC 02B .0206 Flow Design for Effluent Limitations

The majority of the revisions to 15A NCAC 02B .0206 were editorial in nature and are shown in their entirety in Attachment A. The EPA has determined that such editorial changes will have No Effect on listed species or their critical habitat. With regard to 15A NCAC 02B .0206, the EPA will only be consulting on the addition of a 1Q10 flow for protection of aquatic life from acute toxicity.

15A NCAC 02B .0211 Fresh Surface Water Quality Standards for Class C Waters

Many of the revisions to 15A NCAC 02B .0211 were editorial in nature and are shown in their entirety in Attachment A. The EPA has determined that such editorial changes will have No Effect on listed species or their critical habitat. With regard to 15A NCAC 02B .0211, the EPA will be consulting on the addition of acute and revised chronic values for the following non-hardness dependent metals: arsenic, beryllium, and chromium VI; the revision of the chronic silver criterion; the equations associated with hardness based equations for the following acute and chronic metals: cadmium, chromium III, copper, lead, nickel, and zinc; the equations associated with hardness based equations for an acute trout water specific cadmium and an acute silver criterion; and the incorporation of provisions pertaining to the use of Water Effects Ratios (WERs), Recalculation Procedure, and Resident Species Procedure, for all metals and the Biotic Ligand Model (BLM) for copper.

15A NCAC 02B .0212-.0218 Fresh Surface WQS for Class WS-1 Through WS-V Waters

The revisions to 15A NCAC 02B .0212, .0214, .0215, .0216, and .0218 (pertaining to Class Water Supply I, II, III, IV, and V designations) were primarily editorial in nature and are shown in their entirety in Attachment A. The EPA has determined that editorial changes will have No Effect on listed species or their critical habitat and changes which are human health related are considered to be No Discretion. This is because the EPA's discretion to act on a State submission, is limited to determining whether the criteria ensure the protection of designated uses upon which the criteria are based. The EPA has no discretion to revise an otherwise approvable human health criteria to benefit listed species.

15A NCAC 02B .0220 Tidal Salt Water Quality Standards for Class SC Waters

Although North Carolina also made revisions to 15A NCAC 02B .0220, the provisions contained in that section are specific to tidal waters and not specifically addressed in the effects determination section of this BE. The analysis completed for the National Marine Fisheries Service (NMFS), who has jurisdiction in tidal waters, can be provided upon request.

Description of the Geographic Area That May Be Affected by the Action

The action area for this BE includes all fresh waters within the State of North Carolina to which these criteria apply. As noted previously, marine waters are under the jurisdiction of the NMFS and are being addressed in a separate ESA section 7 consultation and BE analysis.

Summary of Species Present in North Carolina

Table 1 provides a list of all threatened and endangered species located in the State of North Carolina, under the jurisdiction of the FWS, as well as species' specific critical habitats (where applicable), species current status, general habitat type, FWS field office with jurisdiction over each species, and the EPA's final ESA section 7 determination of no effect or may affect, not likely to adversely affect (NLAA) with either discountable or insignificant effects.

Table 1. Table Summarizing Species Status, Critical Habitat (if applicable), General Habitat Type, and Office of Jurisdiction

Group	Species	Status	Critical Habitat (North Carolina county listings only)	Aquatic	Aquatic Dependent	Terrestrial	Office	ESA Determination
Mammals	Carolina Northern Flying Squirrel *(Glaucomys sabrinus coloratus)*	E				X	Asheville	No effect
	Gray Bat *(Myotis grisescens)*	E			X		Asheville	May affect, NLAA - discountable
	Indiana Bat *(Myotis sodalis)*	E			X		Asheville	
	Virginia Big-eared bat *(Corynorhinus townsendii virginianus)*	E	Yes (no counties designated in North Carolina)			X	Asheville	No effect
	Northern Long-eared Bat *(Myotis septentrionalis)*	T			X		Asheville Raleigh	May affect, NLAA - discountable
	Red Wolf *(Canis rufus)*	E				X	Raleigh	No effect
	West Indian Manatee *(Trichechus manatus)*	E	Yes (no counties designated in North Carolina)	X			Raleigh	May affect, NLAA - discountable
Mussels and Snails	Appalachian Elktoe *(Alasmidonta raveneliana)*	E	Yes (Graham, Haywood, Jackson, Macon, Mitchell, Swain, Transylvania, and Yancey)	X			Asheville	May affect, NLAA - insignificant
	Carolina Heelsplitter *(Lasmigona decorate)*	E	Yes (Union)	X			Asheville	
	Cumberland Bean Pearlymussel *(Villosa trabalis)*	E		X			Asheville	
	Dwarf Wedgemussel *(Alasmidonta heterodon)*	E		X			Raleigh	
	James Spinymussel *(Pleurobema collina)*	E		X			Asheville	

Group	Species	Status	Critical Habitat (North Carolina county listings only)	Aquatic	Aquatic Dependent	Terrestrial	Office	ESA Determination
	Littlewing Pearlymussel *(Pegias fabula)*	E		X			Asheville	May affect, NLAA - insignificant
	Tar River Spinymussel *(Elliptio steinstansana)*	E		X			Raleigh	
	Noonday Globe *(Patera clarki nantahala)*	T				X	Asheville	No effect
Birds	Piping Plover *(Charadrius melodus)*	E	Yes (Brunswick, Carteret, Dare, Hyde, New Hanover, Onslow, Pender)		X		Raleigh	May affect, NLAA - discountable
	Red-cockaded Woodpecker *(Picoides borealis)*	E				X	Asheville, Raleigh	No effect
	Wood Stork *(Mycteria americana)*	E			X		Raleigh	May affect, NLAA - discountable
	Roseate Tern *(Sterna dougallii dougallii)*	E			X		Raleigh	
	Red Knot *(Calidris canutus rufa)*	T			X		Raleigh	
Reptiles and Amphibians	Green Turtle *(Chelonia mydas)*	T	Yes (no counties designated in North Carolina)	X			Raleigh	May affect, NLAA - discountable
	Hawksbill Turtle *(Eretmochelys imbricate)*	E	Yes (no counties designated in North Carolina)	X			Raleigh	
	Kemp's Ridley Turtle *(Lepidochelys kempii)*	E		X			Raleigh	
	Leatherback Turtle *(Dermochelys coriacea)*	E	Yes (no counties designated in North Carolina)	X			Raleigh	

Group	Species	Status	Critical Habitat (North Carolina county listings only)	Aquatic	Aquatic Dependent	Terrestrial	Office	ESA Determination
	Loggerhead Turtle (*Caretta caretta)*	T	Yes (Brunswick, Carteret, New Hanover, Onslow, and Pender; other locations not in North Carolina)	X			Raleigh	May affect, NLAA - discountable
Fish	Cape Fear Shiner (*Notropis mekistocholas)*	E	Yes (Chatham, Lee, Moore, Randolph)	X			Raleigh	May affect, NLAA - insignificant
	Roanoke Logperch *(Percina rex)*	E		X			Raleigh	
	Spotfin Chub *(Erimonas monachus)*	T	Yes (Macon and Swain)	X			Asheville	
	Waccamaw Silverside *(Menidia extensa)*	T	Yes (Columbus)	X			Raleigh	
Insects and Spiders	Saint Francis' Satyr Butterfly *(Neonympha mitchellii francisci)*	E			X		Raleigh	May affect, NLAA - discountable
	Spruce-fir Moss Spider *(Microhexura montivaga)*	E	Yes (Avery, Caldwell, Haywood, Mitchell, Swain, and Watauga)			X	Asheville	No effect
Plants	American Chaffseed *(Schwalbea americana)*	E				X	Raleigh	No effect
	Blue Ridge Goldenrod *(Solidago spithamaea)*	T				X	Asheville	No effect
	Bunched Arrowhead *(Sagittaria fasciculate)*	E			X		Asheville	May affect, NLAA - discountable

Group	Species	Status	Critical Habitat (North Carolina county listings only)	Aquatic	Aquatic Dependent	Terrestrial	Office	ESA Determination
	Canby's Dropwort *(Oxypolis canbyi)*	E			X		Raleigh	May affect, NLAA - discountable
	Cooley's Meadowrue *(Thalictrum cooleyi)*	E				X	Raleigh	No effect
	Dwarf-flowered Heartleaf *Hexastylis naniflora)*	T				X	Asheville	No effect
	Golden Sedge *(Carex lutea)*	E	Yes (Pender and Onslow)			X	Raleigh	No effect
	Green Pitcher Plant (*Sarracenia oreophila)*	E			X		Asheville	May affect, NLAA - discountable
	Harperella *(Ptilimnium nodosum)*	E		X			Raleigh	May affect, NLAA - discountable
	Heller's Blazing Star *(Liatris helleri)*	T				X	Asheville	No effect
	Michaux's Sumac *(Rhus michauxii)*	E				X	Raleigh	No effect
	Mountain Golden Heather *(Hudsonia montana)*	T	Yes (Burke)			X	Asheville	No effect
	Mountain Sweet Pitcher Plant (*Sarracenia rubra ssp. jonesii*)	E			X		Asheville	May affect, NLAA - discountable
	Pondberry (*Lindera melissifolia*)	E				X	Raleigh	No effect
	Roan Mountain Bluet *(Hedyotis purpurea var. montana)*	E				X	Asheville	No effect
	Rock Gnome Lichen *(Gymnoderma lineare)*	E			X		Asheville	May affect, NLAA - discountable
	Rough-leaf Loosestrife *(Lysimachia asperulaefolia)*	E				X	Raleigh	No effect
	Schweinitz's Sunflower (*Helianthus schweinitzii*)	E				X	Asheville, Raleigh	No effect
	Seabeach Amaranth *(Amaranthus pumilus)*	T				X	Raleigh	No effect

Group	Species	Status	Critical Habitat (North Carolina county listings only)	Aquatic	Aquatic Dependent	Terrestrial	Office	ESA Determination
	Sensitive Joint-vetch *(Aeschynomene virginica)*	T			X		Raleigh	May affect, NLAA - discountable
	Small-anthered Bittercress *Cardamine micranthera)*	E			X		Asheville	May affect, NLAA - discountable
	Small Whorled Pogonia (*Isotria medeoloides*)	T				X	Asheville	No effect
	Smooth Coneflower *Echinacea laevigata*)	E				X	Raleigh	No effect
	Speading Avens *(Geum radiatum)*	E				X	Asheville	No effect
	Swamp Pink (*Helonias bullata*)	T			X		Asheville	May affect, NLAA - discountable
	Virginia Spiraea (*Spiraea virginiana*)	T			X		Asheville	May affect, NLAA - discountable
	White Irisette (*Sisyrinchium dichotomum*)	E				X	Asheville	No effect
-FWS has jurisdiction for sea turtles while on land and NMFS has jurisdiction for sea turtles while in the water. -Based on a clarifying email dated March 3, 2016, from Pat Shaw-Allen, NMFS, the shortnose and Atlantic sturgeon were removed from the FWS species list because they are under the jurisdiction of NMFS.								

Species of Interest for ESA Consultation

According to the Endangered Species Consultation Handbook, in order for the EPA to determine that a proposed action is a may affect, but NLAA action for threatened and endangered species or designated critical habitat, all of the effects of that action must be expected to be discountable, insignificant, or completely beneficial. Discountable effects are those that are extremely unlikely to occur and, based on best judgment, cannot be meaningfully measured, detected, or evaluated. Insignificant effects relate to the size of the impact and should never reach the scale where taking of a species (take) occurs. Beneficial effects are contemporaneous positive effects without any adverse effects to the species or designated critical habitat. As explained later in this document, the EPA concluded that the revisions to North Carolina's water quality standards will not have an adverse effect on any listed species or their designated critical habitats. Therefore, the EPA considered the three distinctions within the may affect, NLAA determination in its analysis of the State's revisions to their water quality standards. As detailed below, the EPA found that its action for each specific revision falls into one of the following categories: may affect, NLAA-discountable; may affect, NLAA-insignificant; or no effect.

In addition, according to the Draft Framework for Conducting Biological Evaluations of Aquatic Life Criteria Methods Manual, there are three different types of species: "aquatic" which have at least one of their life stages spent as a water-breathing organism or plants that are submerged or emergent; "aquatic dependent" which are not water-breathing organisms, but a meaningful amount of their diet includes aquatic organisms; and "terrestrial" which has only limited amount of exposure to "waters of the U.S.".

As a result of the EPA's consideration of the species specific information, there are some listed species that will not be the primary focus of this consultation as the EPA actions will have either no effect or a may affect, NLAA-discountable effect on these species.

- Revisions with no effect determination: The EPA's actions will have no effect on all terrestrial species found within the action area and further detailed in Table 1, including three mammals, one bird, one snail, and one spider (and any designated critical habitat), and 17 terrestrial plant species (including two with designated critical habitat). The EPA arrived at this determination because all of the species will have a limited amount of exposure to "waters of the U.S." where the water quality criteria apply.

  Where the EPA has reviewed editorial and non-substantive changes as part of its CWA 303(c) action and approves those revisions, the EPA considers those revisions to have no effect on any of the listed species or their critical habitat and they are therefore not covered further in this BE. For reference, a summary of these types of changes can be found at the end of this document, with all of the other conclusions described above.

- Revisions with a may affect, NLAA-discountable effects determination: For several species in Table 1, the EPA found that any effect to species will be discountable. Any exposure to pollutants resulting from the approval of North Carolina's revisions to its freshwater water quality standards is considered extremely unlikely due to a lack of prolonged exposure from water, diet, or any other life stage. Based on communications with the NMFS staff, it is the EPA's understanding that for the five turtle species under the FWS office's jurisdiction, the turtles' activities on land, including nesting, involve very limited contact with fresh water, as the

turtles' dietary source and exposure is to salt water. Therefore, the State's freshwater related revisions will have a discountable effect on the five turtles (including the designated critical habitat of the loggerhead turtle).[1] With regard to the manatee, while manatees can occur in fresh and marine waters, given the seasonal migration and other movements throughout the distribution range in and out of North Carolina waters[2], the EPA determined the revisions would also have a may affect, NLAA-discountable effect on the manatee. Similarly, due to limited dietary exposure through consumption of prey species and water, and due to the non-bioaccumulative nature of the parameters being considered, the EPA made a may affect, NLAA-discountable effect determination for the three aquatic dependent bats, Saint Francis' Satyr Butterfly, and four aquatic dependent birds (including the Piping Plover's designated critical habitat). Likewise, the effect of the State's revisions on the 10 aquatic or aquatic dependent plants was determined to be may affect, NLAA-discountable due to limited routes of exposure from discharges in the habitats where these species occur.

Therefore, the EPA focuses the remainder of this final BE on the consideration of possible effects to the seven aquatic mussel species: Appalachian elktoe (*Alasmidonta raveneliane*), Carolina Heelsplitter (*Lasmigona decorate)*, Cumberland bean pearlymussel (*Villosa trabalis*), Dwarf wedgemussel (*Alasmidonta heterdon*), James spinymussel (*Pleurobema collina*), Littlewing pearlymussel (*Pegias fabula*), and the Tar River spinymussel (*Elliptio steinstansana*); the four aquatic fish species: Cape Fear Shiner (*Notropis mekistocholas*) Roanoke logperch (*Percina rex*), Spotfin chub (*Erimonax monachus*), Waccamaw silverside (*Menidia extensa*), and any species-specific designated critical habitat. All of these species are defined as aquatic, because they spend at least one life stage as a water-breathing organism and therefore have increased exposure to fresh water when compared to aquatic dependent or terrestrial species. For these species, the EPA has determined that the effects, while not "discountable", would still be "insignificant" and would not reach the scale where "take" occurs. To support this conclusion, additional analyses were completed related to known toxicity levels associated with exposures to certain parameters. Prior to discussing those analyses for each species, a short summary of the pertinent information about life history and habitat, obtained from information on the Raleigh FWS Field Office and NatureServe websites, is provided. An asterisk appears by a species name that has designated critical habitat under the ESA.

Life History and Habitat Summaries – Mussels

*Appalachian elktoe (*Alasmidonta raveneliane*)

Status:
The status of the Appalachian elktoe is endangered. The species was listed as endangered on November 23, 1994. Critical Habitat areas for the Appalachian elktoe were designated on September 27, 2002. Specific information on areas designated as Critical Habitat and the primary constituent elements defined for this species are contained in the Federal Register notice (67 Fed. Reg. 61,016 – 61,040).

[1] Considering the potential to exposure through dietary ingestion of salt water, the discussion of any dietary ingestion will be provided in the analysis provided to NMFS.
[2] Occasional manatees occur in summer from Texas to North Carolina (e.g., see Schwartz 1995, Brimleyana 22:53-60, for North Carolina records). Accessed on natureserve.org on May 12, 2015.

Location:
The Appalachian elktoe is known only from the mountain streams of western North Carolina and eastern Tennessee. Although the complete historical range of the Appalachian elktoe is unknown, available information suggests that the species once lived in the majority of the rivers and larger creeks of the upper Tennessee River system in North Carolina. In Tennessee, the species is known only from its present range in the main stem of the Nolichucky River.

Currently, the Appalachian elktoe has a very fragmented, relict distribution. The species still survives in scattered pockets of suitable habitat in portions of the Little Tennessee River system, Pigeon River system, Mills River, and Little River in North Carolina. In the Little Tennessee River system in North Carolina, populations survive in the reach of the main stem of the Little Tennessee River, between the City of Franklin and Fontana Reservoir, in Swain and Macon Counties; and in scattered reaches of the main stem of the Tuckasegee River in Jackson and Swain Counties, from below the town of Cullowhee downstream to Bryson City. The species also occurs in the Cheoah River, from the Santeetlah Dam, downstream to its confluence with the Little Tennessee River in the in Graham County.

In the Pigeon River system in North Carolina, a small population of the Appalachian elktoe occurs in small scattered sites in the West Fork Pigeon River and in the main stem of the Pigeon River, above Canton, in Haywood County. The species has been recorded from the Mills River (upper French Broad River system) in Henderson County. The Little River (upper French Broad River system) population of the species, in Transylvania County, North Carolina, is restricted to small scattered pockets of suitable habitat downstream of Cascade Lake.

In the Nolichucky River system, the Appalachian elktoe survives in a few scattered areas of suitable habitat in the Toe River, Yancey and Mitchell Counties, North Carolina; Cane River, Yancey County, North Carolina; and the main stem of the Nolichucky River, Yancey and Mitchell Counties, North Carolina, extending downstream to the vicinity of Erwin in Unicoi County, Tennessee. It has also been found in the North Toe River, Yancey and Mitchell Counties, North Carolina, below the confluence of Crabtree Creek, and in the South Toe River, Yancey County, North Carolina. The majority of the surviving occurrences of the Appalachian elktoe appear to be small to extremely small and restricted to scattered pockets of suitable habitat.

Habitat and Diet:
The species has been reported from relatively shallow, medium-sized creeks and rivers with cool, clean, well-oxygenated, moderate- to fast-flowing water. The species is most often found in riffles, runs, and shallow flowing pools with stable, relatively silt-free, coarse sand and gravel substrate associated with cobble, boulders, and/or bedrock. Stability of the substrate appears to be critical to the Appalachian elktoe, and the species is seldom found in stream reaches with accumulations of silt or shifting sand, gravel, or cobble. Individuals that have been encountered in these areas are believed to have been scoured out of upstream areas during periods of heavy rain, and have not been found on subsequent surveys.

General literature claims that mussels are filter-feeders which remove phytoplankton from the water column. These assumptions appear to be based on casual observations of mussels in situ and a few examinations of rectal contents. Baker (1928) speculated that detritus was the primary energy source.

This has been substantiated by James (1987) and correlates well with microhabitats observed in the field.

Threats:
Poor water quality and habitat conditions have led to the decline and loss of populations of the Appalachian elktoe and threaten the remaining populations. Studies have shown that freshwater mussels, especially in their early life stages, are extremely sensitive to many of the pollutants (chlorine, ammonia, heavy metals, etc.) commonly found in municipal and industrial wastewater releases. Impoundments (dams), channelization projects, and in-stream dredging operations directly eliminate habitat. These activities also alter the quality and stability of remaining stream reaches by affecting the water flow, temperature, and chemistry. Agriculture (both crop and livestock) and forestry operations, roads, residential areas, golf courses, and other construction activities that do not adequately control soil erosion and water runoff contribute excessive amounts of silt, pesticides, fertilizers, heavy metals, and other pollutants that suffocate and poison freshwater mussels. The alteration of floodplains or the removal of forested stream buffers can be especially detrimental. Flood plains and forested stream buffers help maintain water quality and stream stability by absorbing, filtering, and slowly releasing rainwater. This also helps recharge groundwater levels and maintain flows during dry months.

References:
LeGrand, Jr., H.E., J.T. Finnegan, S.E. McRae, S.P. Hall. 2010. Natural Heritage Program List of the Rare Animal Species of North Carolina. N.C. Natural Heritage Program, Raleigh, NC.
U.S. Fish and Wildlife Service. 1996. Appalachian Elktoe Recovery Plan. Atlanta, GA. 32 pp.
http://www.duke-energy.com/pdfs/final_mussel_study_report.pdf
http://www.fws.gov/southeast/5yearReviews/5yearreviews/AppalachianElktoe20090305.pdf
http://ecos.fws.gov/crithab/
http://ecos.fws.gov/docs/federal_register/fr3975.pdf
http://www.fws.gov/raleigh/species/es_appalachian_elktoe.html
http://explorer.natureserve.org/servlet/NatureServe

Carolina Heelsplitter (*Lasmigona decorate)

Status:
The status of the Carolina heelsplitter (*Lasmigona decorate)* is endangered. The species was listed as endangered on June 30, 1993. Critical Habitat areas for the Carolina heelsplitter were designated on September 2, 2002 (67 Fed. Reg. 44,501-44,522).

Location:
Historically the Carolina heelsplitter occurred in several locations within the Catawba and Pee Dee River systems in North Carolina and the Catawba, Pee Dee, Saluda, and Savannah River systems in South Carolina. Today, only ten populations are known to survive. The species still occurs in two small streams in North Carolina – one in the Catawba River system and one in the Pee Dee River systems. In South Carolina, the Carolina heelsplitter remains in the Pee Dee, Catawba, and the Savannah River systems. Finally, one population exists on the North Carolina/South Carolina State line, in the Catawba River System.

Habitat and Diet:
The Carolina heelsplitter requires cool, clean, well-oxygenated water. Stable, silt-free stream bottoms appear to be critical to the species. Typically stable areas occur where the stream banks are well-vegetated with trees and shrubs. Like other freshwater mussels, the Carolina heelsplitter feeds by siphoning and filtering food particles from the water column.

Threats:
Poor water quality and habitat conditions have led to the decline and loss of populations of the Carolina heelsplitter and threaten the remaining populations. Studies have shown that freshwater mussels, especially in their early life stages, are extremely sensitive to many of the pollutants (chlorine, ammonia, heavy metals, etc.) commonly found in municipal and industrial wastewater releases. Impoundments (dams), channelization projects, and in-stream dredging operations directly eliminate habitat. These activities also alter the quality and stability of remaining stream reaches by affecting the water flow, temperature, and chemistry. Agriculture (both crop and livestock) and forestry operations, roads, residential areas, golf courses, and other construction activities that do not adequately control soil erosion and water runoff contribute excessive amounts of silt, pesticides, fertilizers, heavy metals, and other pollutants that suffocate and poison freshwater mussels. The alteration of floodplains or the removal of forested stream buffers can be especially detrimental. Flood plains and forested stream buffers help maintain water quality and stream stability by absorbing, filtering, and slowly releasing rainwater. This also helps recharge groundwater levels and maintain flows during dry months.

References (Accessed May 12, 2015):
http://www.fws.gov/raleigh/species/es_carolina_heelsplitter.html
http://explorer.natureserve.org/servlet/NatureServe

Cumberland bean pearlymussel (*Villosa trabalis*)

Status:
The status of the Cumberland bean (*Villosa trabalis*) is endangered. The species was listed as endangered on June 14, 1976 (41 Fed. Reg. 24,062).

Location:
The Cumberland bean was historically known from ten river systems in the Cumberland and Tennessee River basins in Alabama, Georgia, Kentucky, Tennessee, and Virginia. Currently, the species survives in only a few streams in the upper Cumberland River system, Kentucky and Tennessee and in the upper Tennessee River system, Tennessee. A relatively strong population still exists in a short reach of the Hiwassee River downstream of the North Carolina/Tennessee State line in Polk County, Tennessee. Although no specimens have been collected in North Carolina, the habitat appears suitable, and the FWS believes the species likely also occurs in small numbers in the North Carolina portion of the Hiwassee River below Appalachia Dam, Cherokee County (J. Fridell, FWS, pers. Comm. 2000).

Habitat and Diet:
The Cumberland bean pearlymussel inhabits small rivers and streams in fast riffles with gravel or sand and gravel substrate. Individuals have been found in riffle and run habitat areas with shallow water depths (less than one meter) and clean, stable substrate. Individuals can often be found in transitional zones between sand and gravel substrates.

Threats:
The Cumberland bean, like most mussels in the Ohio River basin, has been directly impacted by impoundments, siltation, channelization, and water pollution. Reservoir construction is the most obvious cause of the loss of mussel diversity in the basin's larger rivers. Most of the main stem of both the Tennessee and Cumberland River and many of their tributaries are impounded. For example, over 2,300 river miles or about 20 percent of the Tennessee River and its tributaries with drainage areas of 25 square miles or greater are impounded (Tennessee Valley Authority 1971). In addition to the loss of riverine habitat within impoundments, most impoundments also seriously alter downstream aquatic habitat, and mussel populations upstream of reservoirs may be adversely affected by changes in the fish fauna essential to a mussel's reproductive cycle.

Coal mining related siltation and associated toxic runoff have adversely impacted many stream reaches. Numerous streams have experienced mussel and fish kills from toxic chemical spills, and poor land use practices have fouled many waters with silt. Runoff from urban areas has degraded water and substrate quality. Because of the extent of habitat destruction, the overall aquatic faunal diversity in many of the basins' rivers has declined significantly (FWS 1984).

References:
U.S. Fish and Wildlife Service Environmental Conservation Online System
U.S. Fish and Wildlife Service. 1984. Cumberland Bean Pearlymussel Recovery Plan. Atlanta, GA. 58 pp.
http://www.fws.gov/nativeamerican/pdf/tek-fishes-gathered-cherokee-country.pdf
http://www.fws.gov/raleigh/species/es_cumberland_bean.html
http://ecos.fws.gov/docs/recovery_plan/cumberland%20bean%20recov%20plan.pdf
http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=F000

Dwarf wedgemussel (*Alasmidonta heterdon*)

Status:
The status of the Dwarf wedgemussel (*Alasmidonta heterdon*) is endangered. The species was listed as endangered on March 14, 1990 (55 Fed. Reg. 9,447).

Location:
Historically, the dwarf wedgemussel was found from the Petitcodiac River in New Brunswick, Canada to the Neuse River in North Carolina, and was found in 15 major Atlantic slope river systems. It is now extinct in Canada, extirpated in the Neuse River, and present in low densities throughout much of its former range. It is known from 54 locations in 15 major watersheds, with the largest populations in the Connecticut River watershed. North Carolina supports the greatest number of known sites: Neuse River Basin in Orange County, Wake County, Johnston County, Wilson County, and Nash County; and Tar River Basin in Person County, Granville County, Vance County, Franklin County, Warren County, Halifax County, and Nash County. Unfortunately, most of these populations are very small and isolated.

Habitat and Diet:
The dwarf wedgemussel appears to be a generalist in terms of its preference for stream size, substrate and flow conditions. It inhabits small streams less than five meters wide to large rivers more than 100 meters wide; it is found in a variety of substrate types including clay, sand, gravel and pebble, and

sometimes in silt depositional areas near banks. It usually inhabits hydrologically stable areas, including very shallow water along streambanks and under root mats, but it has also been found at depths of 25 feet in the Connecticut River. Dwarf wedgemussels are often patchily distributed in rivers.

Threats:
Impacts including riparian disturbance, pollution, sedimentation, impoundments, artificial flow regimes, and stream fragmentation disrupt mussel life cycles, prevent host fish migration, block gene flow, and prohibit recolonization, resulting in reduced recruitment rates, decreased population densities and increased probability of local extinctions. Toxic effects from industrial, domestic and agricultural pollution are the primary threats to this mussel's survival. Increased acidity, caused by the mobilization of toxic metals by acid rain, is thought to be one of the chief causes of the species' extirpation from the Fort River in Massachusetts. One of the largest remaining populations has declined dramatically in the Ashuelot River, downstream of a golf course. This population probably has been affected by fungicides, herbicides, insecticides, and fertilizers which have been applied to the golf course. Agricultural runoff from adjacent corn fields and pastures also is contributing to this population's decline. Freshwater mussels, including the dwarf wedgemussel, are sensitive to potassium, zinc, copper, cadmium, and other elements associated with industrial pollution.

Short life spans, low fecundity, high degree of host specificity, limited dispersal ability of its primary host, low population densities, coupled with the threats facing the species, likely all contribute to the endangered status of the dwarf wedgemussel.

References (Accessed May 12, 2015):
http://www.fws.gov/raleigh/species/es_dwarf_wedgemussel.html

James spinymussel (*Pleurobema collina*)

Status:
The status of the James spinymussel (*Pleurobema collina*) is endangered. The species was listed as endangered on July 22, 1988 (53 Fed. Reg. 27,689).

Location:
This freshwater mussel is found in the upper James and Dan River basins. The species has declined rapidly during the past two decades and now exists only in small, headwater tributaries of the upper James River basin in Virginia and West Virginia. In 2000, it was discovered in the Dan River basin in North Carolina and Virginia.

Habitat and Diet:
Suitable habitat for this species includes free-flowing streams with a variety of flow regimes. The James spinymussel is found in a variety of substrates that are free from silt.

Threats:
The primary reason for its decline is habitat loss and modification. Threats to this species include siltation, invasion of the non-native Asiatic clam (*Corbicula fluminea*), impoundment of waterways, water pollution, stream channelization, sewage discharge, agricultural runoff including pesticides and fertilizers, poor logging and road/bridge construction practices, and discharge of chlorine.

References (Accessed May 12, 2015):
http://www.fws.gov/raleigh/species/es_james_spinymussel.html

Littlewing pearlymussel (*Pegias fabula*)

Status:
The status of the littlewing pearlymussel is endangered. The species was listed on November 14, 1988 (53 Fed. Reg. 45,861).

Location:
This once wide ranging species once inhabited numerous smaller tributaries of the upper Cumberland and Tennessee River basins in Alabama, North Carolina (Little Tennessee River, Swain County and Valley River, Cherokee County), Kentucky, Tennessee and Virginia. Currently, three populations may still survive in the Cumberland River system and three in the Tennessee River system, including a very small population in the Little Tennessee River, North Carolina. According to information on the NatureServe website with respect to North Carolina, Bogan (2002) cites it from the Hiwassee and Little Tennessee River basins but it is likely nearly extirpated there. LeGrand et al. (2006) also cite it from the Little Tennessee River in North Carolina and also formerly in Valley River in Cherokee Co.

Habitat and Diet:
The littlewing pearlymussel inhabits cool, clear, and relatively high gradient streams (of small to medium size) where it is sometimes found lying on a rocky stream bed in shallow water. However, it is more often hidden under large rocks. The mussels' specific food habits are unknown. However, adults are filter feeders and likely ingest food items similar to those consumed by other freshwater mussels (i.e., organic detritus, diatoms, phytoplankton, zooplankton, bacteria).

Threats:
Poor water quality and habitat conditions have led to the decline and loss of populations of the littlewing pearlymussel and threaten the remaining populations. Impoundments (dams), channelization projects, and in-stream dredging operations directly eliminate habitat. These activities also alter the quality and stability of remaining stream reaches by affecting water flow, temperature, and chemistry.

Agriculture (both crop and livestock) and forestry operations, roads, residential areas, golf courses, and other construction activities that do not adequately control soil erosion and water runoff contribute excessive amounts of silt, pesticides, fertilizers, heavy metals, and other pollutants that suffocate and poison freshwater mussels. The alteration of floodplains or the removal of forested stream buffers can be especially detrimental. Flood plains and forested stream buffers help maintain water quality and stream stability by absorbing, filtering, and slowly releasing rainwater. This also helps recharge groundwater levels and maintain flows during dry months. Acid mine drainage and other water quality impacts associated with gas, oil, and mineral extraction also contribute to imperilment.

References:
N.C. Natural Heritage Program. 2001. Guide to Federally Listed Endangered and Threatened Species of North Carolina: Littlewing pearlymussel. NC Department of Environment and Natural Resources, Raleigh, NC. Page 63.
http://www.fws.gov/asheville/htmls/listedspecies/Littlewing_pearlymussel.html
http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=F00L

http://ecos.fws.gov/docs/recovery_plan/890922.pdf
http://ecos.fws.gov/speciesProfile/profile/speciesProfile?spcode=F00L
http://explorer.natureserve.org/servlet/NatureServe

Tar River spinymussel (*Elliptio steinstansana*)

Status:
The status of the Tar River spinymussel (*Elliptio steinstansana*) is endangered. The species was listed on July 29, 1985.

Location:
The Tar River spinymussel is endemic only to the Tar River and Neuse River systems in North Carolina. In the Tar River system, the species has been documented only from the mainstem of the Tar River, Shocco Creek, Fishing Creek, Little Fishing Creek, and Swift Creek. In the Neuse River system, the species has been documented only from the Little River. Based on the most recent survey data, the species may be extirpated from the mainstem of the Tar River (last observation was a single individual in 2000) and Shocco Creek (last and only record was a shell found in 1993). Only 1 individual was found during the most recent surveys in Swift Creek (2004 – 2005); only 16 individuals in Little Fishing Creek (2008 and 2009); only 4 individuals in Fishing Creek (2008 and 2009); and only 3 individuals have been found during the most recent surveys (2006-2008) of the Little River (Neuse River basin) (one each in 2006, 2007, and 2008 in same general area of the river).

Habitat and Diet:
The Tar River spinymussel lives in relatively silt-free uncompacted gravel and/or coarse sand in fast-flowing, well oxygenated stream reaches. It is found in association with other mussels, but it is never very numerous. It feeds by syphoning and filtering small food particles that are suspended in the water.

Threats:
Based on available data, all surviving populations of the Tar River spinymussel are small to extremely small in size, highly fragmented and isolated from one another, and are in decline. The primary factors affecting the species and its habitat appear to be primarily stream impacts (sedimentation, bank instability, loss of instream habitat) associated with the loss of forest lands and forested riparian buffers, and poorly controlled stormwater runoff of silt and other pollutants from forestry and agricultural (livestock and row crop farming) activities, development activities, and road construction, operation, and maintenance. Pesticides were implicated in the largest known mortality event for Tar River spinymussel. In addition to the above, point source discharges continue to affect and threaten habitat quality in the Tar River, and Wake County, North Carolina has proposed a new water supply reservoir and wastewater discharge which threatens the Little River population of the species.

Neither the State of North Carolina nor the local governments with jurisdictions within the watersheds of streams supporting populations of the Tar River spinymussel, currently have regulations/ordinances that are adequate to protect the species from many of the adverse effects of agriculture, private forestry, and residential and commercial development activities (e.g., degradation or loss of riparian buffers, impacts to the streams' hydrographs, stormwater runoff of sediments and other non-point source pollutants, wastewater discharges, etc.). The majority of the land use activities in watersheds of streams supporting the Tar River spinymussel are occurring without any federal nexus or in cases where a

federal nexus has existed, many of the measures necessary for the protection of the spinymussel and its habitat are not within the permitting or funding federal agencies' authority to implement. Water withdrawals are still largely unregulated in the areas where this species occurs, although the State is considering a water allocation program to address this deficiency. Also, recent studies indicate that current federal and State water quality standards for several pollutants commonly found in wastewater discharges and stormwater runoff are either not available (no criteria or standard derived) or likely not protective of freshwater mussels and current regulations controlling the discharge or runoff of these pollutants are not protective.

The genetic viability of the surviving populations remains a significant concern. All of the remaining populations of the Tar River spinymussel appear to be effectively isolated from one another by impoundments and long reaches of highly degraded habitat; and, the numbers of all of the surviving populations appear to be well below the level necessary to maintain a reproductively viable population. In addition, streams supporting populations of the Tar River spinymussel have been affected by severe - exceptional drought conditions which persisted from the fall of 2006 through the spring of 2009. Flow in reaches of several of the streams supporting the species was significantly reduced and in places completely dried up; the post-drought status of populations of the species is being assessed.

References (Accessed May 12, 2015):
http://www.fws.gov/raleigh/species/es_tar_spinymussel.html

Life History and Habitat Summaries - Fish

***Cape Fear Shiner (*Notropis mekistocholas*)**

Status:
The status of the Cape Fear Shiner (*Notropis mekistocholas*) is endangered. The species was listed as endangered on September 25, 1987 and critical habitat was designated on the same date (52 Fed. Reg. 36,034).

Location:
This species is endemic to the Cape Fear River basin in the east-central Piedmont region of North Carolina, occurring within a 30-mile wide area along the Cape Fear River and tributaries near the Fall Line (Page and Burr 2011).

Habitat and Diet:
According to the Raleigh Field Office website, the Cape Fear shiner is generally associated with gravel, cobble, and boulder substrates, and has been observed in slow pools, riffles, and slow runs. These areas occasionally support water willow (*Justicia americana*), which may be used as cover or protection from predators (e.g. flathead catfish (*Pylodictis olivaris*), bass (*Micropterus spp.*) and crappie (*Pomoxis spp.*)). The Cape Fear shiner can be found swimming in schools of other minnow species but is never the most abundant species. The Cape Fear Shiner's diet probably includes detritus, periphyton, and perhaps macroalgae. This is a highly specialized detritus- and plant-eating species (Page and Burr 1991).

Threats:
Threats include deterioration of water quality due to toxic chemical pollution, changes in stream flow, channel modification, siltation, and impoundments (North Carolina Natural Heritage Program). The species is endangered due to limited distribution and vulnerability to habitat degradation. Habitat has been lost and fragmented due to inundation from dam construction. Remaining small populations are vulnerable to potential threats such as proposed dams and coal mining, road construction, channel modification, waste water discharges (Matthews and Moseley 1990), and increasing development. Species appears to be somewhat sensitive to sedimentation such as may result from agricultural activities.

References (Accessed on May 11, 2015):
http://explorer.natureserve.org/servlet/NatureServe
http://www.fws.gov/raleigh/species/es_cape_fear_shiner.html

Roanoke logperch (*Percina rex*)

Status:
The status of the Roanoke logperch (*Percina rex*) is endangered. The species was listed as endangered on August 18, 1989 (54 Fed. Reg. 34,464).

Location:
This species is known from portions of the Chowan and Roanoke River basins within the ridge and valley, piedmont, and upper coastal plain physiographic regions, including recent collections in North Carolina in the Dan River, Mayo River, and Smith River watersheds. It appears that massive habitat loss associated with the impoundments of the Roanoke River basin in the 1950s and 1960s (Roanoke Rapids, Gaston, Kerr, Leesville, Smith Mountain, and Philpott Reservoirs) was the original cause of significant population declines of this species. In North Carolina, upstream range in the Dan and Mayo Rivers is presumably impeded by dams.

Habitat and Diet:
Roanoke logperch typically inhabit medium-to-large sized warm, clear streams and small rivers of moderate to low gradient. Adults usually occupy riffles, runs, and pools containing sand, gravel, or boulders that are free of silt. Young-of-year congregate in mixed-species schools in shallow habitat underlain by sand and gravel along stream margins. Roanoke logperch actively feed during the warmer months by utilizing their snout to overturn gravel to forage on benthic aquatic macroinvertebrates.

Threats:
Current threats are large dams and reservoirs, small dams/barriers, watershed urbanization, agricultural and silvicultural activities contributing non-point source pollution, channelization, roads, toxic spills/accidents, riparian/woody debris loss, and water withdrawals.

References (Accessed on May 11, 2015):
http://www.fws.gov/raleigh/species/es_roanoke_logperch.html

***Spotfin chub(*Erimonax monachus*)**

Status:
The status of the Spotfin chub (*Erimonax monachus*) is threatened. The species was listed as threatened on September 9, 1977 and critical habitat was designated on the same date (42 Fed. Reg. 45,526). Information on the location of the species and critical habitat was taken from FWS citation sources listed below.

Location:
The spotfin chub is known historically from twelve Tennessee River tributaries in Virginia, Tennessee, North Carolina, Georgia, and Alabama. However, much of the species' historical habitat has been destroyed or seriously altered. Today it survives in the following North Carolina tributary systems - the Little Tennessee River, Macon and Swain Counties, North Carolina and the Cheoah River, Graham County, North Carolina.

Habitat and Diet:
Spotfin chubs inhabit clear water over gravel, boulders, and bedrock in large creeks and medium-sized rivers having moderate current. This fish is rarely seen over sand, and appears to avoid silty areas.

Threats:
Agriculture (both crop and livestock) and forestry operations, mining activities, highway and road construction, residential and industrial developments, and other construction and land-clearing activities that do not adequately control soil erosion and stormwater runoff contribute excessive amounts of silt, pesticides, fertilizers, heavy metals, and other pollutants. The runoff of stormwater from cleared areas, roads, rooftops, parking lots, and other developed areas, which is often ditched or piped directly into streams, not only results in stream pollution but also results in increased water volume and velocity during heavy rains. The high volume and velocity cause channel and stream-bank scouring that leads to the degradation and elimination of fish habitat. Construction and land-clearing operations are particularly detrimental when they result in the alteration of flood plains or the removal of forested stream buffers that ordinarily would help maintain water quality and the stability of stream banks and channels by absorbing, filtering, and slowly releasing rainwater. When stormwater runoff increases from land-clearing activities, less water is absorbed to recharge ground water levels. Therefore, flows during dry months can decrease and adversely affect mussels and other aquatic organisms.

References:
http://www.fws.gov/nativeamerican/pdf/tek-fishes-gathered-cherokee-country.pdf
http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=E012
http://ecos.fws.gov/docs/recovery_plan/831121.pdf
http://www.fws.gov/asheville/htmls/listedspecies/spotfin_chub.html
http://ecos.fws.gov/crithab/
https://www.fws.gov/northeast/virginiafield/pdf/MISC/2014_UTRB_imperiled_aquatic_strategy.pdf

***Waccamaw silverside (*Menidia extensa*)**

Status:
The status of the Waccamaw silverside (*Menidia extensa*) is threatened. The species was listed as threatened on April 8, 1987 and critical habitat was designated on the same date (52 Fed. Reg. 11,277).

Location:
This species is endemic to Lake Waccamaw, which is a shallow Coastal Plain lake in Columbus County, southeastern North Carolina and it also commonly occurs in a feeder stream (Big Creek), upstream to County Road 1947 (Page and Burr 1991). During high water, it has been found in Waccamaw River immediately below Lake Waccamaw Dam.

Habitat and Diet:
This species is usually found near the surface in open water, over a dark sand bottom; not associated with aquatic vegetation. Lake Waccamaw has surface area of about 3640 hectares (ha), averages 2.3 meters in depth; with neutral pH. This species spawns in open water near shoreline, not associated with aquatic vegetation and eats mainly zooplankton, especially cladocerans and ostracods (Davis and Louder 1969).

Threats:
According to the Raleigh Field Office website, runoff and siltation from nearby logging practices, land use changes such as stream channelization and bridge/road construction, and watershed development are the top threats to the Waccamaw silverside. Water quality issues (including increased temperature and nutrient enrichment) from pesticide/herbicide use and wastewater discharges are also prevalent threats. Because the Waccamaw Silverside has an annual life cycle, it is susceptible to rapid extinction given reproductive failure for even a single year. Additionally, the recent invasion of the lake by the Brook silverside (*Labidesthes sicculus*), is of concern.

References (Accessed on May 11, 2015):
http://explorer.natureserve.org/servlet/NatureServe
http://www.fws.gov/raleigh/species/es_waccamaw_silverside.html

Effects of the Action on Species of Interest for ESA Consultation

This section sets out the basis for the EPA's conclusions that the revisions to North Carolina water quality standards are not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of designated critical habitat. This is because, the EPA has determined that this action will have may affect, NLAA-insignificant impacts on the above-described species. These conclusions presume any effects are small relative to the size of the impact and should never reach the scale where "take" to listed species occurs. Therefore, such conclusions would support may affect, NLAA determinations for the seven mussel and four fish species, and any respective designated critical habitat, as listed in Table 1.

Non-Substantive Revisions or Detailed ESA Analysis Not Needed

Before proceeding with the main substance of the EPA's review of the revisions contained in 15A NCAC 02B .0211, Fresh Surface Water Quality Standards for Class C Waters, the following discussion documents the EPA's consultation considerations related to conclusions for all of the other revisions described above in the section titled "Description of Specific Provisions Considered by EPA for ESA Consultation," which the EPA considers to be non-substantive or not needing additional consideration with regard to this consultation, as further described below.

- With regard to the substantive revision in 15A NCAC 02B .0206, Flow Design for Effluent Limitations, the addition of a 1Q10 flow for protection of aquatic life from acute toxicity is a recommended and approvable revision by the EPA and is a method for determining design flows for calculating water quality based effluent limits for National Pollutant Discharge Elimination System permits. Since this provision did not exist in North Carolina's water quality standards prior to these revisions, these provisions do ultimately effect the species of interest for this ESA consultation. However, because this provision is intended to protect the designated uses of a waterbody including protection of aquatic life, the EPA concluded this revision may affect, NLAA – insignificant for any of the listed species or designated critical habitat in North Carolina. Further information regarding the technical basis for approving this provision can be found in Attachment D.

- Further detailed in the EPA's decision document at the beginning of the section titled "15A NCAC 02B .0211 Fresh Surface Water Quality Standards for Class C Waters General paragraph and Subparagraphs (1) through (9)"are a number of revisions which the EPA is approving but are considered non-substantive due to the nature of the revisions. Revisions that are considered non-substantive in this section include changes such as improving readability or adding introductory text, removing regulation sections which no longer exist, and reordering and renumbering due to alphabetizing. Such changes are articulated fully in the decision document and the EPA has concluded such revisions will have no effect on any of the listed species or designated critical habitat in North Carolina as they are editorial in nature and do not affect the applicable water quality criteria of the state.

- In the EPA's review of the state's revisions, the EPA is approving the removal of the action level for iron from 15A NCAC 02B .0211(22). In the absence of the action level, the State has indicated that designated uses will continue to be protected by the narrative criterion at 15A NCAC .0211(12), "[o]ils, deleterious substances, colored, or other wastes: only such amounts as shall not render the waters injurious to public health, secondary recreation, or to aquatic life and wildlife, or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated uses." The EPA's consideration for consultation is focused only on the removal of the action level for iron, as that is the only change subject to the EPA's current CWA 303(c) review, but the EPA does note that the narrative standard continues to provide an option for regulating anthropogenic sources of iron. The State provided information indicating that iron occurs at naturally high levels in the state, often above the numeric value of 1 mg/L (value of the action level that is being deleted), and the EPA's scientific review found the revision to be defensible. Since this provision is changing the applicable water quality standard from an action level of 1 mg/L to the narrative criterion that takes into account naturally high

iron levels in the state, these provisions do ultimately effect the species of interest for this ESA consultation. However, since this provision will protect the designated uses of a waterbody including protection of indigenous aquatic life where naturally high iron levels are appropriate, the EPA concluded this revision is a may affect, NLAA-insignificant effect for listed species or their designated critical habitat. Further information regarding the technical basis for approving this provision can be found in Attachment D.

- As noted above, there are revisions to 15A NCAC 02B .0212-.0218, Fresh Surface WQS for Class WS-1 through WS-V Waters. The revisions are located in section (h) of each of the five water supply designated use classifications and remove the manganese numeric criterion and revise the 2, 4 Dichlorophenoxyacetic acid (2, 4 D) numeric criterion. Since both of these criteria are located within a designated use which is related to human uses, the EPA's concluded there is no discretion to consult further on these revisions. This is because the EPA's discretion to act on a State submission, is limited to determining whether the criteria ensure the protection of designated uses upon which the criteria are based. The EPA has no discretion to revise an otherwise approvable human health criteria to benefit listed species.

- Portions of 15A NCAC 02B .0212-.0218 were modified for clarification, grammar, and reorganization. Such changes are articulated fully in the decision document (Attachment D) and the EPA has concluded such revisions will have no effect on any of the listed species or designated critical habitat in North Carolina as they are editorial in nature and do not affect the applicable water quality criteria of the state.

Research Strategy to Supplement Existing Data/Literature for Remaining Provisions

As part of the informal ESA consultation, Tom Augspurger with the FWS, Raleigh, North Carolina Field Office provided a data research strategy on June 9, 2015, with regard to the species which are present in fresh waters, to which the EPA agreed. The strategy defined the approach in which the agencies could work together to request and obtain the best scientific and commercial data available for use in this consultation.

The first step, which was coordinated with EPA Headquarters, was to complete database retrievals regarding available data sets compiled as part of the EPA's development of recommended ambient water quality criteria (AWQC). Discussions with Wade Lehmann (EPA HQ) regarding available databases/datasets relating to AWQC, concluded that chromium III, chromium VI, and copper were most recently addressed in the BE of Oregon's Water Quality Criteria for Toxics dated January 2008, data for arsenic, cadmium, copper could be obtained from the Idaho Water Quality Standards for Toxic Substances Biological Opinion (BO) prepared by the NMFS dated May 2014, and data for cadmium was obtained from the California Toxics Rule (CTR) BO. There were no recent data updates for beryllium, lead, nickel, silver or zinc. More recent work at EPA Headquarters is in progress for cadmium and copper, but is not yet complete.

The EPA considered the suggested BE and BO developed as part of the EPA actions in other regions relating to the same criteria adopted by North Carolina, with the assumption that they reflected a more recent compilation of relevant best available scientific data for the toxics that this consultation addresses. In reviewing these historical documents, it became clear that, while they contained a great

amount of useful information, the results were not completely transferable, in the absence of other supplementary information, for reasons detailed later in the EPA's analysis.

In addition, the EPA asked EPA Headquarters and other regional offices for any recent data synthesis efforts or other consultations. The result of the EPA's inquiries generally pointed back to the existing BE and BO that had been completed for specific consultations. Also, due to the concurrent consultation effort with NMFS, the EPA also inquired and received more information related to existing BOs and other data sources. Similarly, the FWS contacted other sources of potential information (such as other regional FWS offices, ORD labs, science centers, etc.) that might have additional data to aid in the consultation effort. In response to part of the FWS's efforts in this step, Tom Augspurger provided the EPA staff with an extensive amount of journal articles for five of the subject parameters: cadmium, copper, lead, nickel, and zinc - based on files already available for his use and information others provided to supplement those files.

After reviewing the articles Mr. Augspurger provided, the EPA determined many of these papers provided information that could be used as a supplement to the existing BE and BO and, therefore, serve to address gaps that may exist had the EPA solely relied on the results of the existing BE and BO.

A third component of the strategy included asking numerous metals industry groups what was available in their databases. Mr. Augspurger provided the files he received to the EPA and they were evaluated to determine if they could supplement the existing data set.

Finally, the EPA Region 4 staff completed an advanced database query of the ECOTOXicology database (ECOTOX) which is a source for locating single chemical toxicity data for aquatic life, terrestrial plants and wildlife. ECOTOX was created and is maintained by the U.S. EPA, Office of Research and Development and the National Health and Environmental Effects Research Laboratory's Mid-Continent Ecology Division. ECOTOX integrates three previously independent databases - AQUIRE, PHYTOTOX, and TERRETOX - into a unique system which includes toxicity data derived predominately from the peer-reviewed literature, for aquatic life, terrestrial plants, and terrestrial wildlife, respectively. An advanced database query was completed for each chemical using the predefined chemical groups search key to ensure all metal compounds were included. Other search parameters were defined as follows:

Taxonomic Selection

Genus/Species Name(s) to be searched on:
Acipenser brevirostrum – Shortnose sturgeon
Acipenser oxyrhynchus – Atlantic sturgeon
Erimonax monachus – Spotfin chub
Menidia beryllina - for Waccamaw Silverside
Menidia menidia – for Waccamaw Silverside
Menidia peninsulae – for Waccamaw Silverside
Menidia sp. – for Waccamaw Silverside
Notropis mekistocholas – Cape Fear Shiner
Percina caprodes – for Roanoke Logperch
Percina sp. – for Roanoke Logperch
Unionoida – for all 7 mussel species

Test Results Selection

Endpoint(s) to be searched on :
Concentration Based Endpoint(s):
LC/LD xx (all % values)
LC50
LD50

EC/ED xx (all % values)
EC50/ED50

LOEC/LOEL
NOEC/NOEL

Effect Measurement(s) to be searched on :
Behavior Group
Avoidance
Behavior
Feeding Behavior

Growth Group
Developmental
Growth
Morphological

Reproduction Group
Reproduction
Avian/Reptilian Egg

Test Conditions Selection

Test Location(s) to be searched on :
All Field Tests
Field, Artificial
Field, Natural
Field, Undeterminable
Lab

Exposure Media to be searched on :
Water - Fresh Water
Water - Salt Water

Exposure Type(s) to be searched on :
Environmental
Flow-through
Lentic
Lotic
Renewal
Static
Tidal

Control Type(s) to be searched on :
Baseline(B)
Concurrent(C)
Historical(H)

Chemical Analysis Method(s) to be searched on :
Measured

Publication/Updates Selection

Publication Year(s) to be searched on :
Starting Year: One year prior to publication year of 304(a) criteria document
Ending Year: *2016*
All **Authors** to be searched
All **Test Number(s)** to be searched
All **Reference Number(s)** to be searched
All **Independently Compiled Data Sets** to be searched
All **Recent Modification/Updates** to be searched

The advanced database query ECOTOX search, yielded no additional information that was not already included in the previous interim BE prepared to support the ESA section 7(d) memorandum.

Discussion of Expected Improvements in Water Quality in North Carolina

As noted in many of the descriptive narratives for the listed fish and mussel species above, water pollution and in particular metals toxicity represent some of the major threats to these species. It is the EPA's determination that implementation of the new and revised metals criteria will reduce these listed species' exposure to metals. Reducing the allowable level of metals in state waters is a critical step in attaining and/or maintaining the goal of the CWA to restore and maintain the chemical, physical, and biological integrity of the Nation's waters (also referred to as "fishable/swimmable") through the improvement of water quality. It is also the goal of the ESA to conserve listed species and their designated critical habitat in the state of North Carolina. The following table compares North Carolina's previous metals criteria with the new or revised criteria and with EPA's recommended criteria.

Non-Hardness Dependent Metals				
Metal (all values are dissolved)	**NCDWR's Previous Criteria (ug/l)**	**NCDWR New/Revised Criteria (ug/l)**	**EPA's Recommended Criteria (ug/l)**	**EPA's Reference for Recommended Criteria**
Arsenic (acute)	--	340	340	*1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water* (EPA 1995)
Arsenic (chronic)	50 ug/l	150	150	
Beryllium (acute)	--	65	--	N/A
Beryllium (chronic)	6.5	6.5	--	
Chromium VI (acute)	--	16	16	EPA 1995
Chromium VI (chronic)	--	11	11	
Silver (chronic)	0.06 Action Level only	0.06	--	N/A

Hardness Dependent Metals				
Metal (all values are dissolved)	**NCDWR's Previous Criteria (ug/l)**	**NCDWR's Criteria calculated at a hardness of 25 (ug/l)**	**EPA's Nationally Recommended criteria calculated at a hardness of 25 (ug/l)**	**EPA's Reference for Recommended Criteria**
Cadmium (acute)	--	0.82	0.52	EPA 2001
Cadmium (acute, trout waters)	--	0.51	0.52	
Cadmium (chronic)	0.4 ug/l trout waters 2.0 ug/l non-trout waters	0.15	0.09	
Chromium III (acute)	-	180	183.07	*(EPA 1995)* *(EPA 1999)*
Chromium III (chronic)	-	24	23.81	
Copper (acute)	-	3.6	N/A	*(EPA 2007)* *(EPA 1999)*
Copper (chronic)	Action Level 7.0	2.7	N/A	
Lead (acute)	-	14	13.88	*Ambient Water Quality for Lead – 1984; (EPA 1984)*
Lead (chronic)	25	0.54	0.54	
Nickel (acute)	-	140	144.92	*(EPA 1999)*
Nickel (chronic)	8.3	16	16	
Silver (acute)	-	0.30	0.3	*Ambient Water Quality Criteria for Silver;* *(EPA 1980)*
Zinc (acute)	-	36	36	*(EPA 1999)*
Zinc (chronic)	Action Level 50	36	36	

Discussion of Recovery Plans and Exposure Pathways by Species of Concern

The EPA has provided an excerpt from the species-specific recovery plan developed by the FWS and/or NMFS along with a conclusion regarding risks to the species and potential exposure pathways for each species of concern. For those with critical habitat, the designation is denoted in the respective species heading with an asterisk by the species name.

*Appalachian Elktoe**

Although not exclusively specific to metals, the recovery plan for the Appalachian elktoe (dated Aug. 26, 1996) addresses the impact of common pollutants, including metals that could be present in North Carolina's freshwaters:

> Mussels are also known to be sensitive to numerous other pollutants, including, but not limited to, a wide variety of heavy metals, high concentrations of nutrients, and chlorine--pollutants that are commonly found in many domestic and industrial effluents (Havlik and Marking 1987). In the early 1900s Ortmann (1909) noted that the disappearance of unionids (mussels) is the first and most reliable indicator of stream pollution. Keller and Zam (1991) concluded that mussels are more sensitive to metals than commonly tested fish and aquatic insects. The life cycle of native mussels makes the reproductive stages especially vulnerable to pesticides and other pollutants (Ingram 1957, Stein 1971, Fuller

> 1974, Gardner et al. 1976). Effluent from sewage treatment facilities can be a significant source of pollution that can severely affect the diversity and abundance of aquatic mollusks.

According to the Appalachian elktoe's recovery plan, if the species is to survive and expand its range, protection of the existing populations and remaining areas of suitable habitat is vital. One critical step identified is to utilize existing legislation and regulations (including State water quality regulations) to protect the species and its habitat. In summary the recovery plan states "[p]rior to and during implementation of this recovery plan, the present populations can be protected only by the full enforcement of existing laws and regulations. Unless this objective is met, any recovery activities would be essentially moot. Habitat and water quality degradation have severely reduced the species' range and continue to threaten the only remaining populations. Complete compliance with Federal and State laws and regulations designed to protect water and habitat quality must be ensured if the Appalachian elktoe is to survive."

Therefore, the EPA determined that regulating the amount of pollutants that could result in potential exposure to the Appalachian elktoe is an important consideration in the EPA's determination of any potential for effect to this listed species or its critical habitat. Based on the available information at the time this BE was prepared, the Appalachian Elktoe is present in eleven counties in North Carolina, of which nine counties (Graham, Haywood, Jackson, Macon, Mitchell, Swain, Transylvania, and Yancey) are listed as having critical habitat. The two counties without critical habitat identified are Buncombe and Henderson.

*Carolina Heelsplitter**

The Carolina heelsplitter faces essentially the same challenges as the Appalachian elktoe. The recovery plan for the Carolina heelsplitter (dated Jan. 17, 1997) specifically notes:

> Heavy nutrient and pollutant loads (i.e., fertilizers, organic wastes, pesticides, heavy metals, oil, salts, etc.) from wastewater treatment facility effluents, agricultural activities (crop and livestock), forestry operations, urban and rural residential and industrial areas, highways, and other point and nonpoint sources also threaten the continued existence of the remaining populations. Though at present this appears to be more of a problem in the Lynches River than in the other streams, it will likely become more of a threat to the other three populations as development increases within their drainages.

As was noted for the Appalachian elktoe, the use of state regulations, including water quality standards, will need to be utilized to protect the species and its habitat. Therefore, the EPA determined that regulating the amount of pollutants that could result in potential exposure to the Carolina heelsplitter is an important consideration in the EPA's determination of any potential for effect to this listed species or its critical habitat. Based on the available information at the time this BE was prepared, the Carolina Heelsplitter is present in three counties in North Carolina, of which one county (Union) is listed as having critical habitat. The two counties without critical habitat are Burke and Mecklenburg.

Cumberland Bean Pearlymussel

As with the other mussel species, the Cumberland bean pearlymussel recovery plan (dated Aug. 22, 1984) identifies the likely greatest factor resulting in the species' decline as the alteration and destruction of stream habitat. In the case of the Cumberland bean pearlymussel, pollution follows sedimentation in rounding out the three biggest impacts to the species. Ortmann (1918) indicated a number of streams where mussels were no longer present downstream of specific dischargers, including the French Broad River at Asheville and the Big Pigeon River from Canton, to its mouth. Although this study is older, it represents historical findings of the possibility of impacts from point sources and supports the repeating finding for the recovery plans of mussels that encourages protection of the species by encouraging States to use existing laws and regulations.

Therefore, the EPA determined that, as with the other mussel species, the actions that support regulating the amount of pollutants that could result in potential exposure to the Cumberland bean pearlymussel is an important consideration in the EPA's determination of any potential for effect to this listed species. Based on the available information at the time this BE was prepared, the Cumberland Bean pearlymussel is present in one county (Cherokee) in North Carolina.

Dwarf Wedgemussel

Concern with water pollution is again discussed in the recovery plan developed for the Dwarf wedgemussel (dated Feb. 8, 1993). Zinc, copper, and cadmium (Havlik and Marking 1987), along with nickel, lead, and chromium, were investigated by Mathis and Cummings (1973). Mussels appeared to concentrate zinc to a greater degree than all other metals in the study. Havlik and Marking's study indicated long term exposure to copper as low as 25 ppb was lethal. The recovery plan identified point and nonpoint source pollution as threats in North Carolina, although compared to other locations the populations appeared to be faring better than in other states, in most instances. In addition to action items including additional analysis to better understand the location of pollution sources relative to Dwarf wedgemussel populations, the use of existing state regulations was again mentioned as one important action needed to support recovery efforts.

Therefore, the EPA determined that regulating the amount of pollutants that could result in potential exposure to the Dwarf wedgemussel is an important consideration in the EPA's determination of any potential for effect to this listed species. Based on the available information at the time this BE was prepared, the Dwarf wedgemussel is present in 11 counties (Franklin, Granville, Halifax, Johnston, Nash, Orange, Person, Vance, Wake, Warren, and Wilson) in North Carolina.

James Spinymussel and Littlewing Pearlymussel

There was not any substantially different information contained in the recovery plan for the James spinymussel (dated Sept. 24, 1990) or Littlewing pearlymussel (dated Sept. 22, 1989) compared to the mussel species discussed so far. Therefore, the EPA determined that regulating the amount of pollutants that could result in potential exposure to the James spinymussel and Littlewing pearlymussel is an important consideration in the EPA's determination of any potential for effect to this listed species. Based on the available information at the time this BE was prepared, the James spinymussel is present in

three counties (Caswell, Rockingham, and Stokes) in North Carolina and the Littlewing pearlymussel is present in three counties (Cherokee, Macon, and Swain) in North Carolina.

Tar River Spinymussel

The recovery plan for the Tar River spinymussel (dated May 5, 1992) describes in more detail the possibility of threats to the Tar River spinymussel, by noting that "although the area is largely undeveloped, activities within the basin have had profound effects on the aquatic fauna." A report issued by the North Carolina Department of Environment, Health, and Natural Resources (NCDEHNR 1985) indicated that biological and water quality in the Tar River basin is fair to good, but several significant problems still exist. Identified as one of the most significant factors, pollution (including pesticide and nutrient loadings) from private, municipal, industrial, silvicultural, and agricultural sources is believed to be contributing to the past and continuing decline of these species. However, Clarke (1983) stated that mussel populations may become reestablished as a result of improved water quality.

Therefore, as in the case of all other mussel species discussed in this section, the EPA determined that regulating the amount of pollutants that could result in potential exposure to the Tar River spinymussel is an important consideration in the EPA's determination of any potential for effect to this listed species. Based on the available information at the time this BE was prepared, the Tar River spinymussel is present in seven counties (Edgecombe, Franklin, Halifax, Johnston, Nash, Pitt, and Warren) in North Carolina.

*Cape Fear Shiner**

The recovery plan for the Cape Fear shiner (dated Oct. 7, 1998) indicates that "due to the species' limited distribution, any factor that degrades habitat or water quality in the short river reaches it inhabits could threaten the species' survival." In general the recovery action items are similar to those listed for mussels, including the utilization of state regulatory mechanisms.

Therefore, the EPA determined that regulating the amount of pollutants that could result in potential exposure to the Cape Fear shiner is an important consideration in the EPA's determination of any potential for effect to this listed species or its critical habitat. Based on the available information at the time this BE was prepared, the Cape Fear shiner is present in five counties, four of which also have critical habitat (Chatham, Lee, Moore, and Randolph) in North Carolina. The county without critical habitat is Harnett County.

Roanoke Logperch

In addition to the general language related to utilizing state regulatory mechanisms, the recovery plan for the Roanoke logperch (dated Mar. 20, 1992) specifically highlights recommendations made by the FWS and two other agencies to the Virginia Water Control Board to designate specific reaches for the protection of the Roanoke logperch. Additionally, the plan suggests that National Pollutant Discharge Elimination System (NPDES) permits within or upstream of river reaches, occupied by Roanoke logperch, should be conditioned to maintain or improve water quality for this species, in addition to utilizing enforcement of regulations controlling nonpoint sources (such as Section 208 of the Clean Water Act).

Therefore, the EPA determined that regulations which control the amount of pollutants that could result in potential exposure to the Roanoke logperch is an important consideration in the EPA's determination of any potential for effect to this listed species. Based on the available information at the time this BE was prepared, the Roanoke logperch is present in one county (Rockingham) in North Carolina.

*Spotfin Chub**

In the recovery plan for the spotfin chub (dated Nov. 21, 1983), the reasons for the "reduction or extirpation of the initial spotfin chub populations from most of their former range were likely due to intermittent detriments or permanent destruction of their habitats" including habitat modifications and pollution, among other reasons. Although in the North Carolina reaches of the species habitat the recovery plan addresses specific needs related to impacts on the species related to the heavy sediment load, the Virginia portion of the species habitat does address the need to determine the impact of pollution from sources in that state. Given the age of the recovery plan, it would not be unreasonable to assume that even if pollution was not specifically identified as a source of concern in North Carolina, it could have since become an issue as the state has become more populated and developed in the past 30 or more years. Lastly, as is the case for many of the other species, the recovery plan for the spotfin chub also indicates use of existing state regulations as one important action needed to support recovery efforts.

Therefore, the EPA determined that regulating the amount of pollutants that could result in potential exposure to the spotfin chub is an important consideration in the EPA's determination of any potential for effect to this listed species. Based on the available information at the time this BE was prepared, the spotfin chub is present in three counties, two of which also have critical habitat (Macon and Swain) in North Carolina. The county without critical habitat is Buncombe County.

*Waccamaw Silverside**

Although a recovery plan exists for the Waccamaw silverside (dated Aug. 11, 1993), the EPA reviewed the five year review (dated Feb. 10, 2011) that was available on the FWS recovery plan page. In the review, the Waccamaw silverside while still commonly found, is noted as remaining "vulnerable to threats to water quality and habitat degradation from man-made land-use activities." It is also noted that the objective of the recovery plan is to "protect and maintain a self-sustaining population of Waccamaw silverside in Lake Waccamaw and to protect its habitat from present and foreseeable threats." The first objective appears to be taking place and there are notable efforts which have taken place to protect the specie's habitat. The review also indicates the lake has been designated as an Outstanding Resource Water by the North Carolina Division of Water Quality, which includes special management requirements, as well as a portion of the lake being protected as a state park since 1976. Threats remain in the remaining portion of the land which is not under state ownership including land development and alteration that result in substantial nutrient loading. While it appears the residential development and related nutrient impacts to the system are of a primary concern for this waterbody, the EPA has determined that the adoption of new and revised chemical criteria relative to metals, while not specifically known to be relevant at this specific location, would still be a good method by which to improve overall water quality.

Therefore, the EPA determined that regulating the amount of pollutants that could result in potential exposure to the Waccamaw silverside is an important consideration, even at a potentially discountable level, in the EPA's determination of any potential for effect to this listed species. Based on the available information at the time this BE was prepared, the Waccamaw silverside is present in one county (Columbus), which also has designated critical habitat.

Consideration of Best Available Scientific and Commercial Data - Discussion of Existing Biological Opinions and Comparison of Other Data to North Carolina's Revised Water Quality Criteria

As required by the ESA, the EPA has considered and analyzed the best available scientific and commercial data, including historic BEs and BOs from recent ESA section 7 consultations conducted for CWA 303(c) actions with the FWS and NMFS. These BEs and BOs considered the possible effects of the same parameters (often at the same concentrations) that are being considered by the EPA in this review. The findings of those BOs are included in Attachment B. In addition, the EPA also analyzed the best available scientific and commercial data specific to mussels and fish that were considered to be more comparable to the species located in North Carolina's waters than the salmonid-focused conclusions of the existing BOs. The more regionally relevant information associated with the mussel and fish specific information is contained in Attachment C and summarized by parameter as part of Attachment B. The overall findings from these two Attachments are discussed below.

In its analysis, the EPA considered the historic BOs completed by the FWS and NMFS for water quality standards actions in Oregon, Idaho, and the CTR. In Attachment B, the EPA summarizes the conclusions reached from comparing North Carolina's water quality criteria (usually converted to reflect a hardness of 100 mg/L for ease of comparison) to the combination of positive and adverse findings in the historical BOs. For example, some species were determined to have no effect or were determined to be may affect, NLAA by the criteria revisions adopted by the western states. There were also some species, typically salmonids, that were adversely impacted at lower concentrations compared to other species present in the aquatic system. It was noted that, adverse findings in the historical BOs, could be reversed with the implementation of reasonable and prudent alternatives (RPA) developed by the Services. Although there are not specific salmonid species of concern in North Carolina waters, the EPA's consideration of the historical BOs was one initial set of scientific data reviewed to determine any possible adverse effects to listed species of concern for the North Carolina water quality standards action addressed by this BE.

By considering the differences, or in many cases, the similarities between the historical BO analyses to the criteria adopted by North Carolina, the EPA determined whether the North Carolina criteria values had been previously determined to be protective or not, of the western state species. The EPA concluded that when compared to the water quality criteria adopted by North Carolina, many of the historic BOs prepared by FWS and NMFS concluded that an equivalent or more stringent concentration would be unlikely to jeopardize the continued existence of listed species or adversely modify critical habitat. When the conclusion was the North Carolina's criteria were less stringent or that the historic BO had made an adverse finding, additional discussion and analysis, such as that in Attachments B and C, was provided to document the EPA's review. Additional details of the findings, including the specifics of species and critical habitat conclusions, for each BO can be found in the footnotes and general content contained in Attachment B. Attachment B presents a color-coded row for each acute and chronic

numeric criteria value by parameter, further discusses the EPA's analyses for all types of findings from the respective historic BOs, and discusses how it relates to the equivalent concentrations that were adopted by North Carolina and are the subject of this BE. The following table depicts how the EPA characterized the Services' conclusions from the BOs within Attachment B:

Services' Conclusion	**Cell Color**
May affect, NLAA or No Effect	Green Highlighted Cells
May affect, Likely to Adversely Affect (LTAA), but implementation of the Services' RPA, would render the conclusion no longer adverse	Orange Highlighted Cells
Some Effect Finding – Did not rise to level of LTAA and no RPA was identified	Yellow Highlighted Cells

To supplement the EPA's analysis of historical BOs, the EPA compiled the information in Attachment C from papers provided by Tom Augspurger (herein referred to as "supplemental papers"). For each parameter in Attachment B, there is a section titled "EPA's Conclusion for…" in which the EPA has summarized the results of the analyses of the supplemental papers documented in greater detail in Attachment C. It should be noted that EPA's review of the historical BOs addressed the following parameters: arsenic, cadmium, chromium III, chromium VI, copper, lead, nickel, silver, and zinc. As noted above, the BO related information was also supplemented with the results of the EPA's analyses of the supplemental papers for the following parameters: cadmium, chromium VI, copper, lead, nickel, and zinc. Beryllium was not discussed in any of the BOs or supplemental papers.

Before providing a summary of the quantified results of the EPA's analyses of the more localized or relative species comparisons for the six parameters addressed in the supplemental papers, the EPA provides the following discussion regarding its interpretations of the ranges found in the papers:

> In some instances, the supplemental papers provided significant ranges in toxicity values for a given parameter. There are a number of reasons why this range may exist. Differences may be due, in part, to differences in the endpoints studied within a paper (i.e., median lethal concentration of a toxicant with 50% survival rate [LC50] vs. no observed effect concentration [NOEC]), the use of different species within each mussel or fish tests and their resulting sensitivity differences, or the range in hardness values used in each tests (although the EPA attempted to correct for this through comparisons of a most comparable hardness for each test). The goal was also to select the most sensitive result of the study, which could have the effect of providing a potentially less comparable species to those species present in North Carolina.
>
> Based on information in the 1985 Aquatic Life Criteria Guidelines and the generally accepted calculation that an acute value (LC50) divided by 2 results in an LC1 or LC0 value, the EPA determined that any study that has an acute value that is $\geq$2 times the criteria should build the case of the criteria being protective of listed species, or at a minimum resulting in an insignificant effect or exposure to the species. Therefore, additional commentary will be provided for values that reflect results which indicate toxicity is occurring at an equivalent or lower concentration than the adopted criterion value, or more specifically for those studies where the value is <2.

Supplemental Papers Findings

Although more detail can be found in Attachments B and C, the following summarizes the findings and additional commentary discussing values <2 following the EPA's review of the supplemental papers obtained by the call for data carried out by the FWS:

- Cadmium
    - For mussels, the acute toxicity results ranged from ~seven to 597 times the acute non-trout criterion, ~10 to 952 times the acute trout criterion, and ~five to 769 times the chronic criterion.
    - In the four papers available for cadmium effects on fish, the analysis indicated that the toxicity results were ~1.5 to 17 times the acute non-trout, ~ 1.6 to 26 times the acute trout criteria, and ~2 to 7.6 times the adopted chronic criterion at the equivalent hardness levels from the respective studies.
        - The ~ 1.5 times the non-trout acute criterion result reflects the acute LC50 of the Missouri sculpin, which is not a North Carolina species. It is also important to note that 1) the other species in the test, one of which was a rainbow trout which does exist in North Carolina, had higher LC50s which would have improved the comparison and 2) North Carolina has adopted a trout specific acute number which protects aquatic life with more stringent criteria than the acute criterion for non-trout waters. It is possible that these more stringent criterion will apply to some of the same waters where listed mussels and fish species are present; this could be a consideration in any future analysis.
        - The ~1.6 times the acute trout criteria result reflects one study's acute LC50 for rainbow trout for three specific life stages in lab water (18, 46, and 95 days post hatch). There are additional studies that reflect higher LC50 values for rainbow trout. Some studies suggested that site specific characteristics affected cadmium toxicity in site water studies and further analysis into the use of a WER could be a consideration in any future analysis.

- Chromium VI
    - One study that addressed mussels only was available for this parameter. Based on the most stringent toxicity level reported, the toxicity level was ~ 2.5 times greater than North Carolina's acute criterion.

- Copper
    - For mussels, the acute comparison results ranged from 56% of the equivalent acute criterion for copper (except for the zebra mussel studied which was 5%) to 21.7 times the acute criterion, with many of the values being greater than North Carolina's equivalent criterion

values.[5] The chronic mussel results varied from 34 to 63% (based on chronic values) of, 1.2 to 2.5 times greater than, the chronic criterion equivalent.

- The 56% of the acute criterion result was comparable to another study in which 57% was the result, but was based on a longer duration test of the EC50. Although the longer duration study was comparable among most stringent EC50s, another less stringent EC50 result was calculated for the Tar River Spiny mussel, a species present in North Carolina waters. This alternate EC50 was found to be 1.3 times the criterion equivalent. In one additional study, the results were 54% of the criterion, but the study identified the concentration tested as "non-acutely toxic" in order to test the effects of thermal stress in the presence of low copper levels. Therefore, some weight should be given to these percentage of criterion values[6], recognizing that they are important to consider in conjunction with all of the other available results.
- The 5% of the acute criterion result is based on the toxicity of copper to the zebra mussel which is an invasive species; therefore, the EPA determined these toxicity results were not appropriate for consideration. In the same study, a native mussel was used, and although not located North Carolina it provides a better result for inclusions in the EPA's analysis as it represents a native species.
- The 34 and 63% of the chronic criterion results reflect the most stringent chronic values for growth and survival. However, these results should be considered along with the other chronic results, discussed in the following bullet, while also recognizing that there is a much more limited amount of chronic information available compared to the acute copper toxicity information.
- The 1.2 times greater than the chronic criterion result reflects the most stringent NOEC. If the most stringent lowest observed effect concentration (LOEC) is considered, the result goes from 1.2 times greater to 2.5 times greater than the equivalent chronic criterion. For the remaining values in the range of one to two times the equivalent criterion, these do reflect the most stringent species or results within species from the respective studies and are considered among the total results in reaching the EPA's final conclusions on copper toxicity effects on the listed species in North Carolina.

- For fish, the most stringent LC50 values compared to the acute criterion (calculated at a hardness to match the study) were 1.2-7.9 times the value adopted by the state. The 1.2 value is for a Missouri Sculpin. For chronic toxicity, the effects concentrations are ~38% of to 3.4 times the state's criterion (lowest also for Missouri Sculpin).
- Fish species in the freshwater studies for copper toxicity are often not native species to North Carolina (i.e. Missouri sculpin, rainbow trout). There is uncertainty with the comparison and

[5] Out of 28 mussel related studies, 23 studies addressed acute toxicity, two studies addressed chronic toxicity, and three studies were not used. Of the 23 acute mussel studies, six studies gave percentage of the criterion results, six studies gave results between one and two times the adopted criterion equivalent, and 11 studies gave results two times or greater than the adopted criterion equivalent. Of the six percentage of the criterion results, three of those are given less weight and moved into the second category (one to two times the criterion). Therefore, of the 23 acute results, 20 of 23 (~87%) are equivalent or greater than the acute criterion equivalent adopted by North Carolina.

[6] There were two additional percentages, 72% and 85%, which reflected 48 hour LC50 values, and were considered in the EPA's total weighting of the results for copper, addressed in footnote 3.

extrapolation of data from species that are not native to the state. Differences in geographic ranges result in potential differences in water quality parameters, such as hardness, pH, and DOC that could affect copper toxicity. Further investigation into site specific considerations is important in determining copper toxicity. North Carolina has adopted WERs and the Biotic Ligand Model as part of their criteria. A quantitative comparison of BLM criteria to the laboratory studies was not possible, because the multiple input water quality parameters for the BLM were not always reported in the studies. Thus, application of a WER or BLM standard, which uses site specific water quality parameters, is an important consideration.

- Lead
  - Among the mussel information provided for lead, the acute toxicity levels were ~ 2.5 to 3.5 times greater than the acute criterion equivalent. With regard to the mussel chronic toxicity information, the 28 day chronic value was 10.9 times greater than the adopted criterion equivalent and Mosher et al. 2012 indicated that the equivalent chronic criterion level, 0.92 µg/L at 40 mg/L hardness, was comparable to a level (0.9 µg/L) found in natural populations of mussels in North Carolina.
  - For fish, the acute toxicity information indicates levels at ~ 3.5 to 36 times the acute criterion equivalents. The chronic toxicity information indicates levels greater than 10.8 times the State's chronic criterion.

- Nickel
  - The acute values for mussels ranged from 88% of , to ~1.6 times greater than the acute criterion. For chronic considerations, a NOEC for survival was determined to be ~ 1.3 times the chronic criterion.
    - The 88% of the acute criterion result reflects the most stringent 96 hr LC50 test result from the study.
    - The 1.6 times greater than the acute criterion result represents a 24 hr LC50 for the most sensitive species. The least sensitive species had an LC50 three times greater than the most sensitive species.
    - The 1.3 times greater than the chronic criterion result represents the NOEC-survival level and LOEC-growth and biomass levels.

- Zinc
  - The mussel toxicity values were greater than the acute criterion equivalent, ranging from ~1.6 to 16.7 times greater. In one instance, where hardness could not be verified, the toxicity information potentially resulted in a value 73% of the acute criterion equivalent. The chronic toxicity information of mussels showed a similar range of greater than values, ranging from ~1.6 to 16.7 times greater than the chronic criterion adopted by North Carolina.
    - The ~1.6 times greater than the acute criterion result represents a 48 hr EC50, but confounding factors, including low pH and simultaneous testing with other metals, make a more direct comparison of this value to other results difficult.
    - The ~1.6 times greater than the chronic criterion result represents a NOEC level. If the LOEC was used the difference would be greater.

- The toxicity values for acute and chronic effects to fish ranged from 91% of to 7.2 times greater and 64% of to ~6 times greater than the acute and chronic criteria, respectively.
    - The 91% of the acute criterion result was based on the most sensitive test species in the study and did not reflect local species. The rainbow trout, which is present in North Carolina, had an LC50 ~2.7 times that of the sculpin representing the most stringent LC50. The 64% of the chronic criterion result was based on the most sensitive test species in the study and did not reflect local species. The rainbow trout, which is present in North Carolina, had a chronic value ~2.9 times that of the sculpin representing the most stringent chronic value.
    - The ~1.3 times greater than the chronic criterion result reflects the most stringent value and is an LC20.

The results of the chromium VI and lead analysis indicated values greater than the 2 times greater threshold discussed earlier. The other four parameters, cadmium, copper, nickel, and zinc, had a range of values above and below the threshold of 2 times greater. Based on the additional commentary provided above, the EPA considered that some results less than the threshold should be given less weight for the reasons provided with each result. The EPA considered that the most relevant study results were typically the most sensitive endpoint that could be compared to either the acute or chronic values (or both, where the study contained multiple endpoints) and reflected the most sensitive species from the study, when that information was articulated. Additionally, the EPA expects that for less sensitive species the risk of exposure to adverse amounts of the pollutant is even less.

In conclusion, the EPA's overall determination was that most of the results were greater than 2 times the equivalent criterion and by using these sources of information, the EPA has determined that the amount of exposure to pollutants that would be allowed by North Carolina's revised water quality standards may effect, NLAA-insignificant and is therefore not likely to jeopardize the continued existence of the seven listed mussel species and the four listed fish species or result in the destruction or adverse modification of their designated critical habitat.

<u>Historical BO Findings</u>

In addition to the comparison of specific acute toxicity values, the EPA also summarized its analysis of the historical BOs, as compared to North Carolina's criterion concentrations. Full details are available in Attachment B, but the key points of the information are included here for reference.

- Cadmium
    - As further explained in Attachment B, in comparing the historical Idaho BO findings to the acute non-trout, acute trout, and chronic all waters cadmium criteria adopted by North Carolina, the EPA determined that the State's acute non-trout criterion was less stringent than the positive and adverse findings of the historical BOs, the acute trout criterion was within the range of positive and adverse findings, and the chronic criterion was within the range of positive and adverse findings of the Idaho and Oregon BOs. With regard to the CTR, which was considering a chronic criterion of 1.4 µg/L, the alternative chronic criterion published by EPA in 2001 was 0.25 µg/L, which was much closer to the recommended values provided by the Services in the CTR BO (0.096-0.18 µg/L), and is equivalent (at a hardness of 50 mg/L)

to the chronic criterion adopted by North Carolina. To supplement the historical CTR, Idaho, and Oregon BO findings, the EPA looked at additional information, which was summarized in the discussion for cadmium above.

- Chromium VI
  - In comparing the historical Idaho and Idaho BO findings, to the acute and chronic chromium VI criteria adopted by North Carolina, the EPA determined that the State's acute and chronic criteria were within the range of positive findings and equivalent to the values associated with the adverse finding. Given that the adverse finding did not rise to the scale of any population level, the EPA found this to be supportive that the State's criterion values are protective of listed species. To supplement the historical Oregon BO findings, the EPA looked at additional information, which was summarized in the discussion for chromium VI above.

- Copper
  - In comparing the historical Idaho and Oregon BO findings to the acute and chronic copper criteria adopted by North Carolina, the EPA determined that the State's acute and chronic criteria were within the range of positive and adverse findings. In both the Idaho and Oregon BO findings and the EPA's review of available literature, it was clear that the use of the copper BLM based recommendations is preferable by the Service and noted by many in the more recent scientific literature. Much of the adverse information contained in the historical BOs related to those states' lack of use of the copper BLM or concern with lower hardness levels. In the case of North Carolina, the BLM is an option for the state to use, in addition to the hardness based equations. Furthermore, part of the historical adverse findings from the Service included an RPA for the use of the low end cap for hardness, which is not a revision being approved by the EPA so it is not an ESA consultable item in the case of North Carolina's revisions. To supplement the historical BO findings, the EPA looked at additional information, which was summarized in the discussion for copper above.

- Lead
  - In comparing the historical Idaho and Oregon BO findings to the acute and chronic lead criteria adopted by North Carolina, the EPA determined that the State's acute and chronic criteria were within the range of positive findings and equivalent to the values associated with the adverse finding. Given that the adverse finding did not rise to the scale of any population level, the EPA found this to be supportive that the State's criterion values are protective of listed species. To supplement the historical Idaho and Oregon BO findings, the EPA looked at additional information, which was summarized in the discussion for lead above.

- Nickel
  - In comparing the historical Idaho and Oregon BO findings to the chronic nickel criteria adopted by North Carolina, the EPA determined that the State's chronic criteria were within the range of positive findings and equivalent to the values associated with the adverse

finding. Given that the adverse finding did not rise to the scale of any population level, the EPA found this to be supportive that the State's criterion values are protective of listed species. To supplement the historical BO findings, the EPA looked at additional information, which was summarized in the discussion for nickel above.

- Zinc
    - In comparing the existing Idaho and Oregon BO findings to the acute and chronic zinc criteria adopted by North Carolina, the EPA determined that the State's acute and chronic criteria were equivalent to positive and adverse findings. Given that the adverse finding did not rise to the scale of any population level, the EPA determined the available information supports a may affect, NLTAA-insignificant determination. To supplement the historical BO findings, the EPA looked at additional information, which was summarized in the discussion for zinc above.

Although LC50s at 48 and 96 hours were preferred, some of the studies utilized shorter durations, such as LC50s at 24 hours or were based on EC50. The values selected for comparison were typically the most sensitive endpoint that could be compared to either the acute and/or chronic values and reflected the most sensitive species from the study, when that information was articulated. As noted before, Attachment C contains more detailed information for each study's analysis, but was intended to highlight a conservative assumption, reflecting the amount of difference between the study results and the equivalent state criteria concentrations. The EPA determined the criteria adopted by North Carolina is insignificantly toxic to North Carolina species and the information contained in Attachment B supplements this finding. While there was a larger number of "percentage of the criterion" toxicity levels associated with copper compared to the other metals, after reviewing all of the copper studies, the EPA concluded that there would still be an insignificant toxicity for the North Carolina species. In addition, the EPA considered the option of the State-adopted BLM provision, which allows consideration of site specific factors that can significantly influence the bioavailability of copper to species of concern. The EPA determined, that use of the BLM by the state when needed, would sufficiently address toxicity impacts to the North Carolina species.

Based on the available information, the EPA determined that this action may affect, but is NLAA the listed species or their designated critical habitat as it relates to the revisions to the criteria for cadmium, chromium VI, copper, lead, nickel, and zinc.

For the other parameters, arsenic, beryllium, chromium III, and silver, while there was less information available, the EPA was still able to make conclusions based on the available information for those parameters. The following summarizes the EPA's analysis for those four parameters:

- Arsenic
    - While North Carolina's acute and chronic arsenic criteria are both below the criteria considered in the historical Idaho BO, which were found to be a mix of positive and adverse findings, the information contained in the BO indicated, that even at lower values, the concern outlined in the BO was specific to sensitive life stages and other non-water exposure routes, principally from diet. The BO outlined the opportunity for an improved finding through use of another applicable criterion for arsenic in Idaho's state regulations, the human

health value of 10 µg/L. In North Carolina's case, the arsenic criterion value of 10 µg/L would also be applicable to all waters in the action area. Because it is more stringent than the chronic aquatic life criterion of 150 µg/L, the criterion for the protection of human health that applies to all state waters would be the controlling criterion for permitting actions. Therefore, the EPA expects that the rationale that was used in the Idaho BO to avoid jeopardy for listed species through the use of the human health criterion will apply for the same scenario in North Carolina. Without additional information to compare the salmonid embryo information to more relevant species found in North Carolina, the EPA has determined the use of the human health criterion is sufficient to support the Agency's determination relative to the revised acute and chronic arsenic criteria. The EPA also determined the acute and chronic arsenic criteria revisions to have a may affect, NLAA-insignificant due to the fact that the exposure was limited to a subset of a different sensitive species (salmonids) at a single life stage (embryos).

- Beryllium
    - Only the acute beryllium criterion is being revised as part of North Carolina's change to water quality standards package addressed by this BE analysis. Therefore, the EPA's analysis for ESA consultation purposes is only for the acute criterion of 65 µg/L. In 1980, the EPA concluded that an acute freshwater criterion could not be calculated due to a limited toxicity data base (EPA 440 5-80-024). Therefore, the EPA does not have an acute water quality recommendation for beryllium. The 1980 EPA report did note that acute toxicity could occur at concentrations as low as 130 µg/l. For the revision addressed by this BE, North Carolina utilized the acute data from the 1980 report and derived its acute freshwater criterion in a manner that is consistent with the EPA's 1985 Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses (PB85-227049, EPA 1985). As a result, the state adopted a value which represents half of the lowest acute toxicity concentration identified in the 1980 report as its new acute criterion. Without any further information, the EPA concludes the information available at this time supports a may affect, NLAA-insignificant determination.

- Chromium III
    - In comparing the historical Idaho and Oregon BO findings to the acute and chronic chromium III criteria adopted by North Carolina, the EPA determined that the State's acute and chronic criteria were within the range of positive findings and equivalent to the values associated with adverse finding. Given that the adverse finding did not rise to the scale of any population level, the EPA determined the available information supports a may affect, NLAA-insignificant determination.

- Silver
    - In comparing the historical Idaho and Oregon BO findings to the acute and chronic silver criteria adopted by North Carolina, the EPA determined that the State's acute and chronic criteria were within the range of positive findings and equivalent to the values associated with the adverse finding. Given that the adverse finding did not rise to the scale of any

population level, the EPA found this information supports a may affect, NLAA-insignificant determination.

Based on the available information, this action is not likely to adversely affect the listed species or their designated critical habitat as it relates to the revisions to the criteria for arsenic, beryllium, chromium III, and silver.

Discussion of the Implementation of Water Effect Ratios, Recalculation Procedure, Resident Species Procedure, Hardness Dependent Equations, and Biotic Ligand Model for Copper

Water Effect Ratios, Recalculation Procedure, and Resident Species Procedure

As part of the two new subparagraphs 11(b) and (d) that were added in the State's revisions, the State now has the ability conduct either a WER, Recalculation Procedure, or Resident Species Procedure. The new language clarifies the State's expectations for these types of site specific criteria studies consistent with EPA guidance. Further technical information regarding these provisions can be found in the final decision document for this action provided as Attachment D to this BE. Such clarification was determined to have no effect on federally listed species or their designated critical habitats for the Recalculation Procedure and Resident Species Procedure because use of these provisions will ultimately result in new or revised water quality standards that will require a federal action by the EPA and an ESA section 7 consultation with FWS.

WERs are also processes that allow the State to put site specific water quality criterion in place; however, this is accomplished through modified permit limits for individual dischargers and does not result in a new or revised water quality criterion. The EPA considers a WER as a performance-based standard implemented through NPDES permits. The purpose of a WER is to allow for site-specific water quality characteristics, which may affect metal bioavailability and toxicity, to be considered in the applicable criterion. The EPA found that use of the WER provision by the state, would result in the same level of bioavailability of metals to species of concern as that found in the results of the toxicity tests for the WER[7]. For ESA consultation purposes, the EPA considers this a programmatic consultation defined as a consultation that addresses multiple actions on a program, regional or other basis. Based on the EPA's analysis of this provision, it was concluded that the WER provision is may affect, NLAA – insignificant to designated critical habitat and species of concern.

Hardness Based Equations

A new table, Table A, was added under section .02 11(d) to show the new and revised criteria for hardness dependent metals, including the respective equations. Additionally, as noted in the decision document, North Carolina has chosen to also adopt the Aquatic Life Ambient Freshwater Quality Criteria—Copper 2007 Revision (EPA-822-R-07-001) for calculating acute or chronic freshwater copper values using the Biotic Ligand Model. The BLM criteria, which is discussed further in the next section, is written as a supplement to the EPA's previously published recommendations for copper. With regard to the consultation for the addition of hardness based equations to the State's regulations, the

[7] EPA, 1994, Interim Guidance on the Determination and Use of Water-Effect Ratios for Metals, EPA-823-B-94-001, U.S. Environmental Protection Agency, Office of Water, Washington, DC.

EPA concludes the substance of its review is addressed in the previous discussion regarding the criteria concentrations themselves that result from the use of the equations. Therefore, for this provision, the EPA has concluded a may affect, NLAA effect-insignificant determination for listed species or their designated critical habitat based on the EPA's review of the historical BOs and species specific toxicity information as discussed above.

Biotic Ligand Model Based Criterion for Copper

The BLM is a model that uses receiving water body characteristics to develop site-specific water quality criteria using the best available science to determine the bioavailability of copper. The BLM requires that ten waterbody specific parameters be input into the model, including temperature, pH, dissolved organic carbon, calcium, magnesium, sodium, potassium, sulfate, chloride, and alkalinity rather than just the hardness of a waterbody as required for the hardness-based equation. However, North Carolina determined that the BLM was often not practical to implement when resources or data were not available for the collection or use of all ten parameters and therefore caveated the adoption to note that it will be used where "sufficient data is available". When sufficient data is not available, North Carolina has chosen to utilize the EPA's previously published hardness based equation for copper in order to ensure state wide implementation of copper criteria.

The implementation of the BLM can result in two outcomes: 1) a change to permit limits similar to the implementation of a WER, or 2) a new site specific water quality criterion. No ESA consultation would be required for the first outcome because there is no change to the underlying water quality criterion. This scenario, was therefore determined to have no effect on federally listed species or their designated critical habitats. The use of the BLM to develop a site specific criterion for copper is a process that clarifies the ability of the State to have a revised water quality criterion to support the designated use(s). Such clarification was determined to have no effect on federally listed species or their designated critical habitats. When use of the BLM results in the adoption of a revised water quality criterion, the EPA would evaluate at that time whether or not an ESA section 7 consultation was necessary.

Summary of EPA's Conclusions by Provision

Based on the above information, the EPA concluded that for those species not previously identified as having no effect based on their habitat relative to the subject action or a may affect, NLAA-discountable effect, the following determinations were made on a revision specific basis. Even though some species were located in the action area and/or had the potential for exposure, some revisions were still determined to have no effect on the species due to the nature of the revision. Where this was the case, as well as where the EPA expects the effect to be insignificant, those conclusions have been summarized for each of the revised provisions within North Carolina's regulations for which the EPA is taking an approval action. In conclusion, the EPA has determined that its analysis supports a conclusion that the revisions the EPA's CWA 303(c) action addresses are may affect, NLAA-insignificant, no effect, or no discretion.

Section	Provision	EPA's ESA Determination
15A NCAC 02B.0206 – Flow Design for Effluent Limitations	Addition of a 1Q10 flow for protection of aquatic life from acute toxicity	May affect, NLAA – insignificant
	Editorial Changes shown in Attachment A	No effect
15A NCAC 02B .0211 - Fresh Surface Water Quality Standards for Class C Waters	Addition of Acute/Revised Criteria for Chronic Arsenic	May affect, NLAA – insignificant
	Addition of Acute Beryllium	May affect, NLAA – insignificant
	Addition of Acute and Chronic Chromium VI	May affect, NLAA – insignificant
	Revision of Chronic Silver	May affect, NLAA – insignificant
	Revised Criteria for Chronic Cadmium	May affect, NLAA – insignificant
	Addition of Acute Criteria for Cadmium in Trout and Non-Trout Waters	May affect, NLAA – insignificant
	Addition of Acute and Chronic Criteria for Chromium III	May affect, NLAA – insignificant
	Revised Acute and Chronic Criteria for Copper	May affect, NLAA – insignificant
	Revised Acute and Chronic Criteria for Lead	May affect, NLAA – insignificant
	Revised Acute and Chronic Criteria for Nickel	May affect, NLAA – insignificant
	Revised Acute and Chronic Criteria for Zinc	May affect, NLAA – insignificant
	Addition of Acute Silver Criterion	May affect, NLAA – insignificant
	Removal of Iron Action Level	May affect, NLAA – insignificant
	Use of hardness based equations	May effect, NLAA – insignificant (except the low end hardness cap component of the hardness equation was disapproved under CWA 303(c) – ESA

Section	Provision	EPA's ESA Determination
		section 7 consultation not required.)
	Use of WERs	May affect, NLAA – insignificant
	Recalculation Procedure, and Resident Species Procedure	No effect or determine if future ESA section 7 consultation is required
	Use of BLM for copper	No effect or determine if future ESA section 7 consultation is required
	Editorial Changes shown in Attachment A	No effect
15A NCAC 02B .0212 - Fresh Surface WQS for Class WS-I Waters	Editorial Changes shown in Attachment A	No effect
	Removal of Manganese Numeric Criterion and Revision of 2, 4 D Numeric Criterion	No discretion – human health
15A NCAC 02B .0214 - Fresh Surface WQS for Class WS-II Waters	Editorial Changes shown in Attachment A	No effect
	Removal of Manganese Numeric Criterion and Revision of 2, 4 D Numeric Criterion	No discretion – human health
15A NCAC 02B .0215 - Fresh Surface WQS for Class WS-III Waters	Editorial Changes shown in Attachment A	No effect
	Removal of Manganese Numeric Criterion and Revision of 2, 4 D Numeric Criterion	No discretion – human health
15A NCAC 02B .0216 - Fresh Surface WQS for Class WS-IV Waters	Editorial Changes shown in Attachment A	No effect
	Removal of Manganese Numeric Criterion and Revision of 2, 4 D Numeric Criterion	No discretion – human health
15A NCAC 02B .0218 - Fresh Surface WQS for Class WS-V Waters	Editorial Changes shown in Attachment A	No effect
	Removal of Manganese Numeric Criterion and Revision of 2, 4 D Numeric Criterion	No Discretion – human health

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

APR 6 2016

Mr. Jay Zimmerman
Director
Division of Water Resources
North Carolina Department of Environment
and Natural Resources
1617 Mail Service Center
Raleigh, North Carolina 27604

Dear Mr. Zimmerman:

The United States Environmental Protection Agency has completed its review of the State of North Carolina's 2007 – 2015 Triennial Review of Water Quality Standards (WQS). All of the Triennial Review revisions were approved for adoption by the North Carolina Environmental Management Commission on November 13, 2014, and became effective for state purposes on January 1, 2015. In a letter dated May 1, 2015, the State of North Carolina Department of Justice certified that the WQS revisions, Surface Water and Wetland Standards (15A NCAC 02B .0200) had been duly adopted according to state law. On May 15, 2015, the EPA received the original signed package for review from the Division of Water Resources.

The EPA's decision on these revisions is detailed in the enclosed document, *Decision Document of the United States Environmental Protection Agency Review of North Carolina's 2007 - 2015 Triennial Review of Changes to Surface Waters and Wetlands Standards 15A NCAC 02B .0200 Under Section 303(c) of the Clean Water Act.* The approved portion of the new and revised WQS adopted by the State include upgrades to toxic criteria to meet national recommendations for arsenic, chromium III, chromium VI, copper, lead, nickel, silver and zinc and a scientifically defensible alternative for cadmium for non-trout waters. The EPA is also approving the removal of a numeric Action Level for iron and the numeric criterion for manganese (Water Supply waters only). Both parameters will be controlled through the use of a narrative WQS.

The EPA is disapproving revisions relating to biological confirmation for toxics in assessment and three revisions relating to the implementation of the hardness based equations for metals under the National Pollutant Discharge Elimination System (NPDES) permits, including the use of action levels, the use of a low end hardness cap, and the use of the median of the 8-digit hydrologic unit for determining hardness when developing NPDES permits. These revisions are inconsistent with the requirements of 40 C.F.R. Part 131 and the Clean Water Act (CWA) and therefore, are disapproved. The EPA recommends that NCDENR remove these provisions during the next rulemaking.

In addition to the EPA's review pursuant to section 303 of the CWA, section 7(a)(2) of the Endangered Species Act (ESA) requires federal agencies, in consultation with the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS), to ensure that their actions are not likely to jeopardize the continued existence of federally listed species or result in the destruction or adverse

modification of designated critical habitat of such species. The EPA's decision to approve the revisions contained in the enclosed decision document is subject to the results of consultation under section 7 of the ESA with the USFWS and NMFS office. The EPA will notify NCDENR of the results of the section 7 consultation upon completion of the action.

We would like to commend you and your staff on the completion of this Triennial Review and your continued efforts in environmental protection for the State of North Carolina. In particular, we would like to acknowledge the technical expertise and the hard work of Connie Brower shown during the development of these WQS.

Should you have any questions regarding the EPA's action today, please contact me at (404) 562-8357 or have a member of your staff contact Ms. Lisa Perras Gordon at gordon.lisa-perras@epa.gov or (404) 562-9317.

Sincerely,

Heather McTeer Toney
Regional Administrator

Enclosure

cc: Connie Brower
NCDWR WQS

Jeff Manning
NCDWR WQS

Tom Belnick
NCDWR NPDES

Jeff Poupart
NCDWR NPDES

Decision Document of the United States Environmental Protection Agency Review of North Carolina's 2007-2015 Triennial Review of Changes to Surface Waters and Wetlands Standards 15A NCAC 02B .0200 Under Section 303(c) of the Clean Water Act

Introduction

In a letter dated May 4, 2015, from S. Jay Zimmerman, Director, Division of Water Resources (DWR), North Carolina Department of Environment and Natural Resources, to Heather McTeer Toney, Regional Administrator of the Environmental Protection Agency's (EPA's) Region 4 Office, the DWR submitted new and revised water quality standards (WQS) for review under section 303(c) of the Clean Water Act (CWA or Act). In a letter dated May 1, 2015, the State of North Carolina Department of Justice certified that the WQS revisions, Surface Water and Wetland Standards (15A NCAC 02B .0200) had been duly adopted according to State law. The revisions addressed in this decision document were approved for adoption by the North Carolina Environmental Management Commission on November 13, 2014, and became effective for state purposes on January 1, 2015. The EPA received the original signed package for review from DWR on May 15, 2015.

Clean Water Act Requirements

Section 303 of the CWA, 33 U.S.C. § 1313, requires states to establish WQS and to submit any new or revised standards to the EPA for review and approval or disapproval. The EPA's implementing regulations require states to adopt water quality criteria that protect the designated use. See 40 C.F.R. 131.11(a). Such criteria must be based on a sound scientific rationale and must contain sufficient parameters or constituents to protect the designated use. Id. For waters with multiple use designations, the criteria shall support the most sensitive use. Id. In addition, the EPA's regulations require that in establishing criteria, a state shall consider WQS of downstream waters and shall ensure that its WQS provide for the attainment and maintenance of WQS of downstream waters. See 40 C.F.R. 131.10(b). A state's submission of water quality criteria must include (1) the methods used and analyses conducted to support WQS revisions, (2) water quality criteria sufficient to protect the designated uses and (3) a certification by the State Attorney General or other appropriate legal authority within the state that the WQS were duly adopted under state law. See 40 C.F.R. 131.6.

Endangered Species Act Requirements

In addition to the EPA's review under section 303 of the CWA, section 7(a)(2) of the Endangered Species Act (ESA) requires federal agencies, in consultation with the Fish and Wildlife Service (FWS) and/or the National Marine Fisheries Service (NMFS), to ensure that their actions are not likely to jeopardize the continued existence of federally listed species or result in the destruction or adverse modification of designated critical habitat of such species. With regard to consultation activities for section 7 of the ESA, the EPA Region 4 concluded that the WQS the Agency approved, would either have no effect or may affect, but not likely to adversely affect, threatened and endangered species or their designated critical habitat. The EPA also concluded that they had no discretion for some provisions of the approved WQS because they were derived to protect human health and the EPA has no discretion to revise an otherwise approvable human health criterion to benefit listed species.

The EPA's Decision Summary

The EPA commends the DWR for making revisions to its WQS to bring them up-to-date with long overdue changes. In particular, the State should be commended for adopting the EPA's national recommended criteria developed under CWA section 304(a) or other scientifically justified criteria for toxic metals as well as for adopting both acute and chronic values for those metals. The EPA's 304(a) recommendations provide an extensive technical basis and justification for how the recommended aquatic life criteria adequately protect aquatic life uses. The methodologies have been subject to public review, as have the individual criteria guidance documents. The methodologies have also been reviewed by EPA's Science Advisory Board (SAB) of external experts. While some of the methodologies that the EPA relied on in reaching this decision may be 20 years old, based on data and information considered over the years, EPA considers the science underpinning those recommendations to still be sound.

The goals of the CWA in section 101(a)(3) state that, "it is the national policy that the discharge of toxic pollutants in toxic amounts be prohibited." In the California Toxics Rule (CTR), 65 Fed. Reg. 31,682 (page 31,683) (May 18, 2000), the EPA reaffirmed that in order to achieve the goals and objectives of the Act, toxic pollutants must be controlled. Adopting scientifically defensible water quality standards for toxics establishes water quality goals for State and EPA programs, including providing a precise basis for developing water quality-based effluent limits for National Pollutant Discharge Elimination System (NPDES) permitting under section 402 of the Act; monitoring, assessment, development of Total Maximum Daily Loads (TMDLs); protecting coastal water quality improvement; protecting aquatic ecosystems and human health; and providing endpoints for nonpoint source controls and overall ecological protection. See 65 Fed. Reg. (page 31683). In addition, these standards will be used in other applications such as the State's authority to review federal permits under section 401 of the Act and reviews under the section 404(b)(1) guidelines. North Carolina's action fulfills the statutory requirement under section 303(c)(2)(B) of the CWA.

In particular, the EPA notes that for the first time, the DWR will have scientifically defensible criteria in place for all purposes under the Act for copper, hexavalent chromium, silver and zinc. Additionally, the value for lead, previously almost twenty times higher than recommended, will be consistent with national recommendations. Similarly, the State will now have updated criteria for cadmium in trout waters and nickel consistent with national recommendations. The EPA also supports the added provision to the State's new metal criteria to use the dissolved fraction and to allow the inclusion of water effect ratios directly into the criteria for metals.

The EPA welcomed the opportunity to work with the DWR to address those areas where the State sought to tailor its WQS to conditions within the state rather than to adopt the EPA Section 304(a) national recommendations, as allowed under 40 C.F.R. 131.11. Specifically, the EPA is approving DWR's alternate chronic and acute cadmium criteria for non-trout waters, the removal of iron criteria for aquatic life protection, and the removal of manganese as an organoleptic criteria for waters designated as water supply (WS). The EPA notes that protections will remain in place for all parameters through the use of a narrative water quality standard. Each of these provisions are being approved today as detailed below.

The new and revised WQSs that EPA is approving today are now the applicable water quality standards for all purposes under the CWA, including but not limited to monitoring, assessment, and NPDES permitting. Water quality criteria are intended to protect the designated use (40 C.F.R. 131. 2 and 131.11). Further, 40 C.F.R. 131.2 clarifies that state WQS are to:

"...protect public health or welfare, enhance the quality of water and serve the purposes of the Clean Water Act (the Act). "Serve the purposes of the Act" (as defined in section 101(a)(2) and 303(c) of the Act) means that water quality standards should, wherever attainable, provide water quality for the protection and propagation of fish, shellfish and wildlife, recreation in and on the water, and agricultural, industrial, and other purposes including navigation.

Such standards serve the dual purposes of establishing the water quality goals for a specific water body and serve as the regulatory basis for the establishment of water-quality-based treatment controls and strategies beyond the technology-based levels of treatment required by sections 301(b) and 306 of the Act."

Throughout this triennial review, the EPA has repeatedly and clearly articulated to North Carolina, both verbally and in writing, the Agency's position that certain proposed WQS could not be approved if submitted to the EPA. Consistent with that position and the EPA's publicly available record, the EPA is disapproving the sections of the DWR's water quality standards allowing alternative approaches for the implementation of the newly approved toxics criteria for some purposes under the Act. Specifically, the "biological confirmation" for assessment and the "action levels" for NPDES permitting are disapproved for all purposes under the Act. The State has now adopted separate, more stringent numeric criteria that are approved for all purposes under the CWA and must be implemented in NPDES permits as required by the EPA's national permitting regulations and monitoring and assessment programs. The State's separate "biological confirmation" and "action levels" provisions are not protective of the designated uses. In addition, the EPA communicated its concern with the use of a median instream hardness when calculating hardness dependent metals criteria, another provision designed to allow an alternative approach in NPDES permitting for implementing the State's toxics criteria, because median hardness does not protect designated uses in all waters. EPA also communicated its concern that the State has not demonstrated that the low end hardness cap provision protects designated uses of waters with a hardness below the cap. Therefore, the EPA is also disapproving the median hardness and low end hardness cap WQS.

Finally, numerous changes were made to the structure and formatting of the WQS and each of those changes were reviewed. Where those did not result in substantive changes to the WQS, the EPA is approving the revisions as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of these non-substantive changes does not re-open the EPA's prior approval of the underlying substantive WQSs. Where the revisions were a substantive change to WQS, the EPA reviewed and made individual decisions regarding those changes as detailed below. Where the revisions were not considered changes to WQS, the Agency did not take action, as noted below. During this triennial, the State also provided an opportunity to accept comments on and conducted a review of the variances to water quality standards for Evergreen Paper Products, Mount Olive Pickle Company and Bay Valley Foods. The EPA continues to work with the State on the ongoing review of these water quality standards variances as noted below.

North Carolina should be extremely proud of these revisions to its WQS and the technical expertise demonstrated by its staff and management in the completion of this extended review. Each of the DWR's WQS revisions is addressed in detail below along with the EPA's analysis and decision.

15A NCAC 02B .0200 Classifications and Water Quality Standards Applicable to Surface Waters and Wetlands

Throughout the Classifications and Water Quality Standards Applicable to Surface Waters and Wetlands section .0200, several editorial revisions were made replacing commonly used terms with synonymous terms. For example, the word "which" was changed to "that." These revisions do not alter the meaning or intent of the previously approved corresponding provisions as they are considered editorial. A copy of the revised WQS with these changes highlighted in yellow is provided in Appendix A: Non-Substantive Word Changes. The EPA approves the non-substantive word change revisions in Appendix A as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of these non-substantive changes does not re-open the EPA's prior approval of the underlying substantive WQSs.

15A NCAC 02B .0206 Flow Design Criteria for Effluent Limitations

Subsection 15A NCAC 02B .0206(a)(3) was amended to add:

> *(3) Toxic substance standards to protect aquatic life from acute toxicity shall be protected using the 1Q10 flow.*

In the EPA's *Technical Guidance Manual for Performing Wasteload Allocation. Book IV: Design Conditions,* Chapter 1 (EPA 1986a), the EPA discusses and recommends two methods for determining design flows for calculating effluent limits, the hydrologically-based method and the biologically-based method. Those design flows should be used to calculate both the Criterion Continuous Concentration (CCC, the 4-day average concentration of a pollutant that should not be exceeded more than once every three years on the average also known as the 'chronic' toxicity) and Criterion Maximum Concentration (CMC, the one hour average concentration in ambient water that should not be exceeded more than once every three years on average, also known as the 'acute' toxicity). The EPA recommends the use of the 1Q10 flow as the hydrologically-based design flow for the CMC and the 7Q10 as the hydrologically-based design flow for the CCC. The North Carolina WQS already includes a provision for the 7Q10 design flow for chronic toxicity (15A NCAC 02B .0206 (a)(2)). This revision adds the 1Q10 flow that will now be applicable for the new acute criteria that are being adopted during this triennial. Note: in this context the flow values that are listed are solely to be used for the calculation of water quality based effluent limitations as discussed under 15A NCAC 02B .0206(a). They do not indicate or refer to in any manner setting actual instream flows.

Considering the scientific and technical information supporting the EPA's Guidance, the EPA concludes that this change to subsection 15A NCAC 02B .0206 is consistent with the CWA section 303(c), 40 C.F.R. sections 131.11 and 131.13, and the EPA's guidance on stream design flows that are protective of aquatic life. This change is protective of the designated use. Therefore, this change is approved by the EPA under CWA section 303(c).

15A NCAC 02B .0211 Fresh Surface Water Quality Standards for Class C Waters
General paragraph and Subparagraphs (1) through (10)

The following revisions were made to the General opening paragraph and subparagraphs (1) through (10) of Section 15A NCAC 02B .0211.

> *General. The water quality standards for all fresh surface waters ~~are~~ shall be the basic standards applicable to all Class C waters. ~~See Rule .0208 of this Section for standards for toxic substances and temperature.~~ Water quality standards for temperature and numerical water quality standards for the protection of human health applicable to all fresh surface waters are in Rule .0208 of this Section.*

The language regarding the reference to Rule .0208 was changed in this paragraph. The applicability of Rule .0208 to freshwaters of North Carolina has not been changed, nor has the content of Rule .0208 been changed. The EPA has reviewed this change and determined that it is non-substantive and therefore, the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

The General paragraph was also modified as follows:

> *Additional and more stringent standards applicable to other specific freshwater classifications are specified in Rules. .0212, .0214, .0215, .0216, ~~.0217,~~ .0218, .0219, .0223, .0224 and .0225 of this Section.*

Subparagraph .0217 was repealed with an effective date of January 1, 1988. There are no provisions under that Rule. Therefore, reference to that Rule has been removed. The EPA has reviewed this change and determined that it is non-substantive and therefore, the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

The following sentence was added as the final sentence to the general paragraph:

> *Action levels for purposes of National Pollutant Discharge Elimination System (NPDES) permitting are specified in Item (22) of this Rule.*

The EPA has reviewed this change and determined that it is non-substantive and therefore, the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs. For the substantive discussion of the EPA's decision regarding revisions to action levels in fresh surface waters, see page 28.

The following subparagraphs were renumbered for alphanumeric reordering only:

(1) Best Usage of Waters
(2) Conditions Related to Best Usage
(4) Chlorophyll a (corrected)
(6) Dissolved Oxygen
(8) Floating Solids, settleable solids, or sludge deposits

(10) Gases, total dissolved.

There were no other changes to these standards except for the numbering. The EPA has reviewed these changes and determined that they are non-substantive and therefore, the EPA approves these revisions as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that this approval of these non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.
Subparagraph (3) was amended as follows:

~~*(3) Quality standards applicable to all fresh surface waters:*~~

This sentence came before all of the criteria in the old format prior to the alphabetical reorganization of the WQS. The State indicated that this sentence was found to be redundant with the information in the General paragraph. The General paragraph listed just above this states that the WQS "…for all fresh surface waters are the basic standards applicable to Class C waters." 15A NCAC 02B .0101 General Procedures provides a definition for Class C waters which includes that "*Class C: freshwaters protected for secondary recreation, fishing, aquatic life including propagation and survival, and wildlife. All freshwaters shall be classified to protect these uses at a minimum.*" The EPA has reviewed this change and determined that it is non-substantive and therefore, the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

New subparagraph (3) was created:

(3) Chlorine, total residual: 17 ug/l;

This revision moves chlorine from its previous location at Rule .0211(3)(l)(iv) without revision in order to alphabetize the criteria. The EPA has reviewed this change and determined that it is non-substantive and therefore, the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

New subparagraph (5) was created:

(5) Cyanide, total: 5.0 ug/L;

The new paragraph moves cyanide from its previous location at Rule .0211(3)(l)(vi) and retains the same numeric value. Therefore, this revision is a non-substantive change to WQSs and the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

However, the original cyanide criterion included the following language after the numeric criteria that is no longer included, "*…unless site-specific criteria are developed based upon the aquatic life at the site utilizing The Recalculation Procedure in Appendix B of Appendix L in the Environmental Protection Agency's Water Quality Standards Handbook hereby incorporated by reference including any subsequent amendments.*" That language is struck out in the original location and not carried over to the new criterion's location.

States are not required to utilize the site-specific procedures, therefore the EPA concludes that this change to subsection 15A NCAC 02B .0211(11)(a)(5) is consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. Therefore, this change is approved by the EPA under CWA section 303(c). North Carolina notes that the site-specific criterion for cyanide has never been used since its original adoption. According to the state, Rule .0226 Exemptions from Surface Water Quality Standards, may be modified in the next triennial to include reference to the Handbook procedures that will allow the State to develop site-specific criteria. Until such time, the language allowing the use of the site-specific criteria has been removed and cannot be used for CWA purposes.

New paragraph (7) was added to move the criteria for fecal coliform into alphabetical order.

(7) Fecal coliform:

The fecal coliform criteria was previously Rule .0211(3)(e) and included the language "*Organisms of the coliform group:*" in front of the criteria. Those introductory words have been replaced with the words "*Fecal coliform:.*" No other changes were made to the criteria. The EPA has reviewed this change and determined that it is non-substantive and therefore, the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

New paragraph (9) was added to move the criterion for fluorides from Rule .0211(3)(l)(vii) in order to alphabetize the criteria, as follows:

(9) Fluorides: 1.8 mg/l;

The numeric value of the criterion did not change. The EPA has reviewed this change and determined that it is non-substantive and therefore, the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

15A NCAC 02B .0211 Fresh Surface Water Quality Standards for Class C Waters Subparagraph (11)(a)

A new subparagraph under 15A NCAC 02B .0211(11)(a) has been added as follows:

(11) Metals:

(a) *With the exception of mercury and selenium, freshwater aquatic life standards for metals shall be based upon measurement of the dissolved fraction of the metal. Mercury and selenium water quality standards shall be based upon measurement of the total recoverable metal.*

The DWR did not adopt updated criteria for mercury or selenium, leaving in place the previous values which are based on the total recoverable metal. Therefore, the reference to those parameters in the first sentence is a non-substantive change to standards. The EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

The EPA's most current national recommended water quality criteria for protection of aquatic life include the recommendation that fresh and salt water criteria for metals (including specifically arsenic, cadmium,

chromium III, chromium VI, copper, lead, nickel, silver and zinc) be expressed in terms of the dissolved metal in the water column (EPA 1993). The EPA further stated in this guidance that "[t]he use of dissolved metal to set and measure compliance with water quality standards is the recommended approach, because dissolved metal more closely approximates the bioavailable fraction of metal in the water column than does total recoverable metal."

Considering the scientific and technical information supporting the 304(a) recommendations, the EPA concludes that this change to subsection 15A NCAC 02B .0211(11)(a) is consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. Therefore, this change is approved by the EPA under CWA section 303(c).

15A NCAC 02B .0211 Fresh Surface Water Quality Standards for Class C Waters Subparagraph (11)(b)

A new subparagraph 11(b) was added as follows that adds and revises criteria for non-hardness dependent metals and includes the ability to conduct a water effect ratio (WER) as follows:

> *(11) Metals:*
> *(b) Freshwater metals standards that are not hardness-dependent shall be as follows:*
> *(i) Arsenic, dissolved, acute: WER· 340 ug/l;*
> *(ii) Arsenic, dissolved, chronic: WER· 150 ug/l;*
> *(iii) Beryllium, dissolved, acute: WER· 65 ug/l;*
> *(iv) Beryllium, dissolved, chronic: WER· 6.5 ug/l;*
> *(v) Chromium VI, dissolved, acute: WER· 16 ug/l;*
> *(vi) Chromium VI, dissolved, chronic: WER· 11 ug/l;*
> *(vii) Mercury, total recoverable, chronic: 0.012 ug/l;*
> *(viii) Selenium, total recoverable, chronic: 5 ug/l;*
> *(ix) Silver, dissolved, chronic: WER· 0.06 ug/l;*

With the adoption of these criteria under 15A NCAC 02B .0211(11)(b), North Carolina's water quality criteria for non-hardness dependent metals, listed above, are consistent with the EPA's most current national recommended water quality criteria or derived using an EPA recommended approach as detailed below.

Arsenic

In this revision, North Carolina adopted the EPA's most recent national recommendation of 340 ug/l as an acute criterion for arsenic in freshwater. This is the first time that North Carolina has had an acute criterion for arsenic.

The State revised its chronic freshwater criterion for arsenic to adopt the EPA's most current recommended value of 150 ug/l replacing the previous State criterion of 50 ug/l (EPA 1995). The State noted in its adoption of this value that, "[c]urrent arsenic water quality standards designed for the protection of human health in *all* waters of the state remains at 10 ug/l, measured as total recoverable arsenic. The DWR maintains this protective standard which is equivalent to the current National Drinking Water standard." 40 C.F.R. section 131.11 states, "[f]or waters with multiple use designations, the criteria shall support the most sensitive use." In this instance, the human health value of 10 ug/l would be the criteria supporting the most sensitive use applicable to all waters of the State.

Considering the scientific and technical information supporting the 304(a) recommendations, the EPA has determined that the changes to subsections 15A NCAC 02B .0211(11)(b)(i) and (ii) protect North Carolina's aquatic life use and, therefore, are consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. These changes are approved by the EPA under CWA section 303(c).

Beryllium

In this revision, North Carolina adopted an acute criterion for beryllium in freshwater of 65 ug/l. This is the first time that the State has adopted an acute value for beryllium. In 1980, the EPA concluded that an acute freshwater criterion could not be calculated due to a limited toxicity data base (EPA 1980a). Therefore, the EPA does not have an acute water quality recommendation for beryllium. The 1980 EPA report did note that acute toxicity could occur at concentrations as low as 130 ug/l. North Carolina used the acute data from the 1980 report and derived its acute freshwater criterion in a manner that is consistent with the EPA's *1985 Guidelines for Deriving Numerical National Water Quality Criteria for the Protection Of Aquatic Organisms and Their Uses* ("1985 Guidelines," EPA 1985).

North Carolina's methodology for deriving acute criteria for beryllium is scientifically defensible and results in values that protect North Carolina's aquatic life use. The EPA concludes that the change to subsection 15A NCAC 02B .0211(11)(b)(iii) is consistent with the CWA and 40 C.F.R. section 131.11. Therefore, this change is approved by the EPA under CWA section 303(c).

The State is maintaining its chronic freshwater criterion for beryllium of 6.5 ug/l. For alphabetizing purposes the chronic beryllium criterion was moved from 15A NCAC 02B .021(3)(l)(ii) to 15A NCAC 02B .0211(11)(b)(iv), which is a non-substantive change to standards and therefore the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

Chromium VI

Before these revisions, North Carolina did not have criteria for chromium III or chromium VI, instead having a single chronic value for total recoverable chromium of 50 ug/l. In this Rule, North Carolina is adopting the EPA's national recommended criteria for chromium VI of 16 ug/l (acute) and 11 ug/l (chronic) (EPA 1995).

Considering the scientific and technical information supporting the 304(a) recommendations, the EPA has determined that the changes to subsections 15A NCAC 02B .0211(11)(b)(v) and (vi) protect North Carolina's aquatic life use and, therefore, are consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. These changes are approved by the EPA under CWA section 303(c).

Mercury and Selenium

The EPA notes that the numeric values for both mercury and selenium were not changed during this triennial review. The numeric criterion for mercury was moved from 15A NCAC 02B .021(3)(l)(ix) to 15A NCAC 02B .0211(11)(b)(vii) for alphabetizing purposes only. The numeric criterion for selenium was moved from 15A NCAC 02B .021(3)(l)(xiii) to 15A NCAC 02B .0211(11)(b)(viii) for alphabetizing purposes only. As the numeric value did not change for either of these criteria, the EPA determined that it is non-substantive and therefore, the EPA approves the revision as being consistent with the CWA and the

EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

Silver

In this revision, North Carolina is adopting a chronic water quality criterion for silver of 0.06 ug/l in subsection 15A NCAC 02B .0211(11)(b)(ix) of this Rule. Currently, the EPA does not have a national recommended chronic criteria for silver. The State calculated this criterion using the lowest LC50 for total recoverable silver of 1.2 ug/l and multiplying it by a safety factor of 0.05. These calculations are consistent with previously approved procedures for the calculation of toxics criteria for the protection of aquatic life under subsection 15A NCAC .0208 (a)(1) Standards for Toxic Substances and Temperature.

North Carolina's methodology for deriving chronic criteria for silver is scientifically defensible and results in values that protect North Carolina's aquatic life use. The EPA concludes that the change to subsection 15A NCAC 02B .0211(11)(b)(ix) protects North Carolina's aquatic life use and, therefore, is consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. This change is approved by the EPA under CWA section 303(c).

The above changes are summarized in the table below for ease of reference.

Metal (all values are dissolved)	**NCDWR's Previous Criteria (ug/l)**	**NCDWR New/Revised Criteria (ug/l)**	**EPA's Recommended Criteria (ug/l)**	**EPA's Reference for Recommended Criteria**
Arsenic (acute)	--	340	340	EPA 1995
Arsenic (chronic)	50 ug/l	150	150	
Beryllium (acute)	--	65	--	N/A
Beryllium (chronic)	6.5	6.5	--	
Chromium VI (acute)	--	16	16	EPA 1995
Chromium VI (chronic)	--	11	11	
Silver (chronic)	0.06 Action Level only	0.06	--	N/A

Water Effect Ratios

The following was added underneath the non-hardness dependent criteria in Subparagraph 11(b):

> *With the exception of mercury and selenium, acute and chronic freshwater aquatic life standards for metals listed in this Subparagraph apply to the dissolved form of the metal and apply as a function of the pollutant's water effect ratio (WER). A WER expresses the difference between the measures of the toxicity of a substance in laboratory waters and the toxicity in site water. The WER shall be assigned a value equal to one unless any person demonstrates to the Division's satisfaction in a permit proceeding that another value is developed in accordance with the "Water Quality Standards Handbook: Second Edition"*

published by the US Environmental Protection Agency (EPA-823-B-12-002), free of charge, at http://water.epa.gov/scitech/swguidance/standards/handbook, hereby incorporated by reference including any subsequent amendments. Alternative site-specific standards may also be developed when any person submits values that demonstrate to the Commissions' satisfaction that they were derived in accordance with the "Water Quality Standards Handbook: Second Edition, Recalculation Procedure or the Resident Species Procedure", hereby incorporated by reference including subsequent amendments at http://water.epa.gov/scitech/swguidance/standards/handbook/. This material is available free of charge.

This provision allows the use of a WER directly for each of the above non-hardness dependent metals (criteria x WER). The DWR provides the citation for the EPA Water Quality Standards Handbook, incorporated by reference including any amendments ("WQS Handbook," EPA 2014). Within the WQS Handbook, Appendix L, *Interim Guidance on Determination and Use of Water-Effect Ratios for Metals* ("WER Guidance", EPA 1994a), including the transmittal memo, "Use of the Water-Effect Ratio in Water Quality Standards (EPA 1994b), provides specific details on the applicability of WERs and how to develop WERs for site-specific criteria for metals. The WER guidance notes that one of the options under 40 C.F.R. 131.11 (b)(1) allows states to establish criteria based on 304(a) Guidance modified to reflect site-specific conditions. The WER transmittal memo notes that site-specific criteria are subject to EPA review and approval/disapproval under section 303(c) of the CWA. The two options allowed for this review are:

Option 1: A state may derive and submit each individual water-effect ratio determination to EPA for review and approval.

Option 2: A State can amend its water quality standards to provide a formal procedure with includes derivation of water-effects ratios, appropriate definition of sites, and enforceable monitoring provisions to assure that designated uses are protected. Both this procedure and the resulting criteria would be subject to full public participation requirements. Public review of a site-specific criterion could be accomplished in conjunction with the public review required for permit reissuance. EPA would review and approve/disapprove this protocol as a revised standard once. For public information, we recommend that once a year the State publish a list of site-specific criteria.

By referencing the procedures in the WQS Handbook, which includes the WER Guidance and the WER transmittal memo, the DWR has chosen to proceed with Option 2, adopting the EPA's protocol and all associated procedures to conduct WERs. The requirements for public review of a WER will be incorporated through the permit process. The State has chosen to include a WER of 1 in the WQS, which the EPA considers a "rebuttable presumption until a site-specific WER is derived." National Toxics Rule (NTR), 57 Fed. Reg. (page 60,866) (December 22, 1992). The WER Transmittal memo emphasizes that ". . . although a water-effect ratio affects permit limits for individual dischargers, it is the State in all cases that determines if derivation of a site-specific criterion based on the water-effect ratio is allowed and it is the State that ensures that the calculations and data analysis are done completely and correctly." The EPA strongly recommends that the first WERs developed by the State are reviewed in the study plan phase by the EPA to ensure that WERs that are developed meet the required procedures. The EPA looks forward to working with the State to ensure a quick review of the study plans.

This section also allows for alternative site-specific standards to be developed using the Recalculation Procedure or the Resident Species Procedure in accordance with the WQS Handbook. In deriving site-specific criteria, the Recalculation Procedure (found at Appendix A of Appendix L of the WQS

Handbook) takes into account the differences in sensitivities between the species used in the national dataset in developing the national recommended criteria and the organisms at the site. The Resident Species Analysis (see Chapter 3.7 - Developing Site-Specific Criteria of the WQS Handbook) accounts for that difference as well as the difference between the toxicity of the metal in lab water versus site water similar to a WER. Chapter 3.6 - Policy on Aquatic Life Criteria for Metals was updated to also include procedures to conduct a Streamlined Water-Effects Ratio Procedure for the Discharge of Copper that may be used.

The EPA concludes that the changes to subsection 15A NCAC 02B .0211(11)(b) to add the use of a WER and to include a WER multiplier in each of the criteria is consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. Therefore, these changes are approved by the EPA under CWA section 303(c).

The following provision was added at the end of this subparagraph:

Hardness-dependent freshwater metals standards are located in Sub-Item (c) and (d) and in Table A: Dissolved Freshwater Standards for Hardness-Dependent Metals;

The EPA has reviewed this change and determined that it is non-substantive and therefore, the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

15A NCAC 02B .0211 Fresh Surface Water Quality Standards for Class C Waters Subparagraph (11)(c)(i)

A new subsection 11(c)(i) was added as follows:

> *(11) Metals:*
>
> *(c) Hardness-dependent freshwater metals standards shall be as follows:*
>
> *(i) Hardness-dependent metals standards shall be derived using the equations specified in Table A: Dissolved Freshwater Standards for Hardness-Dependent Metals. If the actual instream hardness (expressed as $CaCO_3$ or Ca+Mg) is less than 25 milligrams/liter (mg/l), standards shall be calculated based upon 25 mg/l hardness. If the actual instream hardness is greater than 25 mg/l and less than 400 mg/l, standards shall be calculated based upon the actual instream hardness. If the instream hardness is greater than 400 mg/l, the maximum applicable hardness shall be 400 mg/l;*

Section 15A NCAC 02B .0211(11)(c)(i) identifies the hardness value to be used in the newly adopted hardness based equations found in Table A (located after 15A NCAC 02B .0211(11)(d) Alternatives). As stated in the CTR, the EPA has found that "hardness and/or other water quality characteristics that are usually correlated to hardness can reduce or increase the toxicities of some metals. Hardness is used as a surrogate for a number of water characteristics which affect the toxicity of metals in a variety of ways." See 65 Fed. Reg. (page 31692). The relationship between hardness and toxicity is inversely proportional, that is, as the hardness increases, the toxicity is reduced. Therefore, the EPA's national recommended criteria for some metals (cadmium, chromium III, copper, lead, nickel, silver and zinc) are expressed as hardness based equations in order to most accurately reflect the site-specific toxicity of those metals.

As noted in letters[1] to the DWR, the EPA strongly supports the use of the nationally recommended hardness based equations for the derivation of criteria for hardness dependent metals. Using these equations should assure that the water quality standards are not *underprotective in low hardness waters* (setting criteria that are too high) or *overprotective in high hardness waters* (setting criteria that are too low). It is important that the correct hardness be used in those equations to ensure that the criteria are derived appropriately. This new section states in part that the hardness dependent standards shall be derived using the equations and that, "standards shall be calculated *based upon the actual instream hardness*." (Emphasis added). The EPA reads this section to state that the hardness to be used in the equation to derive the standard is based upon the actual instream hardness up to 400. This is consistent with the EPA's approach, where for instance, in the CTR, the EPA stated that the criteria should be calculated "using the actual ambient hardness of the surface water."

Low end Hardness Cap

This section also includes a provision that states "If the actual instream hardness (expressed as $CaCO_3$ or Ca+Mg) is less than 25 milligrams/liter (mg/l), standards shall be calculated based upon 25 mg/l hardness." This low end hardness "cap" for calculating criteria is not consistent with current EPA published recommendations. EPA published an update to the national recommended water quality criteria in 2002 that included the hardness dependent metals (EPA 2002). The EPA did not include a minimum hardness cutoff. Further, where the EPA has promulgated hardness based equations in the past such as in the CTR, a low end hardness cap was not included. In that rule, the EPA directly addressed this issue stating, "[I]n the past, EPA generally recommended that 25 mg/l as $CaCO_3$ be used as a default hardness value in deriving freshwater aquatic life criteria for metals when the ambient (or actual) hardness value is below 25 mg/l as $CaCO_3$. However, use of the approach results in criteria that may not be fully protective. Therefore, for waters with a hardness of less than 25 mg/l as $CaCO_3$, criteria should be calculated using the actual ambient hardness of the surface water."

North Carolina's 2015 adoption of a low end hardness cap is not consistent with EPA guidance, even with the State's application of a WER if deemed necessary for additional protection. The State did not provide adequate scientific justification to support its adoption of the cap as an alternative approach to EPA's recommendation. In its summary, the State cited EPA's 2002 Guidance stating toxicity data are somewhat limited below hardness of 25 mg/l, resulting in inconclusive data, and a hardness floor may not be fully protective. The EPA's Guidance states "Capping hardness at 25 mg/L without additional data or justification may result in criteria that provide less protection than that intended by EPA's Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses. Therefore, EPA now recommends that hardness not be capped at 25 mg/L, or any other hardness on the low end." North Carolina is concerned that use of actual ambient hardness in waters where hardness is below 25 mg/l may be overly protective. However, the State has not presented additional data or justification, demonstrating that designated uses would be protected if standards are calculated based upon 25 mg/l hardness in waters with a hardness less than 25 mg/L. Without such supporting justification, North Carolina's methodology for deriving a low end hardness cap is not scientifically defensible and the EPA cannot determine whether the cap would protect designated uses. The EPA concludes that the changes to subsection 15A NCAC 02B .0211(11)(c)(i) providing a low end hardness cap are not consistent with the CWA section 303(c) and 40 C.F.R. sections 131.6 and 131.11, and cannot be approved

[1] See Appendix B, EPA letters to DWR dated April 30, 2009, August 20, 2010, and January 3, 2014 and emails to DWR on August 22, 2014 and August 25, 2014.

as a protective water quality standard. Therefore, the EPA is disapproving the low end hardness cap changes under CWA section 303(c). The approved provision reads:

(11) Metals:

(d) Hardness-dependent freshwater metals standards shall be as follows:

(i) Hardness-dependent metals standards shall be derived using the equations specified in Table A: Dissolved Freshwater Standards for Hardness-Dependent Metals. If the actual instream hardness (expressed as $CaCO_3$ or Ca+Mg) is ~~less than 25 milligrams/liter (mg/l), standards shall be calculated based upon 25 mg/l hardness. If the actual instream hardness is greater than 25 mg/l and~~ less than 400 mg/l, standards shall be calculated based upon the actual instream hardness. If the instream hardness is greater than 400 mg/l, the maximum applicable hardness shall be 400 mg/l;

The EPA recommends that the State delete the low end hardness cap language to match the approved provision above during the next triennial review.

High End Hardness Cap

This section includes the provision, "*If the instream hardness is greater than 400 mg/l, the maximum applicable hardness shall be 400 mg/l*", which is consistent with published EPA recommendations that state, "[a]t high hardness there is an indication that hardness and related inorganic water quality characteristics do not have as much of an effect on toxicity of metals as they do at lower hardnesses. Related water quality characteristics do not correlate as well at high hardnesses." The EPA recommends that for hardness over 400 mg/l as $CaCO_3$ calculation of a criterion with a default WER of 1.0 should provide the protection intended in the 1985 Guidelines. See 57 Fed. Reg. (page 60,916). The EPA does note that "capping hardness at 400 mg/l might result in a level of protection that is higher than that intended by the 1985 guidelines, but any such increase in the level of protection can be overcome by use of the WER procedure." Id. As DWR is adding in the WER procedures in this rulemaking, the state will have the ability to ensure that the proper level of protection is ensured in waters with high hardness.

The EPA concludes that the changes to subsection 15A NCAC 02B .0211(11)(c)(i) providing a high end hardness cap are consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. Therefore, these changes are approved by the EPA under CWA section 303(c).

15A NCAC 02B .0211 Fresh Surface Water Quality Standards for Class C Waters Subparagraph (11)(c)(ii)

A new subsection 11(c)(ii) was added as follows:

(11) Metals:

(c)(ii) Hardness-dependent metals in NPDES permitting: for NPDES permitting purposes, application of the equations in Table A: Dissolved Freshwater Standards for Hardness-Dependent Metals shall have hardness values (expressed as $CaCO_3$ or Ca+Mg) established using the median of instream hardness data collected within the local US Geological Survey (USGS) and Natural Resources Conservation Service (NRCS) 8-digit Hydrologic Unit (HU). The minimum applicable instream hardness shall be 25 mg/l and the maximum applicable instream hardness shall be 400

mg/l, even when the actual median instream hardness is less than 25 mg/l and greater than 400 mg/l;

As stated above, the EPA approved for all purposes under the CWA the use of the actual instream hardness for calculating the appropriate water quality criteria when using the equations in Table A, except for hardness above 400 mg/l $CaCO_3$. The newly adopted provision in this subparagraph adds an alternate method for choosing the hardness value to be used when calculating permit limits for NPDES permits under Section 402 of the CWA.

The DWR stated that this section was adopted to ensure that a set value was used for deriving permit limits that did not vary from day-to-day. Use of the median of instream hardness data collected using the 8-digit Hydrologic Unit (HU) where a facility was located was intended to provide a uniform measurement of hardness both for deriving the permit limit and for determining compliance. The DWR was concerned that the use of the actual instream hardness could also be unduly influenced by effluent which could have higher hardness than the receiving waters, resulting in a metal criterion that would not be protective of downstream waters. North Carolina's evaluation also took into account elevated instream hardness from stormwater run-off in urban centers, which they state has been found to be inconsistent with "unimpacted upstream or downstream hardness values."

However, subpart 15A NCAC 02B .0211(11)(c)(ii), in effect, creates an alternate criteria for permitting purposes from 15A NCAC 02B .0211(11)(c)(i). The EPA regulations found at 40 C.F.R. 131.2 states that water quality standards define "the water quality goals of a water body, or portion thereof, by designating the use or uses to be made of the water and by setting criteria necessary to protect the uses…and serve the purposes of the Clean Water Act." Those references goals include all section 101(a)(2) goals, such as ensuring that waters are fishable/swimmable. 40 C.F.R. 131.2 states that "[s]uch standards *serve the dual purposes* of establishing the water quality goals for a specific water body and serve as the regulatory basis for the establishment of water quality based treatment controls and strategies beyond the tech-based levels of treatment required by section 301(b) and 306 of the Act" (emphasis added). Section 15A NCAC O2B .0211(11)(c)(ii) results in alternative metals effluent limitations for purposes of permitting that are inconsistent with North Carolina's newly established metals criteria and are inconsistent with the water quality standards regulations.

North Carolina has discussed the challenges associated with determining the proper instream hardness values, but has not provided a scientifically defensible justification for the use of the median hardness. Use of the median, by definition, ensures that the hardness value is too high (not protective enough) for half of the facilities and too low (needlessly overprotective) for half the facilities. The size of the 8-digit HUs is such that it could cross ecoregions or subecoregions and include a wide range of hardness values, as demonstrated by the data provided by the State. The purpose of the hardness dependent criteria is to reflect conditions in waters at or near a facility and derive criteria that protect designated uses in those waters. North Carolina has not demonstrated that use of the median hardness will protect designated uses. The EPA NPDES permitting program will work with North Carolina to ensure that the hardness procedures used for implementation will address North Carolina's concerns. For instance, the EPA recommends that hardness samples be collected in the receiving stream upstream and away from the influence of the effluent as discussed in the CTR and those recommendations could be part of the implementation procedures for permitting. The EPA notes that typically these types of provisions are considered through NPDES permitting implementation procedures and should not be included as a WQS. The EPA concludes that the changes to subsection 15A NCAC 02B .0211(11)(c)(ii) are not protective of designated uses and, therefore, are not consistent with the CWA section 303(c) or 40 C.F.R. section 131.11. Therefore, these changes are not approved by the EPA under CWA section 303(c). The EPA

notes in disapproving this section that provisions for determining hardness to use in the hardness based equations shall be conducted using the approved provisions under 15A NCAC 02B .0211(11)(c)(i). The EPA recommends that the State delete the entire provision for median hardness in NPDES permitting during the next triennial review.

15A NCAC 02B .0211 Fresh Surface Water Quality Standards for Class C Waters Subparagraph (11)(d)

New subparagraph (11)(d) was added as follows to allow for the use of WERs for the metals listed in Table A:

> *(d) Alternatives:*
> *Acute and chronic freshwater aquatic life standards for metals listed in Table A apply to the dissolved form of the metal and apply as a function of the pollutant's water effect ratio (WER), which is set forth in Sub-Item (b). Alternative site-specific standards may also be developed as set forth in Sub-Item (b);*

As discussed in the review of the use of WERs under subparagraph .0211(11)(b), the use of WERs is consistent with the EPA's policy and guidance. The discussion in that section's review are incorporated into the review of this section by reference. For the same reasons set out in that section, the EPA concludes that the changes to subsection 15A NCAC 02B .0211(11)(d) to add in the use of a WER and to include a x1 multiplier in each of the criteria for the criteria in Table A is consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. Therefore, these changes are approved by the EPA under CWA section 303(c). The EPA strongly recommends that the first WERs developed by the State are reviewed in the study plan phase by the EPA to ensure that WERs that are developed meet the required procedures. The EPA looks forward to working with the State to ensure a quick review of the study plans.

15A NCAC 02B .0211 Fresh Surface Water Quality Standards for Class C Waters Table A under .0211(d)

A new table, Table A, was added to this section for new or revised criteria for hardness dependent metals:

> *Table A: Dissolved Freshwater Standards for Hardness-Dependent Metals*
> *Numeric standards calculated at 25 mg/l hardness are listed below for illustrative purposes. The Water Effects Ratio (WER) is equal to one unless determined otherwise under Sub-Item (d) of this rule.*

Metal	*Equations for Hardness-Dependent Freshwater Metals (ug/l)*	*Standard at 25 mg/l hardness*
Cadmium, Acute	*WER· [{1.136672-[ln hardness](0.041838)} · e^{0.9151 [ln hardness]-3.1485}]*	*0.82*
Cadmium, Acute, Trout waters	*WER· [{1.136672-[ln hardness](0.041838)} · e^{0.9151[ln hardness]-3.6236}]*	*0.51*
Cadmium, Chronic	*WER· [1.101672-[ln hardness](0.041838)} · e^{0.7998[ln hardness]-4.4451}]*	*0.15*
Chromium III, Acute	*WER· [0.316 · e^{0.8190[ln hardness]+3.7256}]*	*180*
Chromium III, Chronic	*WER· [0.860 · e^{0.8190[ln hardness]+0.6848}]*	*24*

Copper, Acute	*WER· [0.960 · e^{0.9422[ln hardness]-1.700}]* *Or,* *Aquatic Life Ambient Freshwater Quality Criteria—Copper 2007 Revision*	*3.6* *NA*
Copper, Chronic	*WER· [0.960 · e^{0.8545[ln hardness]-1.702}]* *Or,* *Aquatic Life Ambient Freshwater Quality Criteria—Copper 2007 Revision* *(EPA-822-R-07-001)*	*2.7* *NA*
Lead, Acute	*WER· [{1.46203-[ln hardness](0.145712)} · e^{1.273[ln hardness]-1.460}]*	*14*
Lead, Chronic	*WER· [{1.46203-[ln hardness](0.145712)} · e^{1.273[ln hardness]-4.705}]*	*0.54*
Nickel, Acute	*WER· [0.998 · e^{0.8460[ln hardness]+2.255}]*	*140*
Nickel, Chronic	*WER· [0.997 · e^{0.8460[ln hardness]+0.0584}]*	*16*
Silver, Acute	*WER· [0.85 · e^{1.72[ln hardness]-6.59}]*	*0.30*
Zinc, Acute	*WER· [0.978 · e^{0.8473[ln hardness]+0.884}]*	*36*
Zinc, Chronic	*WER· [0.986 · e^{0.8473[ln hardness]+0.884}]*	*36*

Note: For ease of review, this evaluation will be separated into two sections: Cadmium and other metals.

Hardness based equations for all metals except cadmium

The EPA commends the DWR for adopting the hardness based equations for metals to bring them in line with the EPA's national recommended criteria. Use of the equations, rather than the previously used default number at a set hardness, aligns North Carolina's criteria with the national recommended criteria. The equations were developed to most accurately identify the biologically available fraction available for uptake by organisms and therefore most likely to cause a toxic effect to aquatic life. With the exception of cadmium, discussed in more detail below, each of the hardness based equations in Table A is consistent with the national recommended equations and the values for the metal specific variables.

Freshwater Conversion Factors and Parameters for Calculating Freshwater Dissolved Metals Criteria that Are Hardness-Dependent

Chemical	mA	bA	mC	bC	Freshwater Conversion Factor: CMC	Freshwater Conversion Factor: CCC
Cadmium	1.0166	-3.924	0.7409	-4.719	1.136672-[(*ln*hardness)(0.041838)]	1.101672-[(*ln*hardness)(0.041838)]
Chromium III	0.8190	3.7256	0.8190	0.6848	0.316	0.860
Copper	0.9422	-1.700	0.8545	-1.702	0.960	0.960
Lead	1.273	-1.460	1.273	-4.705	1.46203-[(*ln*hardness)(0.145712)]	1.46203-[(*ln*hardness)(0.145712)]
Nickel	0.8460	2.255	0.8460	0.0584	0.998	0.997
Silver	1.72	-6.59	--	--	0.85	--
Zinc	0.8473	0.884	0.8473	0.884	0.978	0.986

Chromium III

Prior to these revisions, North Carolina did not have criteria for chromium III or chromium VI, instead having a single chronic value for total recoverable chromium of 50 ug/l. In this Rule, North Carolina is adopting the EPA's national recommended criteria for chromium III which are expressed as hardness based equations:

Acute: WER· [0.316 · e^{0.8190[ln hardness]+3.7256}] = 180 ug/l when calculated at 25 $CaCO_3$
Chronic: WER· [0.860 · e^{0.8190[ln hardness]+0.6848}] = 24 ug/l when calculated at 25 $CaCO_3$

Considering the scientific and technical information supporting the 304(a) recommendations, the EPA has determined that the changes to subsection 15A NCAC 02B .0211(11) Table A for acute and chronic chromium III criteria protect North Carolina's aquatic life use and, therefore, are consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. These changes are approved by the EPA under CWA section 303(c).

Copper

In this triennial, North Carolina has adopted in Table A the Aquatic Life Ambient Freshwater Quality Criteria—Copper 2007 Revision (EPA 2007) for calculating acute and chronic freshwater copper values using the Biotic Ligand Model (BLM). The BLM uses receiving water body characteristics to develop site-specific water quality criteria using the best available science to determine the bioavailability of copper. The BLM will require ten parameters to be put into the model, including temperature, pH, dissolved organic carbon, calcium, magnesium, sodium, potassium, sulfate, chloride, and alkalinity rather than just the hardness required for the hardness based equation.

North Carolina determined that the BLM was not often practical to implement when resources or data were not available for the collection or use of all ten parameters and therefore caveated the adoption to note that it will be used where sufficient data are available. On February 16, 2016, the EPA made available its Draft Technical Support Document: Recommended Estimates for Missing Water Quality Parameters for Application in EPA's Biotic Ligand Model (EPA 2016). The EPA recommends North Carolina review the document and consider its use when developing site-specific copper criteria.

When sufficient data are not available, North Carolina has chosen to use the EPA's previously published hardness based equation for copper in order to ensure state wide implementation of copper criteria. These EPA equations were derived in EPA's "National Recommended Water Quality Criteria – Correction" (EPA 1999). The DWR notes that this criteria document is a modification of previously published 304(a) aquatic life that was issued in the "1995 Updates: Water Quality Criteria Document for the Protection of Aquatic Life in Ambient Water" (EPA 1995) adopted and approved by all other Region 4 state water quality standards programs. North Carolina also notes that the EPA derived these equations using Great Lakes Initiative Guidelines 60 Fed. Reg. 15,393-15,399, (March 23, 1995); also found in 40 C.F.R. 132, Appendix A. Both the BLM and the hardness based equation were derived based on the principles in the 1985 Guidelines.

The hardness based equation is as follows:

Acute: WER· [0.960 · e^{0.9422[ln hardness]-1.700}] = 3.6 ug/l calculated at 25 mg/l $CaCO_3$
Chronic: WER· [0.960 · e^{0.8545[ln hardness]-1.702}] = 2.7 ug/l calculated at 25 mg/l $CaCO_3$

Considering the scientific and technical information supporting the 304(a) recommendations, the EPA has determined that the acute and chronic copper criteria in subsection 15A NCAC 02B .0211(11) Table A protect North Carolina's aquatic life use and, therefore, are consistent with section 303(c) of the CWA and 40 C.F.R. section 131.11(b)(1)(i). These changes are approved by the EPA under CWA section 303(c) for all purposes under the CWA.

Lead

The numeric criterion for lead was moved from 15A NCAC 02B .021(3)(l)(viii) to 15A NCAC 02B .0211(11)(d) Table A for alphabetizing purposes. The criteria for lead were also significantly revised from a total recoverable chronic value of 25 ug/l to the EPA's national recommended hardness based equations as follows:

Acute: WER· [{1.46203-[ln hardness](0.145712)} · e^{1.273[ln hardness]-1.460}] = 14 at 25 mg/l $CaCO_3$
Chronic: WER· [{1.46203-[ln hardness](0.145712)} · e^{1.273[ln hardness]-4.705}] = 0.54 at 25 mg/l $CaCO_3$

Considering the scientific and technical information supporting the 304(a) recommendations, the EPA has determined that the changes to subsection 15A NCAC 02B .0211(11) Table A for acute and chronic lead criteria protect North Carolina's aquatic life use and, therefore, are consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. These changes are approved by the EPA under CWA section 303(c).

Nickel

The numeric criterion for nickel was moved from 15A NCAC 02B .0211(3)(l)(x) to 15A NCAC 02B .0211(11)(d) Table A for alphabetizing purposes. The criteria for nickel were also revised from a total recoverable chronic value of 88 ug/l to the EPA's national recommended hardness based equations as follows:

Acute: WER· [0.998 · e^{0.8460[ln hardness]+2.255}] = 140 ug/l at 25 mg/l $CaCO_3$
Chronic: WER· [0.997 · e^{0.8460[ln hardness]+0.0584}] = 16 ug/l at 25 mg/l $CaCO_3$

Considering the scientific and technical information supporting the 304(a) recommendations, the EPA has determined that the changes to subsection 15A NCAC 02B .0211(11) Table A for acute and chronic nickel criteria protect North Carolina's aquatic life use and, therefore, are consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. These changes are approved by the EPA under CWA section 303(c).

Silver

In this revision, North Carolina is adding an acute criterion for silver that is derived based on the EPA's national recommended hardness based equation:

Acute: WER· [0.85 · e^{1.72[ln hardness]-6.59}] = 30 ug/l at 25 mg/l $CaCO_3$

Considering the scientific and technical information supporting the 304(a) recommendations, the EPA has determined that the change to subsection 15A NCAC 02B .0211(11) Table A for acute silver criteria

protects North Carolina's aquatic life use and, therefore, is consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. Therefore, this change is approved by the EPA under CWA section 303(c).

Zinc

North Carolina has revised its previous water quality standard for zinc from a chronic value of 50 ug/l to the dissolved acute and chronic values expressed by the EPA's national recommended hardness dependent equations:

Acute: WER· [0.978 · e^{0.8473[ln hardness]+0.884}] = 36 ug/l calculated at 25 mg/l $CaCO_3$
Chronic: WER· [0.978 · e^{0.8473[ln hardness]+0.884}] = 36 ug/l calculated at 25 mg/l $CaCO_3$

Considering the scientific and technical information supporting the 304(a) recommendations, the EPA has determined that the zinc criteria in subsection 15A NCAC 02B .0211(11) Table A protect North Carolina's aquatic life use and, therefore, are consistent with section 303(c) of the CWA and 40 C.F.R. section 131.11(b)(1)(i). These changes are approved by the EPA under section 303(c) for all purposes under the CWA.

Using the equations above for hardness dependent metals (other than cadmium), EPA compared North Carolina's new metals criteria to the EPA's recommended criteria, calculating all values for a default hardness of 25 mg $CaCO_3$ to facilitate comparison. Each individual criteria adopted by North Carolina is at least as stringent as the EPA's national recommendations.[2]

Comparison of Table A Hardness Dependent Metals with EPA's National Recommended Criteria			
Metal (all values are dissolved)	**NCDWR's Criteria calculated at a hardness of 25 (ug/l)**	**EPA's National Recommended criteria calculated at a hardness of 25 (ug/l)**	**EPA's Most Current Published Update**
Chromium III (acute)	180	183.07	EPA 1995
Chromium III (chronic)	24	23.81	EPA 1999
Copper (acute)	3.6	3.6	EPA 2007
Copper (chronic)	2.7	2.7	EPA 1999
Lead (acute)	14	13.88	EPA 1984
Lead (chronic)	0.54	0.54	
Nickel (acute)	140	144.92	EPA 1999
Nickel (chronic)	16	16	
Silver (acute)	0.30	0.3	EPA 1980
Zinc (acute)	36	36	EPA 1999
Zinc (chronic)	36	36	

[2] The slight differences in criteria levels shown in the chart is due to how the State and the EPA rounded results of calculations.

Hardness Based Equations for Cadmium

Prior to this revision, North Carolina had a chronic value of 0.4 ug/l for total cadmium in trout waters and 2.0 ug/l for total cadmium in non-trout waters found at 15A NCAC 02B .0211(3)(l)(iii). The revised water quality criteria for acute and chronic cadmium have been moved alphabetically into 15A NCAC 02B .0211 Table A. The new criteria are hardness based equations for the calculation of acute dissolved cadmium for non-trout and trout waters and a single chronic value for all waters.
The equations that North Carolina adopted did not use the variables that are recommended in the EPA's most recent recommendations resulting in criteria that differ from the national recommended criteria as indicated in the Table below.

Comparison of Table A Hardness Dependent Metals with EPA's National Recommended Criteria for Cadmium				
Metal (all values are dissolved)	**Previous NCDWR criteria**	**NCDWR's Criteria calculated at a hardness of 25 (ug/l)**	**EPA's National Recommended criteria calculated at a hardness of 25 (ug/l)**	**Most current EPA National Recommended Value**
Cadmium (acute)	--	**0.82**	0.52	EPA 2001
Cadmium (acute, trout waters)	--	0.51	0.52	
Cadmium (chronic)	0.4 ug/l trout waters 2.0 ug/l non-trout waters.	**0.15**	0.09	

The EPA's national recommended water quality criteria for cadmium were published in 2001 using the following equations:

$$\text{CMC (dissolved)} = (\text{CF})\ \exp\{\mathbf{m_A}\ [\ln(\text{hardness})] + \mathbf{b_A}\}$$
$$\text{CCC (dissolved)} = (\text{CF})\ \exp\{\mathbf{m_C}\ [\ln(\text{hardness})] + \mathbf{b_C}\}$$

The DWR modified those equations to use different variables from the recommended hardness criteria as shown in table below:

Hardness-based Equation Variable	$\mathbf{m_A}$ **(acute)**	$\mathbf{b_A}$ **(acute)**	$\mathbf{m_C}$ **(chronic)**	$\mathbf{b_C}$ **(chronic)**
EPA Recommended Variables for calculating cadmium criteria	1.0166	-3.924	0.7409	-4.719
Variables used by NC to calculate criteria	0.9151 (non-trout) 0.9151 (trout)	-3.1485 (non-trout) 3.6236 (trout)	0.7998	-4.4451

These modifications result in the following adopted equations for cadmium with the criteria shown calculated at 25 mg/l $CaCO_3$.

Acute: WER· [{1.136672-[ln hardness](0.041838)} · e^{0.9151 [ln hardness]-3.1485}] = 0.82
Acute (trout): WER· [{1.136672-[ln hardness](0.041838)} · e^{0.9151[ln hardness]-3.6236}] = 0.51
Chronic: WER· [1.101672-[ln hardness](0.041838)} · e^{0.7998[ln hardness]-4.4451}] = 0.15

North Carolina used the option under Section 131.11(b)(ii) that allows states to establish numerical standards by modifying Section 304(a) Guidance to reflect site-specific conditions. According to the DWR's justification, the State relied upon a study by Chadwick Ecological Consultants (CEC) that calculated alternative cold and warm water acute and chronic criteria for cadmium. Those values were adopted by the State of Colorado (effective date 1/1/2007) and approved by EPA Region 8. In Region 8's approval of those criteria, Region 8 stated:

> *EPA has reviewed the technical information supporting the revised table values. The Region notes that CEC applied the "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and their Uses" (EPA, 1985) in deriving the revised table values. The Region also notes that the differences between the CEC-derived table values and the CWA Section 304(a) criteria are partly attributable to CEC's use of a larger, more current database. Finally, the Region notes that the differences between the CEC-derived table values and the CWA Section 304(a) criteria are small relative to the uncertainties in both analyses. Accordingly, the Region has determined that: (I) the revised acute and chronic table value standards for cadmium were derived using scientifically-defensible methods, (2) the resulting table values generally are appropriate for the protection of Colorado's aquatic life classifications, and (3) the revisions are consistent with federal requirements at 40 C.F.R. 131.11. Accordingly, the revisions are approved today, subject to ESA consultation.*

Region 4 has determined that the CEC report relied on by the State represents the latest compilation of cadmium toxicity data available, consistent with Region 8's determination cited above. Region 4's findings are consistent with the scientific findings of Region 8 cited above and, additionally, Region 4 finds that the resulting values derived by North Carolina protect the State's aquatic life classifications. Region 4 concludes that the changes to subsection 15A NCAC 02B .0211(11)(d) to add the revised criteria in Table A for cadmium are consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. Therefore, these changes are approved by the EPA under CWA section 303(c) for all purposes under the Act.

15A NCAC 02B .0211(11)(e) Fresh Surface Water Quality Standards for Class C Waters

A new subsection regarding monitoring for metals was added as follows:

> *(11) Metals:*
>
> *(e) Compliance with acute instream metals standards shall only be evaluated using an average of two or more samples collected within one hour. Compliance with chronic instream metals standards shall only be evaluated using averages of a minimum of four samples taken on 5 consecutive days, or as a 96-hour average;*

After review of this new provision, the EPA has concluded that it is not a new or revised water quality standard and is therefore taking no action on this provision. This provision does not establish or change a level of protection related to the magnitude, duration, or frequency of water quality criteria nor establish designated uses or antidegradation requirements. Rather, this provision describes the sufficiency or reliability of information necessary for the State to decide whether a water attains or does not attain a water quality standard for purposes of establishing TMDLs under section 303(d)(1)(A) of the Act. As such, this provision is not a water quality standard but is a methodology under section 303(d) of the Act. See 40 C.F.R. § 130.7(b)(6). While this provision was not reviewed by EPA as a new or revised water quality standard, it may be considered by the EPA in reviewing lists of impaired waters submitted by the State under Section 303(d) of the CWA. The decision to not review this provision in no way confers agreement with the use of the provision for making attainment decisions.

15A NCAC 02B .0211 Fresh Surface Water Quality Standards for Class C Waters Subparagraph (11)(f)

A new subsection relating to biological confirmation for the assessment of metals was added as follows:

> *(f) Metals criteria shall be used for proactive environmental management. An instream exceedence of the numeric criterion for metals shall not be considered to have caused an adverse impact to the instream aquatic community without biological confirmation and a comparison of all available monitoring data and applicable water quality standards. This weight of evidence evaluation shall take into account data quality and the overall confidence in how representative the sampling is of conditions in the waterbody segment before an assessment of aquatic life use attainment, or non-attainment, shall be made by the Division. Recognizing the synergistic and antagonistic complexities of other water quality variables on the actual toxicity of metals, with the exception of mercury and selenium, biological monitoring will be used to validate, by direct measurement, whether or not the aquatic life use is supported:*

As the EPA has advised the DWR on multiple occasions, including directly addressing this provision in writing on multiple occasions, the EPA has a long history of not supporting biological confirmation for toxics assessment.[3] The EPA views biological criteria as one component of a comprehensive water quality standards program that works in concert with – *not in place of* – the use of water quality criteria for toxics as detailed further below.

North Carolina is adopting criteria for metals which will bring its water quality standards program in-line with other Region 4 states and EPA's national recommended criteria. These revisions are significant because chemical specific numeric criteria are a vital component of the CWA program for protection of the nation's waters for both assessment and permitting. The EPA has stated that "chemical specific assessments are ideal for predicting the likelihood of ecological impacts where they may not yet have occurred because…critical exposure conditions have not yet been experienced by the aquatic community." It further states that "Basing regulatory and management decisions on chemical assessment of water quality is an important and proven aspect of water quality assessment and protection" Water Quality Standards Regulation; Proposed Rule 63 Fed. Reg. (page 36,796) (July 7, 1998). Therefore, once

[3] See Appendix B, letters from the EPA to DWR dated August 10th, 2010, and January 3, 2014 and emails to DWR on August 22, 2014 and August 25, 2014.

criteria are established, assessment for purposes of listing under section 303(d) of the CWA and for permitting under the NPDES program must be based on all applicable water quality criteria.

In contrast, the EPA has stated that, "...while biological assessments can provide information in determining the cumulative effect of past or current impacts from multiple stressors, these assessments may be limited in their ability to predict, and therefore *prevent*, impacts" (emphasis added.) In fact, once biological impairment has been found, by definition, that impact was not prevented and costs for determining the cause and source and needed restoration can be prohibitive. 63 Fed. Register page 36,795.

The EPA has discussed how results of different tools should be reconciled should they indicate different outcomes, such as passing a biological assessment while exceeding a chemical criteria. "Where biological impact is not detected using biological assessment methods, it is possible that impairment that is projected and plausible, may simply have not yet occurred....EPA's view is that it would be inappropriate to ignore projected impairment simply because the impairment has not yet been observed in the environment" See 63 Fed. Reg. (page 36,801).

Section 101(a) of the CWA directly states the goal that the biological integrity of the Nation's waters be maintained, specifically stating the national policy that the discharge of toxic pollutants in toxic amounts be prohibited in order to maintain biological integrity. To meet that goal, 40 C.F.R. 131.11 provides that criteria for toxics be established at levels that protect designated uses, that is, at levels that *prevent* impairment of waters. It is not protective to defer action until biological impairment has already occurred.

Furthermore, the EPA notes that DWR has adopted as part of this triennial review the use of the dissolved fraction of the toxics criteria, the hardness based equation for the hardness dependent metals and the BLM for copper criteria. Each of these provisions were done to more accurately derive and use criteria that are reflective of the biologically available fraction of the metals.

Finally, the US Fish and Wildlife Service (FWS) commented[4] on this provision during the public comment period. In addition to all of the EPA's stated objections, the FWS pointed out an additional flaw in this provision – the biological monitoring conducted by DWR does not include testing for those species that are most sensitive to toxic effects, including mussels, cladocerons and snails. Therefore North Carolina's biological monitoring is not representative of the impacts to all species that may be the most sensitive to the toxics subject to the new metals criteria adopted by the State during this triennial review.

The EPA has determined that the changes to subsection 15A NCAC 02B .0211(11)(f) do not protect North Carolina's aquatic life use and, therefore, are not consistent with the CWA section 303(c) or its implementing regulations found at 40 C.F.R. section 131.11. Therefore, these changes are disapproved by the EPA under CWA section 303(c). With today's disapproval of this section, the new water quality criteria for metals as approved shall be used for all purposes under the Act, including for purposes of monitoring and assessment. The EPA recommends that the State delete the entire biological confirmation provision during the next triennial review.

[4] See Appendix C. letters from the US FWS to NC DENR dated, January 3, 2014, and August 22, 2014.

15A NCAC 02B .0211 Fresh Surface Water Quality Standards for Class C Waters
Subparagraph 13 - 20

The following parameters were moved in order to alphabetize the state water quality criteria:

(13) Pesticides:
- *(a) Aldrin: 0.002 ug/l;*
- *(b) Chlordane: 0.004 ug/l;*
- *(c) DDT: 0.001 ug/l;*
- *(d) Demeton: 0.1 ug/l;*
- *(e) Dieldrin: 0.002 ug/l;*
- *(f) Endosulfan: 0.05 ug/l;*
- *(g) Endrin: 0.002 ug/l;*
- *(h) Guthion: 0.01 ug/l;*
- *(i) Heptachlor: 0.004 ug/l;*
- *(j) Lindane: 0.01 ug/l;*
- *(k) Methoxychlor: 0.03 ug/l;*
- *(l) Mirex: 0.001 ug/l;*
- *(m) Parathion: 0.013 [~~ug/l;~~] ug/l; and*
- *(n) Toxaphene: 0.0002 ug/l;*

~~(g)~~(14) pH: shall be normal for the waters in the area, which ~~generally shall~~ range between 6.0 and 9.0 except that swamp waters may have a pH as low as 4.3 if it is the result of natural conditions;

~~(h)~~(15) Phenolic compounds: only such levels as shall not result in fishflesh- tainting or impairment of other best usage;

(16) Polychlorinated biphenyls (total of all PCBs and congeners identified): 0.001 ug/l;

~~(i)~~(17) Radioactive substances:
- *~~(i)~~(a) Combined radium-226 and radium-228: the ~~maximum~~ average annual activity level (based on at least one sample collected per quarter)~~four samples collected quarterly)~~ for combined radium226 and radium228 shall not exceed five -picoCuries- per liter;*
- *~~(ii)~~(b) Alpha Emitters: the average annual gross alpha particle activity (including radium226, but excluding radon and uranium) shall not exceed 15 picoCuries- per liter;*
- *~~(iii)~~(c) Beta Emitters: the ~~maximum~~ average annual activity level (based on at least one sample collected per quarter) ~~four samples, collected quarterly)~~ for strontium90 shall not exceed eight picoCuries- per liter; nor shall the average annual gross beta particle activity (excluding potassium-40 and other naturally occurring ~~radio-nuclides)~~ radionuclides) exceed 50 picoCuries per liter; nor shall the ~~maximum~~ average annual activity level for tritium exceed 20,000 picoCuries per liter;*

~~(j)~~(18) Temperature: not to exceed 2.8 degrees C (5.04 degrees F) above the natural water temperature, and in no case to exceed 29 degrees C (84.2 degrees F) for mountain and upper piedmont waters and 32 degrees C (89.6 degrees F) for lower piedmont and coastal plain Waters; the temperature for trout waters shall not be increased by more than 0.5 degrees C (0.9 degrees F) due to the discharge of heated liquids, but in no case to exceed 20 degrees C (68 degrees F);

(19) Toluene: 11 ug/l or 0.36 ug/l in trout classified waters;

(20) Trialkyltin compounds: 0.07 ug/l expressed as tributyltin;

~~(k)~~(21) *Turbidity: the turbidity in the receiving water shall not exceed 50 Nephelometric Turbidity Units (NTU) in streams not designated as trout waters and 10 NTU in streams, ~~lakes~~ lakes, or reservoirs designated as trout waters; for lakes and reservoirs not designated as trout waters, the turbidity shall not exceed 25 NTU; if turbidity exceeds these levels due to natural background conditions, the existing turbidity level shall not be increased. Compliance with this turbidity standard can be met when land management activities employ Best Management Practices (BMPs) [as defined by Rule .0202 of this Section] recommended by the Designated Nonpoint Source Agency [as defined by Rule .0202 of this Section]. BMPs ~~must~~ shall be in full compliance with all specifications governing the proper design, installation, ~~operation~~ operation, and maintenance of such BMPs;*

The EPA has reviewed the revision and since the numeric values of the above listed criteria did not change, they are non-substantive. Therefore, the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

15A NCAC 02B .0211 Fresh Surface Water Quality Standards for Class C Waters Subparagraph (l)

The following language was removed from previously existing 15A NCAC 02B .0211(3)(l) where it had served as the introductory language to all metals criteria as well as criteria for other toxics (chlorine, cyanide flourides, pesticides, polychlorinated biphenyls, toluene and trialkyltin compounds). After alphabetizing the criteria, the metals and toxics criteria are no longer together in one section, therefore, the State removed the following introductory language.

~~*(l) Toxic substances: numerical water quality standards (maximum permissible levels) for the protection of human health applicable to all fresh surface waters are in Rule .0208 of this Section. Numerical water quality standards (maximum permissible levels) to protect aquatic life applicable to all fresh surface waters:*~~

The "General" paragraph listed at the beginning of 15A NCAC 02B .0211 now serves as the introductory paragraph to this section which applies to all metals and toxics criteria. The "General" paragraph states that the WQS "…for all fresh surface waters are the basic standards applicable to Class C waters." 15A NCAC 02B .0101 General Procedures provides a definition for Class C waters which includes that Class C waters are "*freshwaters protected for secondary recreation, fishing, aquatic life including propagation and survival, and wildlife. All freshwaters shall be classified to protect these uses at a minimum.*" EPA has reviewed this change and determined that it is non-substantive. The EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

The following sections were removed from this subparagraph as follows:

~~*(i) Arsenic: 50 ug/l;*~~
~~*(ii) Beryllium: 6.5 ug/l;*~~
~~*(iii) Cadmium: 0.4 ug/l for trout waters and 2.0 ug/l for nontrout waters; attainment of these water quality standards in surface waters shall be based on measurement of total recoverable metals concentrations unless appropriate studies have been conducted to translate total recoverable*~~

~~metals to a toxic form. Studies used to determine the toxic form or translators must be designed according to the "Water Quality Standards Handbook Second Edition" published by the Environmental Protection Agency (EPA 823-B-94-005a) or "The Metals Translator: Guidance For Calculating a Total Recoverable Permit Limit From a Dissolved Criterion" published by the Environmental Protection Agency (EPA 823-B-96-007) which are hereby incorporated by reference including any subsequent amendments. The Director shall consider conformance to EPA guidance as well as the presence of environmental conditions that limit the applicability of translators in approving the use of metal translators;~~

~~(iv) Chlorine, total residual: 17 ug/l;~~

~~(v) Chromium, total recoverable: 50 ug/l;~~

~~(vi) Cyanide, 5.0 ug/l, unless site-specific criteria are developed based upon the aquatic life at the site utilizing The Recalculation Procedure in Appendix B of Appendix L in the Environmental Protection Agency's Water Quality Standards Handbook hereby incorporated by reference including any subsequent amendments;~~

~~(vii) Fluorides: 1.8 mg/l;~~

~~(viii) Lead, total recoverable: 25 ug/l, collection of data on sources, transport and fate of lead shall be required as part of the toxicity reduction evaluation for dischargers who are out of compliance with whole effluent toxicity testing requirements and the concentration of lead in the effluent is concomitantly determined to exceed an instream level of 3.1 ug/l from the discharge;~~

~~(ix) Mercury: 0.012 ug/l;~~

~~(x) Nickel: 88 ug/l, attainment of these water quality standards in surface waters shall be based on measurement of total recoverable metals concentrations unless appropriate studies have been conducted to translate total recoverable metals to a toxic form. Studies used to determine the toxic form or translators must be designed according to the "Water Quality Standards Handbook Second Edition" published by the Environmental Protection Agency (EPA 823-B-94-005a) or "The Metals Translator: Guidance For Calculating a Total Recoverable Permit Limit From a Dissolved Criterion" published by the Environmental Protection Agency (EPA 823-B-96-007) which are hereby incorporated by reference including any subsequent amendments. The Director shall consider conformance to EPA guidance as well as the presence of environmental conditions that limit the applicability of translators in approving the use of metal translators;~~

~~(xi) Pesticides:~~

~~(A) Aldrin: 0.002 ug/l;~~

~~(B) Chlordane: 0.004 ug/l;~~

~~(C) DDT: 0.001 ug/l;~~

~~(D) Demeton: 0.1 ug/l;~~

~~(E) Dieldrin: 0.002 ug/l;~~

~~(F) Endosulfan: 0.05 ug/l;~~

~~(G) Endrin: 0.002 ug/l;~~

~~(H) Guthion: 0.01 ug/l;~~

~~(I) Heptachlor: 0.004 ug/l;~~

~~(J) Lindane: 0.01 ug/l;~~

~~(K) Methoxychlor: 0.03 ug/l;~~

~~(L) Mirex: 0.001 ug/l;~~
~~(M) Parathion: 0.013 ug/l;~~
~~(N) Toxaphene: 0.0002 ug/l;~~
~~(xii) Polychlorinated biphenyls: (total of all PCBs and congeners identified) 0.001 ug/l;~~
~~(xiii) Selenium: 5 ug/l;~~
~~(xiv) Toluene: 11 ug/l or 0.36 ug/l in trout waters;~~
~~(xv) Trialkyltin compounds: 0.07 ug/l expressed as tributyltin;~~

The struck provisions for arsenic, beryllium, cadmium, chromium, lead and nickel have been replaced by new criteria as noted above. The remaining numeric values in this section were moved to other sections as previously noted. As the criteria are not changed, the EPA determined that these changes are non-substantive and therefore, the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

15A NCAC 02B .0211(22) Fresh Surface Water Quality Standards for Class C Waters

North Carolina has had a provision in place to allow the use of action levels for copper, iron, silver, zinc and chloride rather than using water quality criteria for all purposes under the CWA. Under North Carolina's WQS, action levels are numerical water quality standards except for NPDES permitting. For NPDES permitting purposes, a facility would need reasonable potential to exceed a water quality criteria (or in this case, the action level), and must fail a Whole Effluent Toxicity (WET) test prior to receiving a limit in its NPDES permit. If a facility had reasonable potential for a parameter, such as copper or zinc, but passed a WET test, the facility would not be required to limit or control the parameter in its permit. Therefore, a facility may cause or contribute to an exceedance of an action level parameter and pass a WET test thereby not controlling for the action level parameters in its permit.

A subsection relating to action levels was revised to change the values for copper, silver and zinc, remove iron and remove the language that states that action levels are considered water quality standards. Each of the revisions are addressed individually below:

~~(1)~~(22) Action Levels for Toxic ~~Substances:~~ Substances Applicable to NPDES Permits:
(a) ~~Copper: 7 ug/l;~~Copper, dissolved, chronic: 2.7 ug/l;
~~(b) Iron: 1.0 mg/l;~~
(c) ~~Silver:~~Silver, dissolved, chronic: 0.06 ug/l;
(d) ~~Zinc:~~Zinc, dissolved, chronic: ~~50 ug/l;~~36 [~~ug/l;~~] ug/l; and
(e) Chloride: 230 mg/l;
The hardness-dependent freshwater action levels for ~~Copper and Zinc,~~ copper and zinc, provided here for illustrative purposes, corresponds to a hardness of 25 mg/l. Copper and [~~Zinc~~] zinc action level values for other instream hardness values shall be calculated per the chronic equations specified in Item (11) of this Rule and in Table A: Dissolved Freshwater Standards for Hardness-Dependent Metals. If the ~~Action Levels~~ action levels for any of the substances listed in this ~~Subparagraph~~Item (which are generally not bioaccumulative and have variable toxicity to aquatic life because of chemical form, solubility, stream characteristics or associated waste characteristics) are determined by the waste load allocation to be exceeded in a receiving water by a discharge under the specified ~~low flow~~ 7Q10 criterion for toxic ~~substances (Rule .0206 in this Section),~~ substances, the discharger shall monitor the chemical or biological effects of the discharge; efforts shall be

made by all dischargers to reduce or eliminate these substances from their effluents. Those substances for which ~~Action Levels~~ action levels are listed in this ~~Subparagraph~~Item shall be limited as appropriate in the NPDES permit ~~based on the Action Levels listed in this Subparagraph~~ if sufficient information (to be determined for metals by measurements of that portion of the dissolved instream concentration of the ~~Action Levels~~ action levels parameter attributable to a specific NPDES permitted discharge) exists to indicate that any of those substances may be a causative factor resulting in toxicity of the effluent. ~~NPDES permit limits may be based on translation of the toxic form to total recoverable metals. Studies used to determine the toxic form or translators must be designed according to "Water Quality Standards Handbook Second Edition" published by the Environmental Protection Agency (EPA 823-B-94-005a) or "The Metals Translator: Guidance For Calculating a Total Recoverable Permit Limit From a Dissolved Criterion" published by the Environmental Protection Agency (EPA 823-B-96-007) which are hereby incorporated by reference including any subsequent amendments. The Director shall consider conformance to EPA guidance as well as the presence of environmental conditions that limit the applicability of translators in approving the use of metal translators.~~

~~For purposes other than consideration of NPDES permitting of point source discharges as described in this Subparagraph, the Action Levels in this Rule, as measured by an appropriate analytical technique, per 15A NCAC 02B .0103(a), shall be considered as numerical instream water quality standards.~~

Removal of the Action Level for Iron

North Carolina has removed the action level for iron and has not replaced that value with a new or revised numeric water quality criterion. DWR proposed this revision and worked with the EPA in the scientific review and development of a justification that demonstrates that iron occurs at naturally high levels in some areas of the state, often above the value of 1 mg/l that is being removed. The EPA Region 4 conducted an independent evaluation of the State's findings and supports the removal of the iron criterion because iron occurs at naturally high levels. DWR has agreed that in order to protect the designated use for any potential impairment determined to be caused by iron (for instance, from mining operations or increased iron in the tailwaters below dams), the State will rely upon the existing narrative WQS at 15A NCAC .0211(12), "[o]ils, deleterious substances, colored, or other wastes: only such amounts as shall not render the waters injurious to public health, secondary recreation, or to aquatic life and wildlife, or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated uses."

The EPA has determined that the change to subsection 15A NCAC 02B .0211(22) to remove the iron criterion protects North Carolina's aquatic life use and, therefore, is consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. The change is approved by the EPA under CWA section 303(c) for all purposes under the Act.

Revision to Copper, Silver and Zinc as an Action Level

As the EPA has advised the DWR on multiple occasions, the EPA does not support North Carolina's continued use of action levels, and directly addressed this provision in multiple letters to DWR.[5] The EPA reiterates its previous comments. The EPA's section 304(a) criteria were developed to take into account site specific factors such as solubility and chemical form in determining the biologically available fraction

[5] See Appendix B. EPA letters to DWR dated April 30, 2009, August 20, 2010, and January 3, 2014 and emails to DWR on August 22, 2014 and August 25, 2014.

available for uptake by biological organisms and, therefore, the fraction most likely to cause a toxic effect. The use of the dissolved fraction and the use of the hardness-based equations for hardness dependent metals, such as copper and zinc, further addressed variability caused by stream characteristics. Hardness is used as a surrogate for a number of water quality characteristics, which affect the toxicity of metals in a variety of ways. See 65 Fed. Reg. (page 31,692). North Carolina's adoption of the hardness dependent equations negates the need for the continued use of action levels as the criteria equations address issues related to protection of downstream waters and brings North Carolina in-line with the criteria used in surrounding states. This is particularly true as North Carolina is adopting the procedures for the use of the Biotic Ligand Model for copper as well as including a reference for EPA approved site-specific criteria development, such as WERs, under 15A NCAC 02B .0211(11)(b).

North Carolina's action level requirements, set forth above, provide that NPDES limits shall be set for metals if information exists to indicate that a particular substance may be a *causative* factor resulting in the toxicity of the effluent. 40 C.F.R. 122.44(d)(1)(i) states that limits must be put in place to control pollutants which may be discharged at a level "which will cause, have the reasonable potential to cause or contribute to an excursion above any State water quality standard." This regulation does not indicate that the effluent must be the sole cause of toxicity before the parameter should be limited. The provision states that the pollutant should be limited under NPDES if it could cause or if it could *contribute* to a water quality standards excursion. This requirement is significant because there may often be multiple sources of pollutants in receiving waters, from non-point source run-off, from point sources and from storm water. No one facility or source may be the sole cause of the impairment, but rather multiple discharges contribute to the toxicity and excursion of water quality standards. That is, a facility could contribute to an impairment while also passing a WET test. Therefore, when a point source discharges zinc levels with a reasonable potential to cause or contribute to exceedance of the State's zinc criteria, the permit must include effluent limitations as stringent as necessary to achieve the WQS.

The Region recognizes that North Carolina has a strong WET testing program. WET testing can be "effective for controlling discharges containing multiple pollutants. It can also provide a method for addressing synergistic and antagonistic effects on aquatic life" from multiple pollutants. See 63 Fed. Reg. (page 36,768). However, where criteria exist to directly control toxic pollutants, those criteria should be used to limit the discharge of pollutants. WET should be used to address those instances where criteria may not be available to limit toxicity. The EPA has explained that states can reconcile biological data, such as WET, with 'reasonable potential' analysis and concludes "EPA would not support a radical shift away from chemical criteria and limits or toxicity criteria and limits. Those tools are simply too important as proven tools for assessing potential impact to surface waters and improving water quality." See 63 Fed. Reg. (page 36,802). If needed, an effort should be made to refine the applicable criteria, through WERs and other tools, to ensure that appropriate criteria be developed for each facility. It is not protective, however, and is not consistent with EPA's permitting regulations, to defer permit limitations once there is reasonable potential to exceed a water quality criteria.

The State now has approved copper, silver and zinc criteria applicable for all purposes under the CWA in 15A NCAC 02B .0211(11) in place of the action levels, which were applicable only for NPDES permitting. The EPA concludes that the changes to subsection 15A NCAC 02B .0211(22) do not protect North Carolina's aquatic life use and, therefore, are not consistent with the CWA section 303(c) or its implementing regulations found at 40 C.F.R. section 131.11. The changes to (22)(a), (c), and (d) and the added language to the narrative following (22)(e) are disapproved by the EPA under CWA section 303(c). The deletions of the narrative language below (22)(e) at the end of the provision are approved by the EPA under CWA section 303(c) as consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. The EPA notes in disapproving this section that no new standards are required to be promulgated in its place

and the new water quality criteria for metals as approved in 15A NCAC 02B .0211(11) shall be used for all purposes under the Act.

The EPA's disapproval of the revisions to the action level provision means that the previously approved action levels are applicable WQS under the CWA, per the Alaska Rule.[6] However, the State's newly adopted and approved metals criteria are also applicable WQS under the CWA and, therefore, must also be implemented in all CWA programs, including the NPDES permitting program. The EPA's permitting regulations at 40 C.F.R. 122.44(d)(1)(vii)(A) require that effluent limitations be derived from and comply with all applicable water quality standards. Where the State has two applicable water quality standards addressing the same or similar parameters, permit limitations based on those WQS must protect the more stringent criteria. Based on EPA's understanding of the permitting provisions in North Carolina's action level section, effluent limitations derived to comply with the new metals criteria in 15A NCAC 02B .0211(11) will likely be more stringent than limitations derived to comply with the action level provision. The EPA recommends that the State delete the entire action level section during the next triennial review.

Action Level for Chloride

Chloride remains the only parameter in the action levels provision for which there is not an associated criterion in Table A or elsewhere in the State water quality standards. Prior to this revision, the following language applied to the action levels,

> "*For purposes other than consideration of NPDES permitting of point source discharges as described in this Subparagraph, the Action Levels in this Rule, as measured by an appropriate analytical technique, per 15A NCAC 02B .0103(a), shall be considered as numerical instream water quality standards.*"

This language, which was removed from the revised action level provision, was previously added by the State to clarify that the State intended the action level values to be standards for all other CWA purposes besides permitting. In this triennial review, the State adopted numeric water quality criteria for all purposes under the CWA, as water quality standards. The adoption of numeric criteria for all other action level parameters clarifies their use as WQS. The numeric value for chloride still remains and the EPA anticipates that the State will continue using the chloride action level as a WQS for all other purposes under the CWA. The EPA's position is that the chloride action level is still a WQS for all other purposes than permitting even with the sentence above deleted. The EPA notes that with this section 303(c) decision, the only remaining action level is chloride. Therefore, the EPA strongly recommends that North Carolina adopt chloride as a numeric water quality criterion for all purposes under the CWA and remove the Action Level section from the water quality standards.

[6] The Alaska Rule states that water quality standards adopted by states and authorized tribes on or after May 30, 2000 must be approved by the EPA before they can be used as the basis for actions, such as establishing water quality-based effluent limitations or TMDLs, under the CWA.

15A NCAC 02B .0212 Fresh Surface Water Quality Standards for Class WS-I Waters
15A NCAC 02B .0214 Fresh Surface Water Quality Standards for Class WS-II Waters
15A NCAC 02B .0215 Fresh Surface Water Quality Standards for Class WS-III Waters
15A NCAC 02B .0216 Fresh Surface Water Quality Standards for Class WS-IV Waters
15A NCAC 02B .0218 Fresh Surface Water Quality Standards for Class WS-V Waters

Section (h) of each of the five WS designated use classifications was revised as follows:

(h) Toxic and other deleterious substances:
(i) Water quality standards (maximum permissible concentrations) to protect human health through water consumption and fish tissue consumption for noncarcinogens- in Class WS-V waters:
(A) Barium: 1.0 mg/l;
(B) Chloride: 250 mg/l;
~~(C) Manganese: 200 ug/l;~~
~~(D)~~(C) Nickel: 25 ug/l;
~~(E)~~(D) Nitrate nitrogen: 10 mg/l;
~~(F)~~(E) 2,4-D: ~~100 ug/l;~~70 ug/l;

Manganese

The DWR conducted a review of the effects of manganese on human health and taste and odor (organoleptic effects) in WS waters. As part of that evaluation, the State reviewed stream and groundwater data on how often manganese occurs in State waters. The DWR initiated this review because the State's monitoring data often showed levels of manganese that were higher than the State's criterion of 200 ug/l. The results of the review found studies that show high concentrations of naturally occurring manganese in both state surface water and groundwater. For example, a United States Geological Survey (USGS 1992) study indicated concentrations of manganese ranged from "less than 10 to 380 ug/l…" and that "…many mean concentrations of total manganese in stream water exceeded recommended limits…" A second USGS paper found a range of 30-640 ug/l manganese in the French Broad River and noted that the "geology of the region is the primary cause for these high…manganese concentrations." (USGS 1982)

In considering whether or not to remove the ambient water quality criterion for manganese from WS waters, the State reviewed the EPA recommendations both under the CWA and the Safe Drinking Water Act (SDWA). The EPA's currently recommended criterion for manganese under the CWA in freshwater is 50 ug/L. This value is not based on toxic effects, but rather is intended to minimize objectionable quality such as laundry stains and objectionable tastes in beverages (EPA 1986a). North Carolina's WS designated waters are considered safe for drinking, culinary, and food-processing purposes "following treatment required by the Division of Environmental Health" and "shall meet the Maximum Contaminant Level concentrations…which are specified in the national drinking water regulations and in the North Carolina Rules Governing Public Water Supplies, 15A NCAC 18C .1500." There is currently no recommended Maximum Contaminant Level (MCL) for manganese in treated drinking water under the SDWA, however, there is a Secondary MCL of 50 ug/L, established as a guideline for public water systems in managing drinking water systems for taste and odor. The DWR's review concluded that the Secondary MCL, "could be used by water suppliers, if ever warranted, to protect users from objectionable taste and/or staining of laundry." The EPA notes that a health advisory was published for manganese in drinking water of 50 mg/L, as well, which should also be evaluated by North Carolina (EPA 2004). The EPA has noted that it may update the currently recommended ambient water quality criterion for

freshwater manganese at some time in the future. NC has stated that they will review and consider the new recommendations once published.

After reviewing the EPA's recommendations under the CWA and the SDWA and its own data on manganese, the State concluded that there was "no evidence to conclude that discharges of manganese will impact any designed uses of NC's waters." In addition, the DWR has indicated that existing narrative criteria will be used to protect water supplies from any deleterious effects from manganese. The applicable criterion at 15A NCAC 02B .0211(12) states,

> "Oils, deleterious substances, colored, or other wastes: only such amounts as shall not render the waters injurious to public health, secondary recreation, or to aquatic life and wildlife, or adversely affect the palatability of fish, aesthetic quality or impair the water for any designated uses…"

The EPA has determined that North Carolina's WS uses will continue to be protected considering the changes to subsection 15A NCAC 02B .0212(h), 15A NCAC 02B .0214(h), 15A NCAC 02B .0215(h), 15A NCAC 02B .0216(h) and 15A NCAC 02B .0218(h) to remove the numeric criteria for manganese, since the State has committed to use the narrative criterion at 15A NCAC 02B .0211(12) as needed to address deleterious impacts of manganese. Therefore, these changes are consistent with the CWA section 303(c) and the implementing regulations at 40 C.F.R. section 131.11 and are approved by the EPA under CWA section 303(c).

2, 4 Dichlorophenoxyacetic acid (2, 4 D)

The DWR revised its 2, 4 D criterion for WS uses to update it with the most recently published reference dose information from the EPA's Integrated Risk Information System. This resulted in a revision of the criterion from 100 ug/l to 70 ug/l.

Considering the scientific and technical information supporting the 304(a) recommendations, the EPA has determined that the changes to subsection 15A NCAC 02B .0212(h), 15A NCAC 02B .0214(h), 15A NCAC 02B .0215(h), 15A NCAC 02B .0216(h) and 15A NCAC 02B .0218(h) to update the criterion for 2, 4 D will protect North Carolina's WS uses and, therefore, are consistent with the CWA section 303(c) and the implementing regulations at 40 C.F.R. section 131.11. These changes are approved by the EPA under CWA section 303(c).

Many portions of this section were also modified for clarification, grammar, and reorganization. The EPA has reviewed these revisions and determined that they are non-substantive and, therefore, the EPA approves the revisions as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of these non-substantive changes does not re-open the EPA's prior approval of the underlying substantive WQSs.

15A NCAC 02B .0220 Tidal Salt Water Quality Standards for Class SC Waters
General paragraph and Subparagraphs (1) through (6)

The following revisions were made to the General opening paragraph and Sections (1) through (9) of *Section 15A NCAC 02B .0220.*

> *General. The water quality standards for all tidal salt waters shall be the basic standards applicable to Class SC waters. Additional and more stringent standards applicable to other specific tidal salt water classifications are specified in Rules .0221 and .0222 of this Section.*

Action Levels, for purposes of National Pollutant Discharge Elimination System (NPDES) permitting, are specified in Item (20) of this Rule.

The new sentence added as the final sentence to the general paragraph references the use of action levels. The EPA has reviewed this change and determined that it is non-substantive and therefore, the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs. For the substantive discussion of the EPA's decision regarding revisions to action levels in tidal salt waters, see page 42.

The following subparagraphs were renumbered for alphanumeric reordering only:

(3) Chlorophyll a
(5) Dissolved oxygen
(7) Floating solids, settleable solids or sludge deposits
(8) Gases, total dissolved
(12) pH
(13) Phenolic compounds
(15) Radioactive substances
(16) Salinity
(17) Temperature

The EPA has reviewed these changes and determined that they are non-substantive and therefore, the EPA approves these revisions as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that this approval of these non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

The following sentence came before all of the criteria in the old format prior to the alphabetical reorganization of the WQS.

~~*(3) Quality standards applicable to all tidal salt waters:*~~

The State indicated that this sentence was found to be redundant with the information in the General paragraph of this rule. The General paragraph listed just above this states that "*The water quality standards for all tidal salt waters shall be the basic standards applicable to Class SC waters.*" 15A NCAC 02B .0101 General Procedures provides a definition for Class SC waters which includes that "*Class SC: saltwaters protected for secondary recreation, fishing, aquatic life including propagation and survival, and wildlife. All saltwaters shall be classified to protect these uses at a minimum.*" The removal of this sentence does not change or revise the state WQS. The EPA has reviewed this change and determined that it is non-substantive and therefore, the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

New subparagraph (4) was created:

(4) Cyanide: 1 ug/l;

The new paragraph moves cyanide from its previous location at Rule .0220(m)(iv) and retains the same numeric value. Therefore, this revision is a non-substantive change to WQSs and the EPA approves the

revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

New subparagraph (6) was created to move the bacteria criteria into alphabetical order. This section also includes the strike-out as noted below. The state indicated that this language was found to be redundant and not needed. The EPA concurs that all provisions in these Rules are in accordance with the Federal Water Pollution Control Act and that the specific reference in this paragraph is not a substantive change to the criteria. The EPA has reviewed this change and determined that it is non-substantive and therefore, the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

> *(6) Enterococcus, including Enterococcus faecalis, Enterococcus faecium, Enterococcus avium and Enterococcus gallinarium: not to exceed a geometric mean of 35 enterococci per 100 ml based upon a minimum of five samples within any consecutive 30 days. [~~In accordance with 33 U.S.C. 1313 (Federal Water Pollution Control Act) for~~]For purposes of beach monitoring and notification, "Coastal Recreational Waters Monitoring, Evaluation and Notification" regulations (15A NCAC 18A .3400), available free of charge at: http://www.ncoah.com/ , are hereby incorporated by reference including any subsequent amendments;*
>
> ~~*(e) Enterococcus, including Enterococcus faecalis, Enterococcus faecium, Enterococcus avium and Enterococcus gallinarium: not to exceed a geometric mean of 35 enterococci per 100 ml based upon a minimum of five samples within any consecutive 30 days. In accordance with 33 U.S.C. 1313 (Federal Water Pollution Control Act) for purposes of beach monitoring and notification, "Coastal Recreational Waters Monitoring, Evaluation and Notification" regulations (15A NCAC 18A .3400) are hereby incorporated by reference including any subsequent amendments;*~~

15A NCAC 02B .0220 Tidal Salt Water Quality Standards for Class SC Waters Subparagraphs (9)

> *(9) Metals:*
>
> *(a) With the exception of mercury and selenium, tidal salt water quality standards for metals shall be based upon measurement of the dissolved fraction of the metals. Mercury and selenium shall be based upon measurement of the total recoverable metal;*

The EPA's most current national recommended water quality criteria for protection of aquatic life includes the recommendation that fresh and salt water criteria for metals (including specifically arsenic, cadmium, chromium III, chromium VI, copper, lead, nickel, silver and zinc) be expressed in terms of the dissolved metal in the water column. In 1993, the EPA provided additional guidance on the use of the dissolved fraction of metals stating that, "[t]he use of dissolved metal to set and measure compliance with water quality standards is the recommended approach, because dissolved metal more closely approximates the bioavailable fraction of metal in the water column than does total recoverable metal" (EPA 1993).

Considering the scientific and technical information supporting the 304(a) recommendations, the EPA has determined that this change to subsection 15A NCAC 02B .0220(9)(a) protects North Carolina's aquatic

life use and, therefore, is consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. This change is approved by the EPA under CWA section 303(c).

The DWR is not currently adopting updated salt water criteria for mercury or selenium, leaving in place the previous values which are based on the total recoverable metal in the second sentence of paragraph (a). Therefore, the reference to those parameters is a non-substantive change to standards and the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

The following new provision was added in subparagraph (9)(b):

> *(b) Compliance with acute instream metals standards shall only be evaluated using an average of two or more samples collected within one hour. Compliance with chronic instream metals standards shall only be evaluated using averages of a minimum of four samples taken on consecutive days, or as a 96-hour average;*

After review of this new provision, the EPA has concluded that it is not a new or revised water quality standard and is therefore taking no action on this provision. This provision does not establish or change a level of protection related to the magnitude, duration, or frequency of water quality criteria nor establish designated uses. Rather, this provision describes the sufficiency or reliability of information necessary for the State to decide whether a water attains or does not attain a water quality standard for purposes of establishing TMDLs under section 303(d)(1)(A) of the Act. As such, this provision is not a water quality standard but is a methodology under section 303(d) of the Act. See 40 C.F.R. § 130.7(b)(6). While the provision was not reviewed by EPA as a new or revised water quality standard, it may be considered by EPA in reviewing lists of impaired waters submitted by the State under Section 303(d) of the CWA. The decision to not review this provision in no way confers agreement with the use of the provision for making attainment decisions.

The following new subparagraph was added under (9)(c).

> *(c) Metals criteria shall be used for proactive environmental management. An instream exceedence of the numeric criterion for metals shall not be considered to have caused an adverse impact to the aquatic community without biological confirmation and a comparison of all available monitoring data and applicable water quality standards. This weight of evidence evaluation shall take into account data quality and the overall confidence in how representative the sampling is of conditions in the waterbody segment before an assessment of aquatic life use attainment, or non-attainment, is made by the Division. Recognizing the synergistic and antagonistic complexities of other water quality variables on the actual toxicity of metals, with the exception of mercury and selenium, biological monitoring shall be used to validate, by direct measurement, whether or not the aquatic life use is supported.*

As detailed more fully under the disapproval of similar language for freshwater under 15A NCAC .02B .0211(f), the EPA has advised the DWR on multiple occasions, including directly addressing this provision in writing on multiple occasions that the EPA does not support biological confirmation for

toxics assessment.[7] The EPA views biological criteria as one component of a comprehensive water quality standards program that works in concert with – not in place of – the use of water quality criteria for toxics as detailed further below. The EPA incorporates by reference all of the discussion in the disapproval under 15A NCAC .02B .0211(f).

The EPA has determined that the changes to subsection 15A NCAC 02B .0220 (9)(c) do not protect North Carolina's aquatic life use and, therefore, are not consistent with the CWA section 303(c) or its implementing regulations found at 40 C.F.R. section 131.11. Therefore, these changes are disapproved by the EPA under CWA section 303(c). With today's disapproval of this section, the new water quality criteria for metals in salt water as approved shall be used for all purposes under the Act. The EPA recommends that the State delete the biological confirmation provision during the next triennial review.

North Carolina adopted updated acute and chronic metals values under 15A NCAC 02B .0220 (9)(d) for salt water as follows:

> *(d) Acute and chronic tidal salt water quality metals standards are as follows:*
> *(i) Arsenic, acute: WER· 69 ug/l;*
> *(ii) Arsenic, chronic: WER· 36 ug/l;*
> *(iii) Cadmium, acute: WER· 40 ug/l;*
> *(iv) Cadmium, chronic: WER· 8.8 ug/l;*
> *(v) Chromium VI, acute: WER· 1100 ug/l;*
> *(vi) Chromium VI, chronic: WER· 50 ug/l;*
> *(vii) Copper, acute: WER· 4.8 ug/l;*
> *(viii) Copper, chronic: WER· 3.1 ug/l;*
> *(ix) Lead, acute: WER· 210 ug/l;*
> *(x) Lead, chronic: WER· 8.1 ug/l;*
> *(xi) Mercury, total recoverable, chronic: 0.025 ug/l;*
> *(xii) Nickel, acute: WER· 74 ug/l;*
> *(xiii) Nickel, chronic: WER· 8.2 ug/l;*
> *(xiv) Selenium, total recoverable, chronic: 71 ug/l;*
> *(xv) Silver, acute: WER· 1.9 ug/l;*
> *(xvi) Silver, chronic: WER· 0.1 ug/l;*
> *(xvii) Zinc, acute: WER· 90 [ug/l;]ug/l; and*
> *(xviii) Zinc, chronic: WER· 81 ug/l;*
>
> *With the exception of mercury and selenium, acute and chronic tidal saltwater quality aquatic life standards for metals listed above apply to the dissolved form of the metal and apply as a function of the pollutant's water effect ratio (WER). A WER expresses the difference between the measures of the toxicity of a substance in laboratory waters and the toxicity in site water. The WER [~~is~~]shall be assigned a value equal to one unless any person demonstrates to the Division's satisfaction in a permit proceeding that another value is developed in accordance with the Water Quality Standards Handbook: Second Edition'published by the US Environmental Protection Agency (EPA-823-B-12-002), free of charge, at http://water.epa.gov/scitech/swguidance/standards/handbook/, hereby incorporated*

[7] See Appendix B. EPA letters to DWR dated April 30, 2009, August 10th, 2010, and January 3, 2014 and emails to DWR on August 22, 2014 and August 25, 2014.

by reference including any subsequent amendments. Alternative site-specific standards may also be developed when any person submits values that demonstrate to the Commissions' satisfaction that they were derived in accordance with the Water Quality Standards Handbook: Second Edition, Recalculation Procedure or the Resident Species Procedure", hereby incorporated by reference including subsequent amendments at http://water.epa.gov/scitech/swguidance/standards/handbook/. This material is available free of charge;

The EPA notes that the DWR is not currently adopting updated criteria for mercury or selenium, leaving in place the previous values which are based on the total recoverable metal. Those metals have been reordered for alphabetizing purposes only. As the numeric value did not change for either of these criteria, the EPA determined that it is non-substantive and therefore, the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that its approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

For comparison purposes, all other salt water metals are listed in the chart below alongside the EPA's current national recommended criteria.

Metal (all values are dissolved)	**NCDWR's Criteria** (all values ug/l)	**EPA's National Recommended criteria** (all values ug/l)
Arsenic (acute)	69	69
Arsenic (chronic)	36	36
Cadmium (acute)	40	40
Cadmium (chronic)	8.8	8.8
Chromium VI (acute)	1100	1100
Chromium VI (chronic)	50	50
Copper (acute)	4.8	4.8
Copper (chronic)	3.1	3.1
Lead (acute)	210	210
Lead (chronic)	8.1	8.1
Nickel (acute)	74	74
Nickel (chronic)	8.2	8.2
Silver (acute)	1.9	1.9
Silver (chronic)	0.1	--
Zinc (acute)	90	90
Zinc (chronic)	81	81

With the exception of the chronic value for silver, the DWR is directly adopting the EPA's national recommended values for saltwater acute and chronic criteria for metals in saltwater.

The EPA initially published a national recommended criteria for silver in 1980 (EPA 1980). In that document, the EPA recommended that the total recoverable acute silver criteria should not exceed 2.3 ug/ at any time. However, data were not available to develop chronic criteria for salt water. In 1990, the EPA published draft chronic criteria for silver, but after public comment determined that more research was

needed. In a 1992 memo, the EPA addressed how to review chronic silver salt water criteria from states (EPA 1992b). That memo noted that, "States which choose, of their own accord, to take an approach which generates chronic standards, either from data in the 1980 final document, the 1990 draft or other sources, are taking an approach more stringent than EPA criteria, and these standards are approvable." In order to develop its chronic silver criterion, the DWR stated that it they applied a safety factor of 0.05 to the 2.3 ug/l acute criterion from EPA's 1980 publication generating a chronic value of 0.1 ug/l.

As discussed in the approval of the freshwater metals criteria, the EPA's most current national recommended water quality criteria for protection of aquatic life includes the recommendation that fresh and salt water criteria for metals (including specifically arsenic, cadmium, chromium III, chromium VI, copper, lead, nickel, silver and zinc) be expressed in terms of the dissolved metal in the water column. In 1993, the EPA provided additional guidance on the use of the dissolved fraction of metals stating that, "[t]he use of dissolved metal to set and measure compliance with water quality standards is the recommended approach, because dissolved metal more closely approximates the bioavailable fraction of metal in the water column than does total recoverable metal" (EPA 1993).

As discussed in the review of the use of WERs under subparagraph .0211(11)(b), the use of WERs is consistent with the EPA's policy and guidance. The discussion in that section's review are incorporated into the review of this section by reference. The EPA concludes that the changes to subsection 15A NCAC 02B .0220(9)(d) to add in the use of a WER and to include a x1 multiplier in each of the criteria for the criteria in Table A is consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. Therefore, these changes are approved by the EPA under CWA section 303(c).The EPA strongly recommends that the first WERs developed by the State are reviewed in the study plan phase by the EPA to ensure that WERs that are developed meet the required procedures. The EPA looks forward to working with the State to ensure a quick review of the study plans so that the WERs may be used for CWA purposes once completed.

This section also allows for alternative site-specific standards to be developed using the Recalculation Procedure or the Resident Species Procedure in accordance with the *Water Quality Standards Handbook: Second Edition,* referenced as http://water.epa.gov/scitech/swguidance/standards/handbook/. In deriving site-specific criteria, the Recalculation Procedure (found at Appendix A of Appendix L of the WQS Handbook) takes into account the differences between the sensitivity of the species used in the national dataset in developing the national recommended criteria, and the organisms at the site. The Resident Species Analysis (see Chapter 3.7 - Developing Site-Specific Criteria of the WQS Handbook) accounts for that difference as well as the difference between the toxicity of the metal in lab water versus site water similar to a WER. Chapter 3.6 - Policy on Aquatic Life Criteria for Metals was updated to also include procedures to conduct a Streamlined Water-Effects Ratio Procedure for the Discharge of Copper that may also be used.

Considering the scientific and technical information supporting the 304(a) recommendations, the EPA has determined that all of the changes to subsection 15A NCAC 02B .0220(9)(d) protect North Carolina's aquatic life use and, therefore, are consistent with the CWA section 303(c) and 40 C.F.R. section 131.11. These changes are approved by the EPA under CWA section 303(c) for all purposes under the Act.

15A NCAC 02B .0220 Tidal Salt Water Quality Standards for Class SC Waters
Subparagraphs (10) through (19)

> *~~(f)~~(10) Oils, deleterious substances, colored, or other wastes: only such amounts as shall not render the waters injurious to public health, secondary-recreation, aquatic life, and wildlife or*

adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated uses. For the purpose of implementing this Rule, oils, deleterious substances, colored, or other wastes shall include substances that cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines under 40 C.F.R. 110.3;

(11) Pesticides:

(a) Aldrin: 0.003 ug/l;
(b) Chlordane: 0.004 ug/l;
(c) DDT: 0.001 ug/l;
(d) Demeton: 0.1 ug/l;
(e) Dieldrin: 0.002 ug/l;
(f) Endosulfan: 0.009 ug/l;
(g) Endrin: 0.002 ug/l;
(h) Guthion: 0.01 ug/l;
(i) Heptachlor: 0.004 ug/l;
(j) Lindane: 0.004 ug/l;
(k) Methoxychlor: 0.03 ug/l;
(l) Mirex: 0.001 ug/l;
(m) Parathion: 0.178 [ug/l;]ug/l; and
(n) Toxaphene: 0.0002 ug/l;

~~(g)~~(12) pH: shall be normal for the waters in the area, which ~~generally shall~~ range between 6.8 and ~~8.5~~ 8.5, except that swamp waters may have a pH as low as 4.3 if it is the result of natural conditions;

~~(h)~~(13) Phenolic compounds: only such levels as shall not result in fishflesh- tainting or impairment of other best usage;

(14) Polychlorinated biphenyls: (total of all PCBs and congeners identified) 0.001 ug/l;

~~(i)~~(15) Radioactive substances:

~~(i)~~(a) Combined radium-226 and radium-228: The ~~maximum~~ average annual activity level (based on at least one sample collected per quarter)~~four samples collected quarterly)~~ for combined radium226, and radium228 shall not exceed five -picoCuries- per liter;

~~(ii)~~(b) Alpha Emitters. The average annual gross alpha particle activity (including radium226, but excluding radon and uranium) shall not exceed 15 picoCuries- per liter;

~~(iii)~~(c) Beta Emitters. The ~~maximum~~ average annual activity level (based on at least one sample collected per quarter)~~four samples collected quarterly)~~ for strontium90 shall not exceed eight picoCuries- per liter; nor shall the average annual gross beta particle activity (excluding potassium-40 and other naturally occurring ~~radio-nuclides)~~ radionuclides exceed 50 picoCuries per liter; nor shall the ~~maximum~~ average annual activity level for tritium exceed 20,000 picoCuries per liter;

~~(j)~~(16) Salinity: changes in salinity due to hydrological modifications shall not result in removal of the functions of a PNA. Projects that are determined by the Director to result in modifications of salinity such that functions of a PNA are impaired ~~will~~ shall be required to employ water management practices to mitigate salinity impacts;

~~(k)~~(17) Temperature: shall not be increased above the natural water temperature by more than 0.8 degrees C (1.44 degrees F) during the months of June, July, and August nor more than 2.2 degrees C (3.96 degrees F) during other months and in no cases to exceed 32 degrees C (89.6 degrees F) due to the discharge of heated liquids;

(18) Trialkyltin compounds: 0.007 ug/l expressed as tributyltin;

~~(l)~~(19) Turbidity: the turbidity in the receiving water shall not exceed 25 Nephelometric Turbidity Units (NTU); ~~NTU;~~ if turbidity exceeds this level due to natural background conditions, the existing turbidity level shall not be increased. Compliance with this turbidity standard can be met when land management activities employ Best Management Practices (BMPs) [as defined by Rule .0202 of this Section] recommended by the Designated Nonpoint Source Agency (as defined by Rule .0202 of this Section). BMPs ~~must~~ shall be in full compliance with all specifications governing the proper design, installation, ~~operation~~ operation, and maintenance of such BMPs;

~~(m) Toxic substances: numerical water quality standards (maximum permissible levels) to protect aquatic life applicable to all tidal saltwaters:~~

~~(i) Arsenic, total recoverable: 50 ug/l;~~

~~(ii) Cadmium: 5.0 ug/l; attainment of these water quality standards in surface waters shall be based on measurement of total recoverable metals concentrations unless appropriate studies have been conducted to translate total recoverable metals to a toxic form. Studies used to determine the toxic form or translators must be designed according to the "Water Quality Standards Handbook Second Edition" published by the Environmental Protection Agency (EPA 823-B-94-005a) or "The Metals Translator: Guidance For Calculating a Total Recoverable Permit Limit From a Dissolved Criterion" published by the Environmental Protection Agency (EPA 823-B-96-007) which are hereby incorporated by reference including any subsequent amendments. The Director shall consider conformance to EPA guidance as well as the presence of environmental conditions that limit the applicability of translators in approving the use of metal translators;~~

~~(iii) Chromium, total: 20 ug/l;~~

~~(iv) Cyanide: 1.0 ug/l;~~

~~(v) Mercury: 0.025 ug/l;~~

~~(vi) Lead, total recoverable: 25 ug/l; collection of data on sources, transport and fate of lead shall be required as part of the toxicity reduction evaluation for dischargers that are out of compliance with whole effluent toxicity testing requirements and the concentration of lead in the effluent is concomitantly determined to exceed an instream level of 3.1 ug/l from the discharge;~~

~~(vii) Nickel: 8.3 ug/l; attainment of these water quality standards in surface waters shall be based on measurement of total recoverable metals concentrations unless appropriate studies have been conducted to translate total recoverable metals to a toxic form. Studies used to determine the toxic form or translators must be designed according to the "Water Quality Standards Handbook Second Edition" published by the Environmental Protection Agency (EPA 823-B-94-005a) or "The Metals Translator: Guidance For Calculating a Total Recoverable Permit Limit From a Dissolved Criterion" published by the Environmental Protection Agency (EPA 823-B-96-007) which are hereby incorporated by reference including any subsequent amendments. The Director shall consider conformance to EPA guidance as well as the presence of environmental conditions that limit the applicability of translators in approving the use of metal translators;~~

~~(viii) Pesticides:~~

~~(A) Aldrin: 0.003 ug/l;~~

~~(B) Chlordane: 0.004 ug/l;~~

~~(C) DDT: 0.001 ug/l;~~

~~(D) Demeton: 0.1 ug/l;~~

~~(E) Dieldrin: 0.002 ug/l;~~

~~(F) Endosulfan: 0.009 ug/l;~~

~~(G) Endrin: 0.002 ug/l;~~

~~(H) Guthion: 0.01 ug/l;~~

~~(I) Heptachlor: 0.004 ug/l;~~

~~(J) Lindane: 0.004 ug/l;~~

~~(K) Methoxychlor: 0.03 ug/l;~~

~~(L) Mirex: 0.001 ug/l;~~

~~(M) Parathion: 0.178 ug/l;~~

~~(N) Toxaphene: 0.0002 ug/l;~~

~~(ix) Polychlorinated biphenyls: (total of all PCBs and congeners identified) 0.001 ug/l;~~

~~(x) Selenium: 71 ug/l;~~

~~(xi) Trialkyltin compounds: 0.007 ug/l expressed as tributyltin.~~

The struck provisions for arsenic, cadmium, chromium, lead and nickel are replaced by new criteria as described in detail above. The criteria for the remaining criteria were moved into alphabetical order. As the numeric value did not change for these criteria, the EPA determined that it is non-substantive and therefore, the EPA approves the revision as being consistent with the CWA and the EPA's implementing regulations. The EPA notes, however, that is approval of this non-substantive change does not re-open the EPA's prior approval of the underlying substantive WQSs.

15A NCAC 02B .0220 Tidal Salt Water Quality Standards for Class SC Waters Subparagraph (20)

~~(1)~~(20) Action Levels for Toxic ~~Substances:~~Substances Applicable to NPDES Permits:

(a) ~~Copper:~~Copper, dissolved, chronic: ~~3 ug/l;~~3.1 ug/l;

(b) ~~Silver:~~Silver, dissolved, chronic: 0.1 ug/l;

(c) ~~Zinc:~~Zinc, dissolved, chronic: ~~86 ug/l;~~81 ug/l

If the [~~chronic~~] ~~Action Levels~~ action levels for any of the substances listed in this ~~Subparagraph~~Item (which are generally not bioaccumulative and have variable toxicity to aquatic life because of chemical form, solubility, stream ~~characteristics~~ characteristics, or associated waste characteristics) ~~are~~ shall be determined by the waste load allocation to be exceeded in a receiving water by a discharge under the ~~specified low~~7Q10 flow criterion for toxic ~~substances (Rule .0206 in this Section),~~substances, the discharger shall ~~be required to~~ monitor the chemical or biological effects of the discharge; efforts shall be made by all dischargers to reduce or eliminate these substances from their effluents. Those substances for which ~~Action Levels~~ action levels are listed in this ~~Subparagraph~~Item ~~may~~shall be limited as appropriate in the NPDES permit if sufficient information (to be determined for metals by measurements of that portion of the dissolved instream concentration of the ~~Action Level~~ action level parameter attributable to a specific NPDES permitted discharge) exists to indicate that any of those substances may be a causative factor resulting in toxicity of the effluent. ~~NPDES permit limits may be based on translation of the toxic form to total recoverable metals. Studies used to determine the~~

~~*toxic form or translators must be designed according to: "Water Quality Standards Handbook Second Edition" published by the Environmental Protection Agency (EPA 823-B-94-005a) or "The Metals Translator: Guidance For Calculating a Total Recoverable Permit Limit From a Dissolved Criterion" published by the Environmental Protection Agency (EPA 823-B-96-007) which are hereby incorporated by reference including any subsequent amendments. The Director shall consider conformance to EPA guidance as well as the presence of environmental conditions that limit the applicability of translators in approving the use of metal translators.*~~

Revision to Copper, Silver and Zinc as an Action Level

As the EPA has advised the DWR on multiple occasions, including directly addressing this provision in multiple letters,[8] the EPA does not support the maintenance of action levels. The EPA reiterates its previous comments. The EPA's Section 304(a) criteria were developed to take into account specific factors such as solubility and chemical form in determining the biologically available fraction available for uptake by biological organisms and, therefore, the fraction most likely to cause a toxic effect.

North Carolina's action level requirements, stated above, indicate that NPDES limits must be set for metals if information exists to indicate that a particular substance may be a *causative* factor resulting in the toxicity of the effluent. 40 C.F.R. 122.44(d)(1)(i) states that limits must be put in place to control pollutants which may be discharged at a level "which will cause, have the reasonable potential to cause or contribute to an excursion above any State water quality standard." This regulation does not indicate that the effluent must be the sole cause of toxicity before the parameter should be limited. The provision states that the pollutant should be limited under NPDES if it could cause or even if it could *contribute* to a water quality standards excursion.

This requirement is significant because there may often be multiple sources of pollutants in receiving waters, from non-point source run-off, from point sources and from storm water. No one facility or source may be the sole cause of the impairment, but rather multiple discharges contribute to the toxicity and excursion of water quality standards. Therefore, when a point source discharges zinc levels with a reasonable potential to cause or contribute to exceedence of water quality standards, that discharge must be limited. Surrounding states have limited zinc and copper in permits where there is reasonable potential to cause or contribute to the excursion of a water quality standard.

The Region recognizes that North Carolina has a strong WET testing program. WET testing can be "effective for controlling discharges containing multiple pollutants. It can also provide a method for addressing synergistic and antagonistic effects on aquatic life" from multiple pollutants. See 63 Fed. Reg. (page 36,768). However, where criteria exist to directly control toxic pollutants, those criteria should be used to limit the discharge of pollutants. WET should be used to address those instances where criteria may not be available to limit toxicity. The EPA's discussion of reconciling biological data, such as WET, with 'reasonable potential' analysis concludes "EPA would not support a radical shift away from chemical criteria and limits or toxicity criteria and limits. Those tools are simply too important as proven tools for assessing potential impact to surface waters and improving water quality." If needed, an effort should be made to refine the applicable criteria, through WERs and other tools, to ensure that appropriate criteria be developed for each facility. It is not protective, however, and is not consistent with EPA's permitting regulations, to defer permit limitations once there is reasonable potential to exceed the water

[8] See Appendix B. EPA letters to DWR dated April 30, 2009, August 20, 2010, and January 3, 2014 and emails to DWR on August 22, 2014 and August 25, 2014.

quality criteria for toxics.

The EPA has determined that the changes to subsection 15A NCAC 02B .0211(20) do not protect North Carolina's aquatic life use and, therefore, are not consistent with the CWA section 303(c) or its implementing regulations found at 40 C.F.R. section 131.11. These changes are disapproved by the EPA under CWA section 303(c). With today's disapproval of this section, the new water quality criteria for metals as approved shall be used for all purposes under the Act. For more discussion on the implications of the EPA's disapproval, see pages 30-31.

Review of Water Quality Standards Variances

Under 40 C.F.R. section 131.20, each state is required, at least once every three years, to re-examine any water body segment with water quality standards which do not include the uses specified in section 101(a)(2) of the CWA to determine if any new information has become available to indicate the uses are now attainable. North Carolina has three variances from water quality standards in the State, which are subject to this triennial evaluation requirement. During the triennial, the State provided a notice of an opportunity to comment on and conducted a review of each of the variances to water quality standards.

Evergreen Packaging (formerly Blue Ridge Paper Products, NPDES Permit No. NC0000272) has a water quality standards variance for color. The most recent permit reissuance and variance renewal was issued by the State on July 21, 2010. The EPA reviewed and approved the variance on December 21, 2010. A comprehensive review and evaluation of the status of the variance is ongoing concurrent with the facility's permit reissuance process, which will include public hearings and opportunity for comments. Comments received by the State during the triennial will be considered during the permit and variance review as well.

Both Mount Olive Pickle Company (NPDES Permit No. NC0001074) and Bay Valley Foods (formerly Dean Pickle Products, NPDES Permit No. NC0001970) have excess sodium chloride from pickle processing. Limited technology exists for removal of sodium chloride from the waste stream. New variances were issued by the State on March 29, 2011. The EPA approved those variances on September 27, 2011. The information collected during this triennial review will be used for the next scheduled permit and variance review.

APR 6 2016

Date

Heather McTeer Toney
Regional Administrator

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
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SEP 6 _ 2018

Ron Dean
Branch Chief
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National Marine Fisheries Service
1845 Wasp Blvd., Bldg 176, Room 2542
Honolulu, HI 96818

Dear Mr. Dean:

The purpose of this letter is to request the National Marine Fisheries Service (NMFS) written concurrence, under Section 7 of the Endangered Species Act (ESA) and 50 CFR Section 402.13(a), with the U.S. Environmental Protection Agency (EPA) Region 9's determination on the possible effects of approval under Section 303(c)(3) of the Clean Water Act (CWA) of water quality standards (WQS) by the Commonwealth of the Northern Mariana Islands (CNMI) Bureau of Environmental and Coastal Quality (BECQ).

BECQ revised their cadmium water quality standards applicable to all saltwater in CNMI. Their water quality standards were public noticed on May 25, 2018 and a public hearing was held on July 13, 2018. The water quality standards were adopted by CNMI on August 28, 2018 and transmitted to EPA in a letter dated September 5, 2018.

BECQ previously adopted saltwater water quality standards for tributyltin, nonylphenol, carbaryl and diazinon on June 11, 2014. EPA approved the tributyltin, nonylphenol, carbaryl and diazinon water quality standards on May 1, 2015. EPA had previously initiated consultation on these four parameters but ESA consultation had not been concluded. As a result, the analysis of these parameters has been included in the enclosed Biological Evaluation (BE).

The BE documents the EPA's analysis of the effects of approving the water quality standards action on listed species under NMFS jurisdiction. The EPA has determined that approval of the water quality standards may affect, but is not likely to adversely affect threatened or endangered species. This conclusion is based on the effects on listed species which are expected to be discountable or insignificant.

The EPA is requesting NMFS's concurrence with our "may affect, but not likely to adversely affect" determination, in accordance with the procedures outlined in the Memorandum of Agreement Between the Environmental Protection Agency, Fish and Wildlife Service, and

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National Marine Fisheries Service regarding Enhanced Coordination Under the Clean Water Act and Endangered Species Act, dated February 22, 2001. If you have any questions, please contact Nicole Tachiki of my staff at (415) 972-3161 or tachiki.nicole@epa.gov.

Sincerely,

Janet Hashimoto

Janet Hashimoto, Chief
Water Quality Assessment Section

Enclosure

cc: Randy McIntosh, NOAA Fisheries

Biological Evaluation of the Commonwealth of the Northern Mariana's Water Quality Standards for Cadmium, Carbaryl, Diazinon, Nonylphenol, and Tributyltin

Prepared by:

U.S. Environmental Protection Agency
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2018

EPA-HQ-2019-004830 001367

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I. Introduction

This Biological Evaluation (BE) analyzes the U.S. Environmental Protection Agency (EPA) actions on the Commonwealth of the Northern Mariana Islands (CNMI) Bureau of Environmental and Coastal Quality (BECQ) water quality standards. BECQ adopted the water quality standards on August 28, 2018. EPA is submitting this BE as part of a consultation under the Endangered Species Act (ESA) (16 U.S.C. 1531 et seq.). The scope of the consultation includes EPA's action on BECQ's adoption of a saltwater cadmium standard.

The scope of this BE also includes EPA's previous approvals of saltwater standards for diazinon, carbaryl, nonylphenol, and tributyltin standards adopted by CNMI on June 11, 2014 and approved by EPA on May 1, 2015. EPA had previously initiated consultation with NMFS on these four parameters, but ESA consultation had not been concluded.

This BE addresses the potential impacts of cadmium, diazinon, carbaryl, nonylphenol and tributyltin to listed species under the jurisdiction of the National Marine Fisheries Service (NMFS) and in the area affected by the federal action, pursuant to Section 7 of the ESA and 50 CFR Section 402.13(a).

II. Description of Action

BECQ submitted a package of adopted water quality standards to protect aquatic life from acute and chronic exposure to cadmium, ammonia, and selenium for all Commonwealth or state waters. However only cadmium applies to marine waters. The parameters from the 2015 action include adopted acute and chronic standards for carbaryl, diazinon, nonylphenol, and tributyltin standards which all apply to saltwater environments.

Cadmium. CNMI BECQ adopted EPA's 2016 national recommended aquatic life ambient water quality criteria for cadmium which reflects the latest scientific information. EPA published the original national recommended cadmium aquatic life criteria in 1980. The 2016 criteria are an update to the 1980 criteria using the best available science with data for 75 new species and 49 new genera.

Carbaryl. CNMI BECQ adopted EPA's 2012 national recommended aquatic life ambient water quality criteria for carbaryl in 2015. The acute saltwater criterion was based on toxicity data from 12 species (11 genera).

Diazinon. CNMI BECQ adopted EPA's 2006 national recommended aquatic life ambient water quality criteria for diazinon in 2015. The acute criterion was based on toxicity data from 7 invertebrates and 2 fish species.

Nonylphenol. CNMI BECQ adopted EPA's 2005 national recommended aquatic life ambient water quality criteria for nonylphenol in 2015. The EPA acute criteria is based on toxicity data from 8 invertebrate and 3 fish species.

Tributyltin. CMMI adopted EPA's 2004 national recommended aquatic life water quality criteria for tributyltin in 2015. The saltwater acute criterion is 0.42 µg/L and the saltwater chronic criteria is 0.0074 µg/l. The acute criterion was based on toxicity data from 8 invertebrates and 3 fish species. The chronic criterion was initially based on chronic toxicity data species, but the criterion was lowered to address a large body of evidence of tributyltin associated with imposex (i.e. females developing male sex organs) in gastropods.

Table 1 Summary of saltwater criteria that are the subject of this biological evaluation.

Pollutant	Saltwater CMC[1] (µg/L)	Saltwater CCC[2] (µg/L)	CNMI Adoption	EPA Approval
Cadmium	33	7.9	2018	Pending
Carbaryl	1.6	N/A	2014	2015
Diazinon	1.6	0.82	2014	2015
Nonylphenol	7	1.7	2014	2015
Tributyltin	0.42	0.0074	2014	2015

[1] CMC: Criterion Maximum Concentration. The duration and frequency of the acute criteria is a one-hour average concentration not to be exceeded more than once every three years.
[2] CCC: Criterion Continuous Concentration. The duration and frequency is a four-day average concentration not to be exceeded more than once every three years for chronic criterion.

III. Description of the Area Affected

The Commonwealth of Northern Marianas is in the Marianas archipelago. The total land area is 183.5 square mile. The population is 53,883 based on the 2010 Census. Most of the population lives on Saipan. The main industries are tourism and garment manufacturing.

The CNMI water quality standards apply to all waters of the Commonwealth. They are mostly used to establish the appropriate level of treatment for permits. The authority to write permits has not been delegated to CNMI, so all the permits are written by EPA Region 9. There are five National Pollutant Discharge Elimination System (NPDES) permits for Saipan: three wastewater treatment plants (WWTPs) and two stormwater permits.

The Agingan WWTP treats the domestic wastewater from approximately 18,400 people. The capacity of the plant is 3 million gallons per day (MGD). The WWTP also receives about 0.2 MGD of wastewater from commercial and/or industrial operations, such as automobile repair shops, gasoline stations, and power generators. The outfall extends ~650 feet offshore into Tinian Channel and discharges at a depth of 94 feet.

The Sadog Tasi WWTP treats the domestic wastewater for approximately 20,000 people. The plant capacity is 2.9 MGD. The total average daily wastewater flow from all industrial sources in the service area is less than 0.2 MGD. The plant discharges to Saipan Lagoon through an outfall located 1,200 feet offshore, at a depth of about 49 feet.

The new Managaha Island WWTF serves a daily tourist population up to 1,050 and receives domestic sewage with a design flow of 0.005 MGD which drains the treated wastewater to a nearby leach field, located approximately 150 feet inward of the north shoreline of Managaha Island in Saipan Lagoon.

The CNMI Municipal Separate Storm Sewer System (MS4) permit is intended to address stormwater impacts from the urbanized portions of Saipan, roughly the lower 2/3 of the island. There is also an industrial stormwater permit regulating storm-related discharges from the Mobil Oil Bulk storage facility which allows episodic discharges of stormwater to Tanapag Harbor.

The saltwater aquatic life criteria apply to marine and coastal waters including lagoons and harbors. This biological evaluation is focused on threatened and endangered species that may be affected by changes in the water quality standard.

IV. Listed Species

Table 2. Species list confirmed by the NMFS on April 11, 2018

Species	Scientific Name	ESA Status	Federal Register Reference
Green Sea Turtle (Central West Pacific Distinct Population Segment (DPS))	*Chelonia mydas*	Endangered	81 FR 20057
Hawksbill Sea Turtle	*Eretmochelys imbricata*	Endangered	43 FR 32800
Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered	35 FR 8491
Olive Ridley Sea Turtle	*Lepidochelys olivacea*	Threatened	43 FR 32800
Loggerhead Sea Turtle (North Pacific DPS)	*Caretta caretta*	Endangered	76 FR 58868
Blue Whale	*Balaenoptera musculus*	Endangered	35 FR 18319
Fin Whale	*Balaenoptera physalus*	Endangered	35 FR 18319
Sei Whale	*Balaenoptera borealis*	Endangered	35 FR 18319
Sperm Whale	*Physeter macrocephalus*	Endangered	35 FR 18319
Humpback whale. (Western North Pacific DPS)	*Megaptera novaeangliae*	Endangered	81 FR 62259
Oceanic Whitetip Shark	*Carcharhinus longimanus*	Threatened	83 FR 4153

Scalloped Hammerhead Shark. (Indo-West Pacific DPS)	*Sphyrna lewini*	Threatened	79 FR 38213
Giant Manta Ray	*Manta birostris*	Threatened	83 FR 2916
Corals	*Acropora globiceps*	Threatened	79 FR 38213
	Seriatopora aculeata	Threatened	79 FR 53851
	Acropora retusa	Threatened	79 FR 53851
Species	**Scientific Name**	**ESA Status**	**Federal Register Reference**
clam, giant (7 candidate species)	*Hippopus hippopus* *Hippopus porcellanus* *Tridacna costata* *Tridacna derasa* *Tridacna gigas* *Tridacna squamosa* *Tridacna tevoroa*	ongoing petition	82 FR 28946

SEA TURTLES

The green turtle is globally distributed and generally found in tropical and subtropical waters along continental coasts and islands between 30° North and 30° South. Adult green turtles feed primarily on seagrasses and algae. Adult and juvenile green turtles are generally found nearshore as well as in bays and lagoons, on reefs, and especially in areas with seagrass beds. Adults migrate from foraging areas to nesting beaches and may travel hundreds or thousands of kilometers each way.

Hawksbills can be found in tropical and sub-tropical regions throughout the world. This species can be found nesting and foraging in other Pacific US territories but research on the population status and trends in these areas is on-going. Hawksbills feed around coral reefs and rock outcroppings and primarily consume sponges.

Loggerheads have large heads with powerful jaws that enable them to feed on hard-shelled prey, such as whelks and conches. In the eastern Pacific, loggerheads have been reported as far north as Alaska, and as far south as Chile. The west coast of Mexico, including the Baja Peninsula, provides critically important developmental habitats for juvenile loggerheads. The only known nesting areas for loggerheads in the North Pacific are found in southern Japan.

Western Pacific leatherbacks nest in the Indo-Pacific and migrate back to feeding areas off the Pacific coast of North America. Leatherbacks feed on a diet of soft-bodied, pelagic (open ocean) prey, such as jellyfish and salps. Western Pacific leatherbacks swim from tropical nesting beaches in the western Pacific to foraging grounds in the neritic eastern North Pacific. The trans-Pacific journey requires10-12 months to complete.

The Olive Ridley sea turtle is pelagic and migrates great distances between feeding and breeding grounds. They breed annually and have an annual migration from pelagic foraging to coastal

breeding and nesting grounds. The Olive Ridley sea turtle has been known to inhabit coastal areas, including bays and estuaries.

WHALES

Blue whales are found worldwide, from sub-polar to sub-tropical latitudes. Poleward movements in spring allow the whales to take advantage of high zooplankton production in summer. Blue whales are largely pelagic but they can be found in coastal waters.

Fin whales are found in deep, offshore waters of all major oceans, primarily in temperate to polar latitudes, and less commonly in the tropics. They occur year-round in a wide range of latitudes and longitudes. They eat herring, capelin, squid, euphausids and copepod.

Sei whales occur in subtropical, temperate, and subpolar waters around the world. They feed on plankton, small schooling fish, and cephalopods. They are typically observed in deeper waters far from the coastline

Humpback whales live in all major oceans from the equator to sub-polar latitudes. Humpback whales travel great distances during their seasonal migration. In the summer, humpbacks are found in high latitude feeding grounds. In the winter, they migrate to calving grounds in subtropical or tropical waters. During the summer months, humpbacks spend most of their time feeding and building up fat stores (blubber) that they will live off during the winter. Humpbacks filter feed on tiny crustaceans (mostly krill), plankton, and small fish.

Sperm whales are the largest of the toothed whales. Sperm whales are found throughout the world's oceans in deep waters between about 60° N and 60° S latitudes. Sperm whales tend to inhabit areas with a water depth of 1,968 feet (600 m) or more, and are uncommon in waters less than 984 feet (300 m) deep. Their principle prey are large squid, demersal and mesopelagic sharks, skates, and fishes.

SHARKS AND RAYS

The oceanic whitetip shark is found throughout the world in tropical and sub-tropical waters. It is a pelagic species, generally remaining offshore in the open ocean, on the outer continental shelf, or around oceanic islands in water depths greater than 600 feet. They live from the surface of the water to at least 498 feet deep. Oceanic whitetip sharks have a strong preference for the surface mixed layer in warm waters above 20°C, and are therefore a surface-dwelling shark. They feed on squid and octopus and many types of fish. It has also been known to feed on stingrays, sea turtles and birds.

The scalloped hammerhead shark is a pelagic species that can also be found in ocean waters and occurs over continental and insular shelves and adjacent to deeper water. Scalloped hammerhead sharks are found worldwide residing in coastal warm temperate and tropical seas in the Atlantic, Pacific, and Indian Oceans between 46°N and 36°S to depths of 1000 meters. It has been observed close inshore and even entering estuarine habitats. It feeds primarily on fish such as sardines, mackerel, and herring, and occasionally on cephalopods such as squid and octopus.

The giant manta ray is found worldwide in tropical, subtropical, and temperate bodies of water and is commonly found offshore, in oceanic waters, and near productive coastlines. The giant manta ray is a migratory species, and seasonal visitor along productive coastlines with regular upwelling, in oceanic island groups. They are filter feeders and eat large quantities of zooplankton.

CORALS

Acropora globiceps occurs in Guam, CNMI, American Samoa, and the Pacific Remote Island Areas. *A. globiceps* occurs on upper reef slopes, reef flats, and adjacent habitats in depths ranging from 0 to 8 meters.

Acropora retusa is likely to be distributed in the Commonwealth of the Northern Mariana Islands (CNMI). *A. retusa* occurs in shallow reef slope and back-reef areas, such as upper reef slopes, reef flats, and shallow lagoons, and its depth range is 0 to 5 meters.

NMFS considers *Seriatopora aculeata* to occur in Guam and CNMI. *S. aculeata* occurs in a broad range of habitats on the reef slope and back-reef, including but not limited to upper reef slopes, mid-slope terraces, lower reef slopes, reef flats, and lagoons in a depth range of 3 to 40 meters.

CLAMS

The giant clam lives in flat coral sand or broken coral and can be found at depths of as much as 20 m. Giant clams are the largest living marine bivalves and typically inhabit tropical coral reefs in coastal regions throughout the Indo-Pacific.

Giant clams are members of the Subfamily *Tridacnidae*, which consists of two genera: *Hippopus* and *Tridacna*. Modern giant clams are distributed along shallow shorelines and on reefs in the Indo-West Pacific in the area confined by 30° E and 120° W and between 36° N and 30°. The giant clams mainly occur within the tropical Indo-Pacific region. The clam's mantle tissue is a habitat for the symbiotic single-celled dinoflagellate algae (zooxanthellae) from which the adult clams get most of their nutrition. By day, the clam opens its shell and extends its mantle tissue so that the algae receive the sunlight they need to photosynthesize. Giant clams are planktotrophic but they can acquire nutrition required for maintenance from their symbiotic algae, *Symbodinium. Tridacna gigas*, comfortably satisfies all apparent carbon requirements from the combined sources of filter-feeding and prototrophy (Klumpp and Lucas 1994). *T. derasa* can function as a complete autotroph in its natural habitat (down to 20 m), whereas *T. tevoroa* only achieves this in the shallower parts of its distribution (10 to 20 m).

V. Anticipated Effects

Water quality standards establish the concentrations of contaminants that are deemed to be protective of aquatic life. They can be used in evaluating protectiveness of water quality monitoring results. They can also be used to establish effluent limits for discharge permits to

water. States can also use water quality standards to condition Federal actions through 401 certifications. The effects determinations are grouped and summarized below with the supporting information.

Cadmium

Cadmium is a naturally occurring metal found in mineral deposits and is distributed widely at low concentrations in the environment. Cadmium's primary industrial uses are for the manufacture of batteries, pigments, plastic stabilizers, metal coatings, alloys and electronics. Recently, cadmium has been used in manufacturing nanoparticles for use in solar cells and color displays. None of the monitoring data for any of the permitted dischargers on CNMI reveal any effluent levels of cadmium. Acute exposure causes increased mortality in aquatic organisms. Chronic exposure leads to adverse effects on growth, reproduction, immune and endocrine systems, development and behavior in aquatic organisms. Cadmium is widely distributed in the environment and can be introduced to marine organisms by ingestion of food, seawater and maternal transfer.

In equatorial ocean waters, cadmium concentrations are around 9 ng/l in the upper water column and around 100 ng/l below 150 meters depth. Denton et al 2006 reported that cadmium concentrations in sediments in Tanapag Lagoon are low, suggesting that there is not a major source of cadmium to the lagoon.

Whales. Cadmium accumulates in tissues of marine mammals worldwide (Chen et al, 2017, and references therein). All the whale species of concern (Table 2) are migratory and are generally found offshore. As whales do not generally drink saltwater, the primary pathway for the accumulation of toxins is through the food web. Squid species, deep water fish and jellyfish are a significant source of cadmium in marine mammals (Honda et al., 1983; Bustamante et al., 1998). Cadmium concentrations in whales and other large predators generally increase with size (age). Cadmium is concentrated in the liver and kidneys of whales. Cadmium binds to metallothionein in the liver and is subsequently transported to the kidneys.

Sharks. Sharks are generally getting cadmium from food. Cadmium is also known to accumulate in the liver of sharks (Vas, 1991; Turoczy et al., 2000, Endo et al., 2008, Barrera-García et al., 2013). Evans and Weigarten (1989) showed in the lab that cadmium concentrations on the order of 10 to 100 ug/l could cause vasoconstriction of vascular endothelium of dogfish sharks. Similarly, Wang et al., 1999 showed that cadmium levels on the order of 10 to 100 ug/l also affected the vasodilation pressure and the shape of the electrocardiogram in dogfish hearts isolated in the lab.

Sea Turtles. Ingestion is thought to be the biggest route (Storelli et al.,2005, Ikonomopoulou et al., 2011). Green turtles are largely herbivorous. Leatherback feed almost exclusively on jellyfish and loggerhead turtles are carnivorous. Leatherback turtles accumulated higher levels of cadmium as jellyfish are high in cadmium (Caurant et al.,1999). Cadmium is eliminated quickly from turtle blood and stored in the liver where it binds with metallothionein and is eventually stored in the kidney (Guirlet and Das, 2012). Concentrations in Green sea turtle eggs near Hong Kong are low (Lam et al., 2006). Maternal transfer of cadmium to turtle eggs is low (Paez-Osúna et al.,2010, Ikonomopoulou et al., 2011, Sakai et al., 2000, Storelli et al.,2005).

Clams. The EPA cadmium criteria document provided toxicity for 14 bivalve species. The LC_{50}s ranged from 23,200 ug/l for the dogwhelk (*Nucella lapillus*) to 60 ug/l for the horse clam (*Tresus capax*). Cadmium is highly accumulated in molluscs (Honda, 1990). Duquesne and Coll 1995 found significant reduction in the zooxanthellae of *Tridacna crocea* exposed to cadmium concentrations of 200 ug/l over a 10-day period.

Corals. Nacci et al., 1986 established a cadmium EC50 for *Acropora punctulata* at 38,000 ug/l. Reichelt-Brushette and Harrison (1999) observed that fertilization success of gametes from the *Goniastrea aspera* and *Oxypora lacera* were not affected by cadmium concentrations of 200 µg/l and 1,000 ug/l, respectively. The gametes from the reef coral *O. lacera* showed no decrease in fertilization success up to 1000 ug/l of cadmium. Reichelt-Brushette and Harrison (2005) found that *Acropora tenuis* from the Great Barrier reef had fertilization reduced at cadmium concentrations above 5,000 ug/l (NOEC = 2,000 ug/l). Mitchelmore et al., 2007 documented mortality in *Pocillopora damicornis* corals exposed to 50 ug/l.

Summary. EPA's approval of the CNMI's cadmium water quality standard is not likely to affect whales and sharks as they are mostly pelagic organisms and not likely to spend significant time in the near shore environment. EPAs' research has not found any thresholds in the Ecotox database or in the scientific literature for the listed species or surrogates that are less than either the acute (33 ug/l) or chronic (7.9 ug/l) cadmium standards. EPA finds that the cadmium standards are not likely to adversely affect any of the threatened or endangered whales, sharks, turtles, clams or corals identified by NMFS.

Carbaryl

Carbaryl is a member of the N-methyl carbamate class of pesticides, which share a common mechanism of toxicity by affecting the nervous system in animals. Carbaryl also affects plant development and is used to thin fruit in orchards. Carbaryl (Sevin®) is a pesticide used to control insects, slugs and snails and to thin fruit in orchards. It can enter water bodies through runoff and potentially pose risks to aquatic life. Carbaryl is the second most frequently found insecticide in water, with detections in approximately half of monitored urban streams. After contact with or ingestion by aquatic organisms, the toxic mode of action of carbaryl is inhibition of the enzyme acetylcholinesterase (AChE) at synaptic junctions in the nervous system. AChE breaks down the neurotransmitter acetylcholine. Inhibition of AChE results in the accumulation of acetylcholine in the nerve synapses which leads to continual firing of nerve pulses throughout the nervous system. This buildup results in uncontrolled movement, paralysis, convulsions, tetany, and possible death. Without proper nerve function, the respiratory, circulatory and other vital body systems will fail, ultimately causing death of the organism. The acetylcholinesterase inhibition effects of carbaryl are reversible with removal of exposure of the stressor chemical.

Whales. There is no information on carbaryl and mammals in the EPA criteria document or the Ecotox database. Most carbaryl mammal studies are done on mice and rats. A summary of the effects of carbaryl on mammals was provided by Gunasekara et al., 2008 and references therein. "AChE inhibition also causes the toxicity of carbaryl to mammals, although, in contrast to insects, the mammalian effect involves synapses in the peripheral nervous system, including those in glandular structures and at neuromuscular junctions, in addition to those in the central

nervous system. Because of the hydrolytic instability of the carbamate-AChE bond, recovery of mammals from acute effects is expected when exposures are low....The metabolism of carbaryl has been extensively studied in mammals. In general, it does not accumulate in mammalian tissue and is rapidly metabolized to less-toxic substances, particularly 1-naphthol, which are eliminated in urine and feces (Tomlin 2000). The main pathways include oxidation, via hydroxylation and epoxidation, and hydrolysis (Carpenter et al., 1961, Dorough and Casida 1964)."

No acceptable data on the bioaccumulation of carbaryl in freshwater or estuarine/marine waters are available; however, because of its low octanol/water partition coefficient (229), carbaryl is not expected to bioconcentrate to a significant extent (U.S. EPA 2010). There is little threat of carbaryl accumulation through consumption of prey species.

Sharks. The EPA carbaryl criteria document identified toxicity data on Sheepshead minnows (*Cyprinodon variegatus*) and Threespine stickleback (*Gastersosteus aculeatus*). The LC_{50}s for *C. variegatus* were 2,200 and 2,600 ug/l (Suprenant 1985 and Lintott, 1992). The LC_{50} for *G. aculeatus* was 3,990 ug/l (Katz, 1981). As discussed above carbaryl is not expected to bioconcentrate to a significant extent.

Turtles. Aguirre et al., 1994 analyzed the shell and tissue of Green Sea turtle hatchlings from the Hawaiian Islands for a number of chemical contaminants; carbaryl was not detected at concentrations above the detection limit of 100 ug/l. de Solla and Martin (2011) evaluated the uptake of carbaryl on snapping turtles (*Chelydra serpentina*) exposed to soil with carbaryl at the agronomic rate. There was no uptake in the eggs after 8 days of exposure. At ten times the agronomic rate there was uptake after 1 day.

Hopkins et al., 2005 found that carbaryl concentrations of 5,000 ug/l affected the swimming performance of neonate black swamp snakes (*Seminatrix pygaea*) and diamondback water snakes (*Nerodia rhombifer*). Most individuals recovered from the effects of carbaryl on swimming performance within 96 hours. As discussed above, carbaryl is not expected to bioconcentrate to a significant extent.

Clams. The 2016 carbaryl criteria document evaluated LC_{50} for a number of bivalves (mussels, oysters and clams). Stewart et al., 1967 established an LC_{50} for *Mytilus edulis* larvae of 2,300 ug/l. Liu and Lee 1975 published LC_{50}s for embryo/larvae of *M edulis* ranging from 1,210 to 1,800 ug/l. The LC_{50} of *Crassostrea virginica* larvae was reported as 2,700 to 3,000 ug/l (Suprenant et al., 1985, Davis and Hidu 1969). Similarly, Stewart et al., 1967 reported LC_{50} for *Crassostrea gigas* larvae as 2200 ug/l/. The LC_{50} for *C Virginica* juveniles was 2000 ug/l (Hansen 1980, Mayer 1987. LC_{50}s for the larvae of *Mercenaria mercenaria* was 3820 ug/l (Davis and Hindu, 1969). The LC50 for *Clinocardium nutalli* was 3,850. The LC_{50} for *Macoma nasuta* was 17,000 ug/l (Armstrong and Millemann, 1974).

Mora, 1999 established IC_{50}s based on inhibition of acetylcholinesterase after 24-hour exposure to carbaryl for *Mytilus galloprovincialis* (89 ug/l) and *Corbicula fluminea* (190 ug/l). Kopecka-Pilarczyk 2010 exposed *Mytilus trossulus* to a carbaryl concentration of 100 ug/l and found the greatest inhibition of acetylcholinesterase at 12 hours but reported that the effects of carbaryl disappeared after 48 hours.

Coral. Acevedo 1991 saw no effect on the planulae larvae of *Pocillopora damicornis* exposed to 10,000 ug/l carbaryl for 24 hours. Markey et al., 2007 found that carbaryl concentrations of 30 ug/l had no effect on the fertilization rate of *Acropora millepora* but 3 ug/l (LOEC) carbaryl could reduce metamorphosis of 7- and 8-day old larvae

Summary. EPA's approval of the CNMI's carbaryl water quality standard is not likely to affect whales and sharks as they are mostly pelagic organisms and not likely to spend significant time in the near shore environment. EPAs' research has not found any thresholds for the listed species or surrogates in the Ecotox database or in the scientific literature that are less than either the acute criteria of 1.6 ug/l. EPA finds that the carbaryl standards are not likely to adversely affect any of the threatened or endangered species identified by NMFS.

Diazinon

Diazinon is a pesticide traditionally used throughout the U.S. to control insects in agricultural areas, households and urban settings. Diazinon is mobile and moderately persistent in the environment. Diazinon is frequently found in wastewater treatment plant effluent and storm water runoff in urban and agricultural areas. Diazinon is known to be toxic to aquatic life, particularly invertebrates.

After December 31, 2004, it became unlawful to sell diazinon for outdoor, non-agricultural uses in the United States (that is, all residential uses of the insecticide diazinon have been cancelled). However, it is lawful to use diazinon for non-residential or agricultural uses that are consistent with product labeling and precautions approved by EPA under the Federal Insecticide, Fungicide and Rodenticide Act. There is no current use of diazinon on CNMI and is not imported to CNMI (Watts, 2015; Personal Communication with Zabrina Shai, BECQ Pesticide Inspector Aug 21, 2018).

Whales. There is no information on marine mammals in the EPA criteria document or the Ecotox database. Most papers on mammals and diazinon are for mice and rats. The mammalian LD_{50} is 1139 mg/kg (EFSA, 2006b, as reported in Crane et al., 2016). Given bioconcentration factors (BCFs) for a marine fish (sheepshead minnows, *C variegatus*) ranging from 147 and 213 (Goodman et al., 1979) we can develop a first order approximation of carbaryl concentration in prey species at water column concentrations equal to the chronic diazinon criteria (0.82 ug/l). Multiplying the BCF of 213 by the acute criteria of 0.82 ug/l, we estimate that marine prey would have a tissue concentration of 0.175 mg/kg, which is about 10,000 times lower than the mammalian LD_{50}.

Sharks. The EPA diazinon criteria document has toxicity data on two marine fish. The sheepshead minnow (*Cyprinodon variegatus*) and the inland silverside (*Menidea berrylinna*) had LC_{50}s for 1400 ug/l and 1,170 ug/l, respectively. One paper was found in the scientific literature demonstrating potential effects of diazinon on sharks. Hedayati and Tarkhani, 2014 found concentrations of diazinon at 500 ug/l caused changes in a number of blood parameters (such as red blood cell count; white blood cell count, hematocrit) in iridescent shark (*Pangasius hypophthalmus).*

Direct effects to sharks from diazinon are not expected due to dilution with marine waters. Diazinon is readily metabolized and does not accumulate in aquatic organisms, dietary exposure for shark species is of very low concern. Indirect effects (*i.e.*, reductions in prey), are not likely as the area around CNMI represents only a small fraction of the diet of the listed shark species.

Turtles. There is no information on turtles in the EPA criteria document or the Ecotox database. One report from the open literature suggested that diazinon was not present at detectable levels (10 ug/l) in the shell and tissue of Green Sea turtle hatchlings from the Hawaiian Islands (Aguirre et al 1994). The Ecotox database contained at least 14 papers on diazinon and birds. Most were based on incidental consuming of crystals by birds, or studies where diazinon was force fed (gavage). Lacking lethal dose information on turtles and reptiles, we use birds as surrogate species. The mallard duck has an oral dose LD_{50} of 1.44 mg/kg ((EFSA, 2006b, as reported in Crane et al., 2016) and can be used as a surrogate to assess the effect of trophic uptake by sea turtles. Assuming the BCF of 213 for the sheepshead minnow (*C. variegatus*) and assuming the acute diazinon criterion value of 0.82 ug/l we calculate a diazinon prey value of less than 0.175 mg/kg, an order of magnitude lower than the LD_{50} for the mallard. Using this as a first order approximation, we conclude that sea turtles are not likely to get much diazinon from its prey species.

Clams. Hemming and Waller (2004) developed diazinon 96-hr LC_{50}s for the Asiatic clam (*Corbicula fluminea*) and hooked mussel (*Ischadium recurvum*) and 354 µg/l and 4,067 µg/l, respectively. Choi et al., 2011 found a clear dose-response relationship between inhibited cholinesterase in adductor muscle of Manila clams and diazinon; the EC_{50} was 3010 ug/l.

Coral. There is no information in the EPA criteria document or in the Ecotox database on diazinon and cnidarians or zooxanthellae.

Summary. EPA's approval of the CNMI's diazinon water quality standard is not likely to affect whales and sharks as they are mostly pelagic organisms and not likely to spend significant time in the near shore environment. EPAs' research has not found any thresholds for the listed species or their surrogates in the Ecotox database or in the scientific literature that are less than either the acute criteria of 0.82 ug/l. In addition, diazinon is not used nor is it imported to CNMI. EPA finds that the diazinon standards are not likely to adversely affect any of the threatened or endangered species identified by NMFS.

Nonylphenol

Nonylphenols are alkylphenols that consist of a phenol group attached to a 9-carbon chain. They are used in manufacturing antioxidants, lubricating oil additives, laundry and dish detergents, emulsifiers, and solubilizers. These compounds are also precursors to the commercially important non-ionic surfactants alkylphenol ethoxylates and nonylphenol ethoxylates, which are used in detergents, paints, pesticides, personal care products, and plastics. Nonylphenols are likely to be introduced to the marine environment through wastewater and potentially through plastics in the ocean. Nonylphenol has attracted attention due to its prevalence in the environment and its potential role as an endocrine disruptor.

Nonylphenol concentrations in seawater are generally low. Kawahata et al., 2004 reported a maximum concentration of 0.17 ug/l nonylphenol at various sites in Okinawa and Ishigaki

Islands, Japan. Similarly, Kung et al., 2018 reported maximum concentrations of nonylphenol and nonylphenol ethoxylate 0.077 and 0.236 ug/l, respectively, in the coastal waters of southern Taiwan. Higher concentrations can be found in sediments (Kawahata et al 2004). Limited data are available for the effects of 4-nonylphenol on marine life in the Ecotox database or the scientific literature.

Whales. There is no information on the effect of nonylphenol and whales. Studies on rats have been done. Aso et al., 2000 demonstrated in estrus in adult female rats exposed orally to a dose of 150 mg/kg/d for 28 days. Moon et al., 2007 treated pregnant female rats in the late stage of gestation and found that female pups had increased uterus weight and advanced development of mammary tissue at 100 mg/kg/d.

The log K_{OW} of nonylphenol ranges from 3.80 to 4.77, this suggests that moderate bioaccumulation in aquatic organisms may be expected. However, reported laboratory bioconcentration factors (BCFs) and field-derived bioaccumulation factors (BAFs) do not support the expected accumulations in tissues, indicating that some nonylphenol is metabolized. Hecht et al., 2004 reported nonylphenol BCFs for the three marine amphipod species, *Eohaustorius estuarium, Grandidierella japonica* and *Corophidum salmonis*, of 154, 185, and 46 to 133, respectively. Assuming these crustaceans act as a reasonable surrogate for zooplankton, we can approximate the concentration of nonylphenol in the prey if the water column concentration was equal to the chronic nonylphenol concentration (1.7 ug/l). Multiplying 1.7 ug/l x 185, we would expect the prey to be 0.315 mg/kg which is much lower than the doses described above. We conclude that marine mammals are not likely to accumulate nonylphenol through the foodweb.

Sharks. Ward and Boeri 1990 found reduced growth and morphology in Sheepshead Minnow at 240 ug/l nonyphenol. Similarly, Martin-Skilton et al. 2006 found reduced growth and development in Atlantic Cod and Turbot with a NOECs of 29 ug/l nonylphenol. Pickford et al., 2003 evaluated the estrogenic effects of nonylphenol in fathead minnow (*Pimephales promelas*) through water exposure and oral exposure. Pickford et al. concluded that uptake of estrogenic activity was more likely through the gill and skin than through ingestion.

Turtles. While sea turtles are immersed in seawater, contaminants like 4-nonylphenol do not readily pass through their shell and skin into the body. Unlike gilled species, sea turtle exposures are not continuous because they do not drink continuously. Indirect exposures can occur through ingestion of food that has accumulated pollutants. In the Mediterranean Sea, Guerranti et al., 2014 reported that levels of p-nonylphenol in the green sea turtle and the loggerhead sea turtle were only slightly higher than the limits of detection. They noted that this may be the first report of nonylphenols in sea turtles in the scientific literature.

The Ecotox database does not include data on reptiles exposed to 4-nonylphenol, so studies from the open literature were used in this assessment. The induction of vitellogenin, impairment of spermatogenesis, and gonad abnormalities were reported in the Italian wall lizard exposed to drinking water dosed at 500,000 ug/l nonylphenol (Verderame et al., 2010; Verderame and Limatola 2015).

Cheng et al. 2017 demonstrated that the fertilization rates in Japanese quail were significantly reduced at concentrations as low as 0.1 ug/l. Survival rates were reduced with long term (4- to 14- day) exposure to nonylphenol at 1 ug/l. NMFS cited Cheng et al., 2017 Biological Opinion on Environmental Protection Agency's Approval of Florida's Proposed Water Quality Criteria for 4-Nonyphenol and determined that the nonylphenol standard does not adversely affect sea turtles.

Clams. Granno et al., 1989 found that the fertilization and early developmental success of *Mytilus edulis* were not affected at the highest concentration tested at 200 ug/l nonylphenol. Nice et al., 2000 observed a delay in development of D-shaped larvae at concentrations as low as 1 ug/l. Ricciardi et al., 2008 saw increases in vitellogenin in both male and female mussels (*Mytilus galloprovincialis*) at concentrations greater than 50 ug/l nonylphenol.

For the clam *Tapes philipinarum,* exposed over 7 days at 100 ug/l nonylphenol, there was a decrease in clearance rate and scope for growth (Matozzo et al., 2003). Mattozo and Marin, 2005 found increased vitellogenin in the Clam *T. philipinarum* over 7 days at concentrations as low as 100 ug/l. Marin et al., 2008 found toxicity in the cockle *Cerastoderma glaucoma* at concentrations of 300 ug/l. Increases in vitellogenin were observed in concentrations as low as 12.5 ug/l.

Liu et al., 2011 found a 12 h EC_{50} for trochophore of abalone (*Haliotis versicolor*) at 1016 ug/l and 96 hr EC_{50} for metamorphosis at 23 ug/l. Liu developed EC_5 for trochophore and metamorphosis at 319 ug/l and 1.4 ug/l, respectively.

Corals. Only one paper was found showing effects of nonylphenol on corals. Shafir et al., 2014 demonstrated that long-term exposure to nonylphenol ethoxylate caused mortality to two coral species (*Stylophora pistillata* and *Pocillopora damicornis*). They calculated an LC_{50} of 2160 ug/l. Using a freshwater cnidarian (*Hydra attenuate*), an LC_{10} value for embryos of 21 ug/l and an LC_{10} of 67 ug/l were calculated (Pachura et al. 2005, Pachura-Bouchet et al. 2006).

Summary. EPA's approval of the CNMI's nonylphenol water quality standard is not likely to affect whales and sharks as they are mostly pelagic organisms and not likely to spend significant time in the near shore environment. EPA finds that most species thresholds for the listed species or their surrogates in the Ecotox database or in the scientific literature are greater than either the acute (7 ug/l) or chronic (1.7 ug/l) nonylphenol standards. EPA finds that the nonylphenol standards are not likely to adversely affect any of the threatened or endangered species identified by NMFS.

Tributyltins

Tributyltin (TBT) is a class of organotin compounds which contain the (C4H9)3Sn group and were used in anti-fouling paint applied to the hulls of ocean going vessels. In 1988, Congress enacted a partial ban on TBT antifouling paints, which banned the application of antifouling paint containing organotin to vessels less than 25 meters in length. In 2008, organotin compounds were banned in anti-fouling paint by the International Convention on the Control of Harmful Anti-fouling Systems on Ships of the International Maritime Organization. It states that ships cannot bear organotin compounds on their hulls or external parts or surfaces, unless there is a coating that forms a barrier so that organotin compounds cannot leach out to reduce exposure by allowing recovery to occur.

The extent to which TBT is accumulated by saltwater animals from the field or from laboratory tests lasting 28 days or more has been investigated with four species of bivalve molluscs and two species of snails. Thain and Waldock, 1985 reported a BCF of 6,833 for the soft parts of blue mussel spat exposed to 0.24 µg/L for 45 days. In other laboratory exposures of blue mussels, Salazar et al.,1987 observed BCFs of 10,400 to 37,500 after 56 days of exposure. BAFs from field deployments of mussels were similar to the BCFs from laboratory studies: 11,000 to 25,000 in Salazar and Salazar 1990a and from 5,000 to 60,000 in Salazar and Salazar 1991. In a study by Bryan et al., 1987a, laboratory BCFs for the snail *Nucella lapillus* (11,000 to 38,000) also were similar to field BAFs (17,000). Year-long laboratory studies by Bailey et al.,1991 and Harding et al., 1996 produced similar BAFs in *N. lapillus ranging* from 6,172 to 21,964.

<u>*Whales*</u>. TBTs are found in cetacean and pinnipeds globally and are generally are more concentrated in liver tissue than other organs. Butyltins were generally higher in coastal species than pelagic species. Kim et al., 1998 found that hepatic cells exposed in vitro to 290 ug/l TBT had reduction in cytochrome p450 expression. Nakata et al., 2002 found reductions in lymphocyte production at TBT concentrations of 89 ug/l in Dall Porpoise, Bottlenosed Porpoise and Sea Lion.

<u>*Sharks*</u>. Dwivei and Trombetta (2006) found that stingrays exposed to tributyltin-oxide for 3 hours exhibited swollen gill epithelia at concentrations as low as 5 ug/l.

<u>*Sea Turtle*</u>. There is no information in the Ecotox database on TBT in turtles. Our literature search found one paper on TBT in turtles. TBT was not detected in turtle eggs of *Natator depressus* in Australia (Ikonomopoulou et al., 2011).

<u>*Clams*</u>. Inoue et al., 2006 found reduced embryo development in fertilized eggs of the Manila clam (*Ruditapes philippinarum*) exposed to 0.062 ug/l TBT for 23 hours. Maternal clams exposed to 0.061 ug/l TBT for 3 weeks exhibited reduced embryo development.

Mortality studies showed that the LC_{50} of the clam *Anadara rhombea* for 96 h exposure was 370 ug/l for tributyltin-chloride (Ranalalitha et al., 2014). At a concentration of 37 ug/l phosphatase activity was initiated in the digestive glands of *A. rhombea*.

Corals. Negri and Heyward, 2001, showed that fertilization of the coral *Acropora millepora* was inhibited by TBT at 200 ug/l *(IC_{50})* and larval metamorphosis was inhibited at 2 ug/l (IC_{50}). Watanabe et al., 2006 demonstrated significant mortality in *Acropora millepora* after exposure to 5 µg/l of TBT, and partial tissue detachment at 1 µg/l. There was no significant decrease at 0.2 ug/l even after 10 days of exposure. Watanabe et al., 2006 noticed a significant decrease in the symbiont population at 1 ug/l. Bao et al., 2011 showed toxicity of TBT to the larvae of *Acropora tumida* (LC_{50} = 7.5 ug/l; LC_{10} = 0.67 ug/l).

Summary. EPA's approval of the CNMI's tributyltin water quality standard is not likely to affect whales and sharks as they are mostly pelagic organisms and not likely to spend significant time in the near shore environment. EPAs' research has not found any thresholds for the listed species or their surrogates in the Ecotox database or in the scientific literature that are less than either the acute (0.0074 ug/l) or chronic (0.42 ug/l) tributyltin standards. EPA finds that the tributyltin standards are not likely to adversely affect any of the threatened or endangered species identified by NMFS.

VI. Critical Habitat

None

VII. Magnuson-Stevens Fishery Conservation and Management Act – Essential Fish Habitat.

None

VIII. References

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SEP 6 - 2018

Mary Abrams
Field Supervisor
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300 Ala Moana Blvd
Honolulu, HI 96850

Dear Ms. Abrams:

The purpose of this letter is to request the U.S. Fish and Wildlife Service's (USFWS) written concurrence, under Section 7 of the Endangered Species Act (ESA) and 50 CFR Section 402.13(a), with the U.S. Environmental Protection Agency (EPA) Region 9's determination on the possible effects of approval under Section 303(c)(3) of the Clean Water Act (CWA) of water quality standards (WQS) by the Commonwealth of the Northern Mariana Islands (CNMI) Bureau of Environmental and Coastal Quality (BECQ).

BECQ revised their ammonia, cadmium, and selenium water quality standards applicable to all freshwater in CNMI. Their water quality standards were public noticed on May 25, 2018 and a public hearing was held on July 13, 2018. The water quality standards were adopted by CNMI on August 28, 2018 and transmitted to EPA in a letter dated September 5, 2018.

BECQ previously adopted freshwater water quality standards for acrolein, carbaryl, diazinon, nonylphenol, and tributyltin on June 11, 2014. EPA approved the acrolein, carbaryl, diazinon, nonylphenol, and tributyltin water quality standards on May 1, 2015. EPA had previously initiated consultation on these five parameters but ESA consultation had not been concluded. As a result, the analysis of these parameters has been included in the enclosed Biological Evaluation (BE).

The BE documents the EPA's analysis of the effects of approving the water quality standards action on listed species under USFWS jurisdiction. The EPA has determined that approval of the water quality standards may affect, but is not likely to adversely affect threatened or endangered species. This conclusion is based on the effects on listed species which are expected to be discountable or insignificant.

The EPA is requesting USFWS's concurrence with our "may affect, but not likely to adversely affect" determination, in accordance with the procedures outlined in the Memorandum of

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Agreement Between the Environmental Protection Agency, Fish and Wildlife Service, and National Marine Fisheries Service regarding Enhanced Coordination Under the Clean Water Act and Endangered Species Act, dated February 22, 2001. If you have any questions, please contact Nicole Tachiki of my staff at (415) 972-3161 or tachiki.nicole@epa.gov.

Sincerely,

Janet Hashimoto

Janet Hashimoto, Chief
Water Quality Assessment Section

Enclosure

cc: Tyler Willsey, USFWS

Biological Evaluation of the Commonwealth of the Northern Mariana's Water Quality Standards for Ammonia, Cadmium, Selenium, Acrolein, Carbaryl, Diazinon, Nonylphenol and Tributyltin

Prepared by:

U.S. Environmental Protection Agency
Region 9
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2018

EPA-HQ-2019-004830 001389

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I. Introduction

This Biological Evaluation (BE) analyzes the U.S. Environmental Protection Agency (EPA) actions on the Commonwealth of the Northern Mariana Islands (CNMI)(Territory) Bureau of Environmental and Coastal Quality (BECQ) water quality standards. BECQ adopted freshwater water quality standards for ammonia, cadmium, and selenium. EPA is submitting this BE as part of a consultation under the Endangered Species Act (ESA) (16 U.S.C. 1531 et seq.). The scope of the consultation includes EPA's action on BECQ's adoption of freshwater ammonia, cadmium, and selenium standards.

The scope of this BE also includes EPA's previous approval of freshwater standards for nonylphenol, tributyltin, carbaryl, diazinon and acrolein adopted by CNMI on June 11, 2014 and approved by EPA on May 1, 2015. EPA had previously initiated consultation with the U.S. Fish and Wildlife Service (USFWS) on these parameters, but ESA consultation has not been concluded.

This BE addresses the potential impacts of ammonia, cadmium, selenium, acrolein, carbaryl, diazinon, nonylphenol, and tributyltin to listed species under the jurisdiction of USFWS in the area affected by the federal action, pursuant to Section 7 of the ESA and 50 CFR Section 402.13(a).

II. Description of Action

BECQ has submitted a package to adopt water quality standards to protect aquatic life from acute and chronic exposure to ammonia, cadmium, and selenium for all commonwealth or state waters. The parameters from the 2015 standards action include adopted WQS for acrolein, carbaryl, diazinon, nonylphenol, and tributyltin standards which all apply to both fresh and saltwater environments.

Water quality standards are not self-implementing, meaning other programs or authorities must be used to achieve water quality standards. For example, water quality standards can be used by the state to assess waterbodies or in writing pollutant discharge permits. Complete descriptions of the national criteria can be found on the EPA website (https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table) and include properties of the pollutant, how the pollutant interacts in the environment, acute and chronic effects on species, criterion calculations, data used to set criterion levels, and more. Below is a summary of the pollutants CNMI plans to adopt.

A. Ammonia

Ammonia is one of several forms of nitrogen that exist in aquatic environments. Unlike other forms of nitrogen, which can cause nutrient over-enrichment of a water body at elevated concentrations and indirect effects on aquatic life, ammonia causes direct toxic effects on aquatic life. Ammonia is produced for commercial fertilizers and other industrial applications. Natural sources of ammonia include the decomposition or breakdown of organic waste matter, gas exchange with the atmosphere, forest fires, animal and human waste, and nitrogen fixation processes. Ammonia can enter the aquatic environment via direct means such as municipal effluent discharges and the excretion of nitrogenous wastes from animals, and indirect means such as nitrogen fixation, air deposition, and runoff from agricultural lands.

CNMI BECQ adopted EPA's 2013 national recommended ambient water quality criteria for ammonia, which applies to freshwater waterbodies. In April 2013, EPA finalized updated ammonia criteria considering the latest toxicity information for freshwater species, including unionid mussels and gill-breathing snails. The most recent literature search covered the period from 1985 through October 2012. These criteria incorporate scientific views received on the draft 2009 criteria and supersede the 1999 criteria, which was based on salmonid fish toxicity for the acute criterion and bluegill sunfish early life stage toxicity for the chronic criterion. The acute and chronic toxicity data used to update the criteria were collected via literature searches of EPA's ECOTOX database, EPA's Ambient Aquatic Life Water Quality Criteria for Ammonia (U.S. EPA 1985, 1998, 1999), and data provided by the USFWS and NOAA National Marine Fisheries Service (NMFS), and EPA regional and field offices. The new criteria are based on robust toxicity data available for 69 genera (acute) and 16 genera (chronic) and are more stringent than previously recommended criteria. Freshwater invertebrates in the Phylum Mollusca, particularly freshwater mussels in the family Unionidae, freshwater clams, and some non-pulmonate snails, are predominantly the most sensitive species for which the criteria protect (USEPA, 2013). Table 1 shows the magnitude, duration and frequency of the new criteria compared to the previous criteria CNMI had in place.

Table 1. Comparison of past and current EPA-recommended aquatic life water quality criteria magnitudes for ammonia. Criteria magnitudes are expressed as total ammonia nitrogen (mg TAN/L) at pH 7 and 20°C

Criterion Duration	1999 Criteria	2009 Draft Updated Criteria	2013 Final Updated Criteria
Acute (1-hour average)	24	19	17
Chronic (30-day rolling average)	4.5*	0.91*	1.9*
*Not to exceed 2.5 times the criterion continuous concentrations as a 4-day average within a 30-day period.			
Criteria frequency: Not to be exceeded more than once in three years on average.			

B. Cadmium

Cadmium is a naturally occurring metal found in mineral deposits and is distributed widely at low concentrations in the environment. Cadmium's primary industrial uses are for the manufacturer of batteries, pigments, plastic stabilizers, metal coatings, alloys and electronics. Recently, cadmium has been used in manufacturing nanoparticles for use in solar cells and color displays. Cadmium enters the environment by natural and human processes. Human sources, such as mining and urban processes, are responsible for contributing approximately 90 percent of the cadmium found in surface waters. None of the monitoring data for any of the permitted dischargers on CNMI reveal any effluent levels of cadmium. Acute exposure causes increased mortality in aquatic organisms. Chronic exposure leads to adverse effects on growth, reproduction, immune and endocrine systems, development and behavior in aquatic organisms (USEPA, 2016).

CNMI BECQ adopted EPA's 2016 national recommended aquatic life ambient water quality criteria for cadmium in order to reflect the latest scientific information. EPA published the original national recommended cadmium aquatic life criteria in 1980 with subsequent revisions. In 1985, acute toxicity values were lowered to better protect the commercially and recreationally important rainbow trout. In 2001, criteria were developed for dissolved cadmium, instead of total recoverable cadmium, to more accurately account for bioavailability and reflect the latest EPA policy for metals risk assessment. The 2016 criteria are developed using the best available science and reflect data for 75 new species and 49 new genera. Table 2 shows the magnitude, frequency and duration of the cadmium criteria CNMI adopted.

Table 2. 2016 Aquatic Life Ambient Water Quality Criteria for Cadmium

	Acute (1-hour, dissolved Cd)[c]	Chronic (4-day, dissolved Cd)
Freshwater (Total Hardness = 100 mg/L as $CaCO_3$)[a]	1.8 µg/L[b]	0.72 µg/L
Estuarine/marine	33 µg/L	7.9 µg/L

[a] Freshwater acute and chronic criteria are hardness-dependent and were normalized to a hardness of 100 mg/L as $CaCO_3$ to allow the presentation of representative criteria values.
[b] Lowered to protect a commercially and recreationally important species (rainbow trout), as per the 1985 Guidelines, Stephen et al. (1985).
[c] The duration of the 2016 acute criteria was changed to 1-hour to reflect the 1985 Guidelines-based recommended acute duration.

C. Selenium

Selenium is a naturally occurring element present in sedimentary rocks, shales, coal and phosphate deposits and soils. There are around 40 known selenium-containing minerals but all are rare and generally occur together with sulfides of metals such as copper, zinc and lead. Selenium can be released into water resources by natural sources via weathering and by anthropogenic sources, such as surface mining, coal-fired power plants, and irrigated agriculture. Selenium is a nutritionally essential element for animals in small amounts, but toxic at higher concentrations. Selenium bioaccumulates in the aquatic food chain and chronic exposure in fish and aquatic invertebrates can cause reproductive impairments. Selenium can also adversely affect juvenile growth and mortality (USEPA, 2016). None of the monitoring data for any of the permitted dischargers on CNMI reveal any effluent levels of selenium.

CNMI BECQ adopted EPA's 2016 national recommended ambient water quality criteria for selenium, which applies to freshwater waterbodies. The 2016 criterion reflects the latest scientific knowledge, which indicates that selenium toxicity to aquatic life is primarily based on organisms consuming selenium-contaminated food rather than by being exposed only to selenium dissolved in water. The final criterion is expressed both in terms of fish tissue concentration (egg/overy, whole body, muscle) and water concentration (lentic, lotic). While more than half the available chornic studies were fish studies, available field data and laboratory toxicity studies suggest that a criterion based on fish will protect amphibians, aquatic invertebrates, and plants since these taxa appear to be less sensitive to selenium than fish. Table 3 shows the magnitude, frequency, and duration of the 2016 criterion compared to the previous 1999 criteria.

Table 3. Comparison of 2016 Selenium Criterion to 1999 Criteria

	Chronic					Short-term
Criterion Version	Egg-Ovary[1] [mg/kg dw]	Whole body[1] [mg/kg dw]	Muscle[1] [mg/kg dw]	Water Lentic[1] [µg/L]	Water Lotic[1] [µg/L]	Water[1] [µg/L]
2016	15.1	8.5	11.3	1.5 (30 day)	3.1 (30 day)	Intermittent exposure equation
1999	N/A	N/A	N/A	5 (4 day)	5 (4 day)	Acute equation based on water column concentration

[1] A note on hierarchy of table: when fish egg/ovary concentrations are measured, the values supersede any whole-body, muscle, or water column elements except in certain situations. Whole body or muscle measurements supersede any water column element when both fish tissue and water concentrations are measured, except in certain situations. Water column values are derived from the egg & ovary concentrations via bioaccumulation modeling. Water column values are the applicable criterion element in the absence of fish tissue measurements, such as waters where fish have been extirpated or where physical habitat and/or flow regime cannot sustain fish populations, or in waters with new discharges of selenium where steady state has not been achieved between water and fish tissue at the site.

D. Previously Adopted Standards

Acrolein, carbaryl, diazinon, nonylphenol and tributyltin water quality standards were approved by EPA in 2015, but ESA consultation has not been completed.

Acrolein: Acrolein is primarily used as an intermediate in the synthesis of acrylic acid and as a biocide. It may be formed from the breakdown of certain pollutants in outdoor air or from the burning of organic matter including tobacco, or fuels such as gasoline or oil. Chronic effects include respiratory congestion and eye, nose, and throat irritation. There is no current use of acrolein on CNMI and there is no import of acrolein to CNMI (Watts, 2015; Personal Communication with Zabrina Shai, BECQ Pesticide Inspector Aug 21, 2018).

Carbaryl: Carbaryl is a member of the N-methyl carbamate class of pesticides, which share a common mechanism of toxicity by affecting the nervous system in animals. Carbaryl also affects plant development and is used to thin fruit in orchards. Carbaryl (Sevin®) is a pesticide used to control insects, slugs and snails and to thin fruit in orchards. It can enter water bodies through runoff and potentially pose risks to aquatic life. Carbaryl is the second most frequently found insecticide in water, with detections in approximately half of monitored urban streams. After contact with or ingestion by

aquatic organisms, the toxic mode of action of carbaryl is inhibition of the enzyme acetylcholinesterase (AChE) at synaptic junctions in the nervous system. AChE breaks down the neurotransmitter acetylcholine. Inhibition of AChE results in the accumulation of acetylcholine in the nerve synapses which leads to continual firing of nerve pulses throughout the nervous system. This buildup results in uncontrolled movement, paralysis, convulsions, tetany, and possible death. Without proper nerve function, the respiratory, circulatory and other vital body systems will fail, ultimately causing death of the organism. The acetylcholinesterase inhibition effects of carbaryl are reversible with removal of exposure of the stressor chemical.

Diazinon: Diazinon is a pesticide traditionally used throughout the U.S. to control insects in agricultural areas, households and urban settings. Diazinon is mobile and moderately persistent in the environment. Diazinon is frequently found in wastewater treatment plant effluent and storm water runoff in urban and agricultural areas. Diazinon is known to be toxic to aquatic life, particularly invertebrates.

After December 31, 2004, it became unlawful to sell diazinon for outdoor, non-agricultural uses in the United States (that is, all residential uses of the insecticide diazinon have been cancelled). However, it is lawful to use diazinon for non-residential or agricultural uses that are consistent with product labeling and precautions approved by EPA under the Federal Insecticide, Fungicide and Rodenticide Act. There is no current use of diazinon on CNMI and there is no import of diazinon to CNMI (Watts, 2015; Personal Communication with Zabrina Shai, BECQ Pesticide Inspector Aug 21, 2018).

Nonylphenol: There is little direct use for nonylphenol except as a mixture with diisobutyl phthalate to color fuel oil for taxation purposes and with acylation to produce oxime as an agent to extract copper. Most nonylphenol is used as an intermediate in the production of other chemicals. Notably, nonionic surfactants of the nonylphenol ethoxylate type are produced through etherification of nonylphenol by condensation with ethylene oxide in the presence of a basic catalyst. The nonionic surfactants are used as oil soluble detergents and emulsifiers that can be sulfonated or phosphorylated to produce anionic detergents, lubricants, antistatic agents, high performance textile scouring agents, emulsifiers for agrichemicals, antioxidants for rubber manufacture, and lubricant oil additives.

Nonylphenol is metabolized by hepatic cytochrome P450 enzymes in the rainbow trout and bile from the fish contained the glucuronic acid conjugates of nonylphenol. Moderate bioaccumulation in aquatic organisms may be expected (USEPA, 2005). A comprehensive literature search in 1999 along with 43 newer studies were used along with U.S. EPA Office of Pollution Prevention and Toxics risk assessment data and analysis to derive the aquatic life criteria for nonylphenol. The acute and chronic criterion are listed in Table 4.

Tributyltin: Tributyltin (TBT) is primarily used as a biocide in antifouling paints. It is toxic to aquatic life and is an endocrine disrupting chemical that causes severe reproductive effects in aquatic organisms. TBT has been measured in the water column

and found highly (70-90%) associated with the dissolved phase but TBT readily adsorbs to sediments and suspended solids where it may persist (USEPA, 2003). The nationally recommended criteria are designed to protect aquatic organisms and water quality uses. The acute and chronic criterion are listed in Table 4.

Table 4. Acute and Chronic Criteria for Nonylphenol and Tributyltin

Pollutant	Saltwater CMC[1] (acute) (µg/L)	Saltwater CCC[2] (chronic) (µg/L)	Freshwater CMC[1] (acute) (µg/L)	Freshwater CCC[2] (chronic) (µg/L)
Acrolein	N/A	N/A	3	3
Carbaryl	1.6	N/A	2.1	2.1
Diazinon	0.82	0.82	0.17	0.17
Nonylphenol	7	1.7	28	6.6
Tributyltin	0.42	0.0074	0.46	0.072

[1] CMC: Criterion Maximum Concentration
[2] CCC: Criterion Continuous Concentration

None of the monitoring data for any of the permitted dischargers on CNMI reveal any effluent levels for acrolein, carbaryl, diazinon, nonylphenol or tributyltin. The duration and frequency of the acute criteria is a one-hour average concentration not to be exceeded more than once every three years and a four-day average concentration not to be exceeded more than once every three years for chronic criterion.

III. Description of the Area Affected

The CNMI water quality standards apply to all commonwealth or state waters. Pursuant to Chapter 65-130 of CNMI's WQS, commonwealth or state waters includes all waters, fresh, brackish, or marine, including wetlands, surrounding or within the commonwealth. The aquatic life criteria apply to all freshwater or saltwater, whichever is appropriate. The acute and chronic toxicity standards apply to all commonwealth or state waters.

IV. Listed Species

EPA received an official species list from the USFWS on April 11, 2018 and is shown in Table 5.

Table 5. USFWS Threatened and Endangered Species List for CNMI

Common Name	**Scientific Name**	**Status**	**Critical Habitat**	**Carried Forward**
Bat, Mariana fruit (=Mariana flying fox)	Pteropus mariannus mariannus	Threatened	No	No
Bat, Pacific sheath-tailed (Mariana subspecies)	Emballonura semicaudata rotensis	Endangered	No	No
Crow, Mariana (=aga)	Corvus kubaryi	Endangered	Yes	No

Kingfisher, Guam	Todiramphus cinnamominus	Endangered	No	No
Megapode, Micronesian	Megapodius laperouse	Endangered	No	No
Moorhen, Mariana common	Gallinula chloropus guami	Endangered	No	Yes
Rail, Guam	Rallus owstoni	Endangered	No	No
Swiftlet, Mariana gray	Aerodramus vanikorensis bartschi	Endangered	No	No
Warbler, nightingale reed (old world warbler)	Acrocephalus luscinia	Endangered	No	Yes
White-eye, Rota bridled	Zosterops rotensis	Endangered	No	No
Sea turtle, green	Chelonia mydas		No	Yes
Sea turtle, hawksbill	Eretmochelys imbricata		No	Yes
Skink, Slevin's	Emoia slevini	Endangered	No	No
Snail, fragile tree	Samoana fragilis	Endangered	No	Yes
Snail, Guam tree	Partula radiolata	Endangered	No	Yes
Snail, humped tree	Partula gibba	Endangered	No	Yes
Snail, Langford's tree	Partula langfordi	Endangered	No	Yes
Butterfly, Mariana eight-spot	Hypolimnas octocula marianensis	Endangered	No	No
Butterfly, Mariana wandering	Vagrans egistina	Endangered	No	No
Damselfly, Rota blue	Ischnura luta	Endangered	No	Yes
Siboyas halumtanu	Bulbophyllum guamense	Threatened	No	No
No common name	Dendrobium guamense	Threatened	No	No
Ufa halumtanu	Heritiera longipetiolata	Endangered	No	No
No common name	Nervilia jacksoniae	Threatened	No	No
No common name	Nesogenes rotensis	Endangered	No	No
No common name	Osmoxylon mariannense	Endangered	No	No
Aplokating palaoan	Psychotria malaspinae	Endangered	No	No
Iagu, Hayun (=(Guam), Tronkon guafi (Rota))	Serianthes nelsonii	Endangered	No	No
Biringenas halumtanu	Solanum guamense	Endangered	No	No
No common name	Tabernaemontana rotensis	Threatened	No	No
No common name	Tinospora homosepala	Endangered	No	No
No common name	Tuberolabium guamense	Threatened	No	No
Fadang	Cycas micronesica	Threatened	No	No

The plant species will not be the focus of this consultation. These plants are considered terrestrial, none of which are considered aquatic or aquatic-dependent.

V. Anticipated Effects

The EPA approval of the ammonia, cadmium, and selenium water quality standards may have effects when CNMI permits are implemented. Cadmium and selenium are not currently being discharged from any of the permitted facilities in CNMI. The quantity of ammonia effluent discharged from the facilities is much lower than the concentration limits allowed in the permits. The effects determinations are grouped and summarized below and the supporting information and specific rationales are also provided for each species. USFWS shares jurisdiction of Chelonia mydas and Eretmochelys imbricata with NMFS.

No effect was determined for species which were not aquatic or aquatic dependent, and species that did not occur or have critical habitat in the project area:

Plants: *Bulbophyllum guamense, Dendrobium guamense, Heritiera longipetiolata, Nervilia jacksoniae, Nesogenes rotensis, Osmoxylon mariannense, Psychotria malaspinae, Serianthes nelsonii, Solanum guamense, Tabernaemontana rotensis, Tinospora homosepala, Tuberolabium guamense, Cycas micronesica*

Insects: *Hypolimnas octocula marianensis, Vagrans egistina*

Mammals: *Pteropus mariannus mariannus, Emballonura semicaudata rotensis*

Reptile: *Emoia slevini*

Bird species: *Todiramphus cinnamominus, Corvus kubaryi, Megapodius laperouse, Rallus owstoni, Aerodramus vanikorensis bartschi, Zosterops rotensis*

Not Likely to Adversely Affect was determined for the remaining species: *Gallinula chloropus guami, Acrocephalus luscinia, Chelonia mydas, Eretmochelys imbricate, Samoana fragilis, Partula radiolata, Partula gibba, Partula langfordi* and *Ischnura luta.*

A. Mariana common moorhen (*Gallinula chloropus guami*)

The Mariana common moorhen inhabits freshwater lakes, marshes, swamps, and man-made as well as natural wetlands. Guam biologists have observed that moorhens often stay near vegetation bordering the water because it acts as an escape cover. The moorhen feeds on both plant and animal matter in or near the water including grass, adult insects, and insect larvae. The largest threat facing the Mariana common moorhen is disappearing suitable wetland habitat due to extensive human use and the spread of undesirable vegetation (USFWS, 1991).

B. Nightingale reed warbler (*Acrocephalus luscinia*)

On Saipan, the warbler is found in thicket-meadow mosaics, forest edge, reed marshes, and forest openings. On Pagan, the warbler inhabits freshwater wetland and wetland edge vegetation almost exclusively. Data on the warbler's foraging habits is limited but have been observed to eat

insects, larvae, lizards, snails and spiders. Threats to the warbler include habitat destruction, volcanism, and introduced predators and competitors (USFWS, 1998).

NLTAA Rationale for Birds:

Ammonia: The few studies available on the effects of ammonia to birds focus on the inhalation of atmospheric ammonia in poultry. The moorhen and warbler will not be exposed to significant atmospheric ammonia concentration levels. Poultry have been exposed to concentrations between 50-100 ppm, or even up to 200 ppm, because of reduced ventilation in commercial poultry houses (Carlile, 1984). These levels of exposure can cause irritation to the mucous membranes in the eyes and respiratory system, increase susceptibility to respiratory diseases, and affect food intake and growth rate (Kristensen and Wathes, 2000). The current suggested level of ammonia not to be exceeded is 25 ppm based on human health rather than animal welfare. Poultry can develop a variety of disorders when exposed to ammonia levels at 20 ppm for long periods of time.

The national ammonia criteria for water is 17 mg/L for acute and 1.9 mg/L chronic and is expected to be protective of birds because these levels are lower than the values shown to have impacts. Because the moorhen and warbler diets consist of both animal and plant matter, and particularly terrestrial organisms for warblers, there is limited exposure through ingestion. The UK Marine Special Areas of Conservation reported that birds are unlikely to be affected directly by ammonia toxicity.

Cadmium: Toxicity studies have not been performed on the Mariana common moorhen, Nightingale reed warbler, or any type of moorhen or warbler. As a result, the data gathered from a study of the lesser scaup and greater scaup populations that examined the effects of cadmium, mercury, selenium and corticosterone on pair status and male reproductive indices will be used to understand the impacts of cadmium and selenium. The geometric mean concentration of cadmium in the ducks was 9.20 µg/g (range 0.78 to 93.6) and for selenium was 4.33 µg/g (range 2.12 to 12.72) (Pollock and Machin, 2008).

While cadmium can alter testicular function and suppress the production and secretion of testosterone, cadmium concentrations at the high end of 93.6 µg/g were still below concentrations shown to cause altered testicular function or morphology in birds (Pollock and Machin, 2008). Another study showed that the kidneys of mallard ducks fed 2 and 20 mg/L cadmium in their diet were relatively unaffected after 90 days, but ducks that were fed 200 mg/L cadmium had slight to severe kidney lesions after 60 days (White et al, 1977). The amount of cadmium shown to have an effect in mallard kidneys is well above the national criteria set by EPA of 1.8 µg/L (acute) and 33 µg/L (chronic). There were no significant lesions found on mallard testes from the mallards that fed on a 2 mg/L cadmium diet, and only a few birds that were fed a 20 mg/L cadmium diet showed slight to moderate gonad alterations. The testes of mallards fed 200 mg/L diets had atrophied and the spermatogenic process had ceased after 90 days. Again, the concentrations at which cadmium affected mallard testes were well above the national criteria set by EPA. Background level of cadmium concentrations in waterfowl is 7 µg/g (Puls, 1994) and 100 µg/g is considered the threshold for major toxic effects (Furness, 1996). The national cadmium criteria are expected to be protective of the bird species.

Selenium: Toxicity studies have not been performed on the Mariana common moorhen, Nightingale reed warbler, or any type of moorhen or warbler. As a result, the data gathered from a study of the lesser scaup and greater scaup populations that examined the effects of cadmium, mercury, selenium and corticosterone on pair status and male reproductive indices will be used to understand the impacts of cadmium and selenium. The geometric mean concentration of selenium in the ducks was 4.33 μg/g (range 2.12 to 12.72) (Pollock and Machin, 2008).

The mean concentration of selenium (4.33 μg/g) did not show any significant correlation to impacts on scaup reproductive indices. No significant correlation existed between impacts and the selenium concentration levels of up to 12.72 μg/g found in ducks. The national selenium criteria are 8.5 mg/kg for whole body and 11.3 mg/kg for muscle concentration in fish tissue. The national selenium criteria are expected to be protective of bird species given the concentration limits placed on the fish and the concentrations at which no significant impacts were observed on the birds.

Acrolein: EPA concludes that there will be no effect of diazinon on birds in relation to this action because the CNMI BECQ pesticide office confirmed that there is no reported use or import of diazinon on the islands (Shai, 2018). Information has been included for background information: Acute oral toxicity and repellency of acrolein to Redwinged blackbirds and Starlings occurred at 10 mg/kg (Schafer et al, 1983). The median LD_{50} value for acrolein on birds is 5.25 mg/kg (Ware, 2001). The national criteria for acrolein is 3 μg/L for both acute and chronic conditions. The national criteria are expected to be protective of birds because these levels are below any of the concentrations shown to have a toxic effect on birds.

Carbaryl: Hybrid red-legged partridges given malathion or carbaryl alone, via oral administration of 200 mg/kg, showed no visible signs of toxicity (Johnston et al, 1994). However, carbaryl was lethal to 4 out of 12 birds when the birds were pretreated with malathion. Acute oral toxicity and repellency of carbaryl to Redwinged blackbirds occurred at 56.2 mg/kg (Schafer et al, 1983). The median LD_{50} value for carbaryl on birds is 1870.50 mg/kg (Ware, 2001). The EPA national criteria for carbaryl is 2.1 μg/L for both acute and chronic conditions. The national criteria are expected to be protective of birds because these levels are below any of the concentrations shown to have a toxic effect on birds.

Diazinon: EPA concludes that there will be no effect of diazinon on birds in relation to this action because the CNMI BECQ pesticide office confirmed that there is no reported use or import of diazinon on the islands (Shai, 2018). Information has been included for background information: Acute oral toxicity and repellency of diazinon occurred at 2.0 to 3.16 mg/kg for Redwinged blackbirds, 110-316 mg/kg for Starlings, and 4.22 mg/kg for Coturnix quails (Schafer et al, 1983). The median LD_{50} value for diazinon on birds is 14.06 mg/kg (Ware, 2001). The EPA national criteria for diazinon is 0.17 μg/L for both acute and chronic conditions. The national criteria are expected to be protective of birds because these levels are below any of the concentrations shown to have a toxic effect on birds.

Nonylphenol: Most of the current studies use embryo injection to deliver nonylphenol into egg yolk or egg white to investigate its effect on the development of sexual organs. One study put 4-

nonylphenol (4-NP) in drinking water to investigate more realistic exposure conditions and effects of nonylphenol on Japanese quail reproductive ability (Cheng et al, 2017). Quails were administered various doses in their drinking water (0.1 μg/L, 1.0 μg/L, 10 μg/L, and 100 μg/L) for 18 weeks. The 4-NP had no significant impact on food intake, egg production, eggshell thickness, or broken egg rates. Quail groups exposed to 10 μg/L experienced adverse effect on body weight. There was a significant difference in fertilization rate between the control group and the group exposed to 10 μg/L or more. There was a significant difference in hatchability of quails between the control group and the group exposed to 10 μg/L or more. There was moderately negative correlation between treatment dose and 14 day survival rate and reduced spermatogenesis in seminiferous tubules at the 1.0 μg/L treatment dose.

Seabirds in Morro Bay, California were found to have 15,700 +/- 3,600 ng/g nonylphenol in the liver (Diehl, 2012). A wild duck in Switzerland had nonylphenol concentrations of 1.20 mg/kg in muscle tissue, 0.10 mg/kg in the liver, 0.54 mg/kg in the stomach, <0.3 mg/kg in the heart, and 0.19 mg/kg in the brain (Ahel, 1993). Hu et al. 2005 found no trophic magnification for 4-NP in the aquatic food web of their study. Staniszewska et al. 2014 found that the process of nonylphenol removal takes precedence over the process of accumulation in tissues and organs of birds. High concentrations of nonylphenol were found in guano of herring gulls compared with concentrations found in fish. Despite the limited data available, the national criteria for nonylphenol is expected to be protective of birds because the effect levels from the existing literature exceed the values set in the national criteria.

Tributyltin (TBT): The effects of tributyltin on birds has not been well studied. Because no data is available on the impacts of TBT to moorhens and warblers, a study on the occurrence of butyltin compounds (monobutyltin, dibutyltin, tributyltin) in the tissue of water birds and ducks in the U.S. and Canada will be used to assess the impacts of TBT on birds. Butyltin concentrations in the liver of coastal birds in the U.S. ranged from 7-84 ng/g (Kannan et al, 1998).

Waterfowl that feed primarily on bivalve mollusks, such as mussels, accumulate greater concentrations of butyltins than predatory birds that feed on fish, other birds or small mammals. The common moorhen feeds on plant and animal matter such as grass, insects, snails, and algae. The warbler feeds predominantly on terrestrial organisms such as lizards, spiders, insects and snails. Because bioaccumulation of TBT through the food chain is the main exposure pathway of TBT to birds, these birds have more limited exposure to TBT due to the nature of their non-aquatic diet.

Butyltin concentrations were greater in the ventral feathers of mallard ducks than in their livers. The feathers of cormorants contained 20-30% of the total burden of butyltins in the body (Guruge et al, 1996). Seasonal molting of feathers can be a natural detoxification mechanism, which could result in less accumulation of butyltins in birds than in other aquatic animals. Based on the limited data available on the impacts of TBT to birds, the national TBT criteria is expected to be protective of the warbler and moorhen due to the nature of their diet, molting of their feathers, and the manner in which the criteria is meant to be protective of the most sensitive freshwater organisms.

C. Green turtle (*Chelonia mydas*)

Green turtles primarily inhabit open ocean convergence zones, beaches for nesting, and coastal areas for benthic feeding. Hatchlings swim from beaches to offshore areas where they live for several years. Once juveniles reach a certain age, they leave the pelagic habitat and travel to nearshore foraging grounds. The adult diet consists of seagrasses and algae. The largest threat to green turtles is the long-term harvest of eggs and adults on nesting beaches and juveniles and adults on feeding grounds. Other threats include incidental capture in fishing gear and a disease called fibropapillomatosis.

D. Hawksbill turtle (Eretmochelys imbricata)

Hatchlings inhabit the pelagic environment and feed at the surface. After a few years, juveniles forage in coastal areas and feed on animals associated with the coral reef environments. The diet consists of algae, sponges, and other invertebrates. In addition to coral reef environments, hawsbills are found around rocky outcrops, high-energy shoals, mangrove-fringed bays, and estuaries. The primary threat to hawksbills is habitat loss of coral reef communities. Coral reefs are vulnerable to destruction by human activities and global climate change. Hawksbills are harvested for their eggs and meat and for commercial exploitation. Increased recreational and commercial use of nesting beaches and incidental capture in fishing gear are additional threats.

NLTAA Rationale for Turtles: The effects analysis for turtles was completed for all saltwater water quality standards, which include cadmium, carbaryl, diazinon, nonylphenol, and tributyltin, because these standards apply to turtle habitat. The freshwater water quality standards, which include ammonia, selenium and acrolein, were not included in the effects analysis because they do not apply to turtle habitat.

Cadmium: Ingestion is thought to be the biggest route (Storelli et al.,2005, Ikonomopoulou et al., 2011). Green turtles are largely herbivorous. Leatherback feed almost exclusively on jellyfish and loggerhead turtles are carnivorous. Leatherback turtles accumulated higher levels of cadmium as jellyfish are high in cadmium (Caurant et al.,1999). Cadmium is eliminated quickly from turtle blood and stored in the liver where it binds with metallothionein and is eventually stored in the kidney (Guirlet and Das, 2012). Concentrations in Green sea turtle eggs near Hong Kong are low (Lam et al., 2006). Maternal transfer of cadmium to turtle eggs is low (Paez-Osúna et al.,2010, Ikonomopoulou et al., 2011, Sakai et al., 2000, Storelli et al.,2005). EPA finds that the cadmium standards are not likely to adversely affect any of the threatened or endangered turtles.

Carbaryl: Aguirre et al. 1994 analyzed the shell and tissue of Green Sea turtle hatchlings from the Hawaiian Islands for a number of chemical contaminants. Carbaryl was not detected at concentrations above the detection limit of 100 ug/l. de Solla and Martin (2011) evaluated the uptake of carbaryl on snapping turtle (*Chelydra serpentina*) exposed to soil with carbaryl at the agronomic rate. There was no uptake in the eggs after 8 days of exposure. At ten times the agronomic rate there was uptake after 1 day.

Hopkins et al., 2005 found that carbaryl concentrations of 5,000 ug/l affected the swimming performance of neonate black swamp snakes (*Seminatrix pygaea*) and diamondback water snakes (*Nerodia rhombifer*). Most individuals recovered from the effects of carbaryl on swimming performance within 96 hours. As discussed above carbaryl is not expected to bioconcentrate to a significant extent. EPAs' research has not found any thresholds in the Ecotox database or in the scientific literature that are less than either the acute criteria of 1.6 ug/l. EPA finds that the carbaryl standards are not likely to adversely affect any of the turtles.

Diazinon: There is no information on turtles in the EPA criteria document or the Ecotox database. One report from the open literature suggested that diazinon was not present at detectable levels (10 ug/l) in the shell and tissue of Green Sea turtle hatchlings from the Hawaiian Islands (Aguirre et al 1994). The Ecotox database contained at least 14 papers on diazinon and birds, and most were based on incidental consuming of crystals by birds or studies where diazinon was force fed (gavage). Lacking lethal dose information on turtles and reptiles, we used bird information as a surrogate species. The mallard duck has an oral dose LD_{50} of 1.44 mg/kg ((EFSA, 2006b, as reported in Crane et al., 2016) and can be used as a surrogate to assess the effect of trophic uptake by sea turtles. Assuming the bioconcentration factor of 213 for the sheepshead minnow (*C variegatus*) and assuming the acute diazinon criterion value of 0.82 ug/l we calculate a diazinon prey value of less than 0.175 mg/kg, an order of magnitude lower than the LD_{50} for the mallard. Using this as a first order approximation, we conclude that sea turtles are not likely to get much diazinon from its prey species. EPA finds that the diazinon standards are not likely to adversely affect any of the turtles.

Nonylphenol: While sea turtles are immersed in seawater, contaminants like 4-nonylphenol do not readily pass through their shell and skin into the body. Unlike gilled species, sea turtle exposures are not continuous because they do not drink continuously. Indirect exposures can occur through ingestion of food that has accumulated pollutants. In the Mediterranean Sea, Guerranti et al., 2014 reported that p-nonylphenol levels in the green sea turtle and the loggerhead sea turtle were only slightly higher than the limits of detection. They noted that this may be the first report of nonylphenols in sea turtles in the scientific literature.

The Ecotox database does not include data on reptiles exposed to 4-nonylphenol, so studies from the open literature were used in this assessment. The induction of vitellogenin in response to nonylphenol, impairment of spermatogenesis, and gonad abnormalities were reported in the Italian wall lizard exposed to drinking water dosed at 500,000 ug/l nonylphenol (Verderame et al 2010; Verderame and Limatola 2015).

Cheng et al. 2017 demonstrated that the fertilization rates in Japanese quail were significant at concentrations as low as 0.1 ug/l; Survival rates were reduced with long term (4 to 14 day) exposure to nonylphenol at 1 ug/l. NMFS cited Cheng et al., 2017 Biological Opinion on Environmental Protection Agency's Approval of Florida's Proposed Water Quality Criteria for 4-Nonyphenol and determined that the nonylphenol standard would not adversely affect sea turtles.

Tributyltin (TBT): There is no information in the Ecotox database on TBT in turtles. Our literature search found one paper on TBT in turtles. TBT was not detected in turtle eggs of *Natator depressus* in Australia (Ikonomopoulou et al, 2011). EPAs' research has not found any

thresholds in the Ecotox database or in the scientific literature that are less than either the acute (0.0074 ug/l) or chronic (0.42 ug/l) tributyltin standards. EPA finds that the tributyltin standards are not likely to adversely affect any of the turtles.

E. Tree Snails

Fragile tree snail (*Samoana fragilis*)

The fragile tree snail is a tree-dwelling species known to inhabit the forest ecosystems of Rota. The small population is continuing to decline due to habitat loss and destruction from agriculture, urban development, nonnative animals and plants, and typhoons. Climate change is expected to exacerbate existing threats. Shell trading and predation by rats and flatworms also contribute to population decline (USFWS, 2015).

Guam tree snail (*Partula radiolata*)

The Guam tree snail is endemic to the forest ecosystem of Guam and occur in several populations on CNMI. Habitat destruction and predation by the manokwari flatworm are significant threats to the species (USFWS, 2015).

Humped tree snail (*Partula gibba*)

Endemic to the forest ecosystem, humped tree snails are more mobile during higher ambient humidity and precipitation and less mobile during dry periods. They live on bushes or trees and feed primarily on dead or decaying plant material. The snail occurs in cool, shaded forest habitats with high humidity and reduced air movement that prevents excessive water loss. The population is in decline and threatened by habitat loss and predation by nonnative species (USFWS, 2015).

Langford's tree snail (*Partula langfordi*)

Endemic to the forest ecosystem of Aguiguan, the Langford's tree snail has not been observed in the wild since 1992 when one live individual was observed on the island. Surveys in 2006 and 2008 revealed only shells of dead Langford's tree snails. Given that so few surveys have been conducted on Aguiguan, it is possible that Langford's tree snails may be found. The largest threat to Langford's tree snails are habitat loss and degradation by nonnative animals, development, predation by nonnative animals, and loss of genetic representation (USFWS, 2015).

NLTAA Rationale for Snails: During correspondence regarding a different ESA consultation for tree snails in American Samoa, general information regarding Pacific Island tree snails was exchanged via email correspondence between EPA, USFWS, and a former National Park Service field ecologist staff. EPA requested technical assistance from USFWS regarding the effect of ammonia water quality standards in American Samoa on tree snails. The information obtained from the technical assistance regarding tree snails is useful information that is applicable to the tree snails in CNMI. Therefore, the information from the technical assistance is included below.

Tree snails are generally found in trees 5-15 feet off the ground and get their water exposure from rain rather than surface water. In American Samoa, streams in even remote locations often have periodic contamination of ammonia loads because of feral pig activity. These water quality issues did not directly affect American Samoa's two snail endangered species – Tutuila Tree Snail (*Eua zebrina*) and Sisi snail (*Ostodes strigatus*) (Brown and Browning, 2017).

Land snails do not require contact with rivers, streams, or puddles. Instead they rely on the microhabitat they are found in such as semi-moist areas with frequent rain showers, drip fog, or cloud forests. Tutuila tree snails can exist in riparian areas but do not interact with the aquatic or fresh water ecosystems. Because tree snails do not require interaction with marine or fresh water ecosystems for food or habitat, the exposure to contaminants in aquatic ecosystems is extremely limited and very unlikely. Most land snails have a diet that can include leaves, stems, soft bark, fruit, vegetables, fungi and algae.

Ammonia: Additional protection is afforded to terrestrial snails because EPA's 2013 nationally recommended criteria for ammonia considered data for several sensitive freshwater mussel species in the Family Unionidae and freshwater non-pulmonate (gill-bearing) snails. The criteria is fully protective of these aquatic snails. Since no toxicity data is available for the species specific to CNMI, the freshwater mussel and non-pulmonate snails, which share the same Mollusca phylum as CNMI's terrestrial snails, will be used as surrogates to understand the impacts of ammonia to the snails. The criteria are based on a sensitivity distribution comprised of ranked genus mean acute values (GMAVs), calculated from combined species mean acute values (SMAVs) within each genus for acceptable data. SMAVs are calculated using the geometric mean for all acceptable measures of effect based on the results of toxicity tests within a given species (e.g. all EC_{50}s from acceptable acute tests for *Daphnia magna*). The most sensitive mussel was the Green Floater with a SMAV of 23.41 mg TAN/L, while the most sensitive snail was the Pagoda hornsnail with a SMAV of 68.54 mg TAN/L. The criteria is set at 17mg TAN/L, which is lower than the SMAV of the most sensitive aquatic snail (USEPA, 2013).

Cadmium: The acute criteria for cadmium incorporated toxicity data for the snail species (*Aplexa hypnorum*), which has a SMAV of 204.1 µg/L. The freshwater mussels Neosho mucket (*Lampsilis rafinesqueana*), *Lampsilis straminea claibornensis*, and *Lampsilis siliquoidea* have SMAV values of 44.67 µg/L, 93.17 µg/L, and 35.73 µg/L, respectively, all of which are an order of magnitude higher than the acute cadmium criteria value of 1.8 µg/L (USEPA, 2016).

Selenium: Toxicity studies that were collected when creating the national selenium criteria show that invertebrates are relatively insensitive to selenium compared to fish. Therefore, the fish whole-body concentration limits in the criteria are expected to be generally protective of invertebrates as well as fish. Snail, Asian clam, and Zebra mussel information was included in the analysis of the selenium criterion (USEPA, 2016).

Acrolein: EPA concludes that there will be no effect of acrolein on snails in relation to this action because the CNMI BECQ pesticide office confirmed that there is no reported use or import of acrolein on the islands (Shai, 2018). Information has been included for background information: Laboratory studies indicate that snail immersion in solution of 10 mg/L acrolein for 3 hours or 2.5 to 5 mg/L acrolein for 24 hours is lethal. Exposure to concentrations below these

levels for the same duration had some effect but snails made full recovery once moved back to freshwater solution (Ferguson et al, 1961). The EPA national acrolein criteria is 3 µg/L for acute and chronic exposure. The national criteria are expected to be protective of snails because these levels are below any of the concentrations shown to have a toxic effect on snails.

Carbaryl: The 96-h LC_{50} value of carbaryl was 14.6 µg/mL for the snail *Pomacea patula* (Mora et al, 2000). The 24-h and 96-h LC_{50} values of carbaryl were 20.05 mg/L and 14.19 mg/L, respectively for the freshwater snail *Lymnaea acuminate* (Srivastava and Singh, 2001). Fecundity of *Lymnaea acuminate* was reduced at the 11.00 mg/L concentration of carbaryl (Singh and Agarwal, 1986). The EPA national criteria for carbaryl is 2.1 µg/L for both acute and chronic conditions. The national criteria are expected to be protective of snails because these levels are below any of the concentrations shown to have toxic effects on snails.

Diazinon: EPA concludes that there will be no effect of diazinon on snails in relation to this action because the CNMI BECQ pesticide office confirmed that there is no reported use or import of diazinon on the islands (Shai, 2018). Information has been included for background information. Laboratory tests indicate that the LC_{50} values for the 4-h and 96-hour exposure times were 93 mg/L and 11 mg/L, respectively for the freshwater snail *Gillia altilis*. These values are greater than the LC_{50} values for bluegill and rainbow trout. The bioconcentration of diazinon in freshwater fish is 5 to 10 fold greater than levels in snails (Robertson and Mazzella, 1989). The LC_{50} value of *Biomphalaria alexandrina* snails to diazinon is 3.10 mg/L (Bakry et al, 2016). The EPA national diazinon criteria is 0.17 µg/L for acute and chronic exposure. The national criteria are expected to be protective of snails because these levels are below any concentrations shown to have toxic effects on snails.

Nonylphenol: Since no toxicity data is available for the specific species to CNMI, toxicity data for the snail, *Pysella virgata,* will be used as a surrogate. Toxicity data for *Pysella virgata* was used in creating the national criteria for nonylphenol and showed acute toxicity to nonylphenol at concentration 774 µg/L. This is well above the national criterion at 28 µg/L (USEPA, 2005).

Tributyltin (TBT): Since no toxicity data is available for the species specific to CNMI, toxicity data for the snail, *Nucella lapillus*, of the same Gastropoda class as the tree snails will be used as a surrogate. Toxicity data for the *Nucella lapillus* was used in setting the tributyltin national criteria. Acute toxicity of TBT to the *Nucella lapillus* occurred at 72.7 µg/L and chronic toxicity occurred at 0.0143 µg/L. These levels are above the national criteria at 0.42 µg/L and 0.0074 µg/L. The freshwater clam had an acute value of 24,600 µg/L, which is well above the 0.46 µg/L acute value for freshwater (USEPA, 2003).

F. Rota blue damselfly (*Ischnura luta*)

The Rota blue damselfly is endemic to the island of Rota and known only to exist in the freshwater streams of the Talakhaya watershed. The primary source of the Rota blue damselfly stream habitat is spring water emerging at the limestone-basalt interface below the highly permeable limestone of the Sabana plateau (USFWS, 2015). This spring also serves as the main source of fresh water supply for the population of Rota. The Talakhaya watershed is remote and relatively inaccessible, so the damselfly is largely protected from human impact.

Adults feed on small flying insects such as midges and other flies. Adults have only been observed in association with a single perennial stream on Rota, so it is believed that the larval stage is aquatic, like most other damselfly species. The immature larval life stage of the damselfly is the only aquatic life stage where they breathe through flattened abdominal gills and feed on small aquatic organisms. Threats to the damselfly would include a reduction or removal of stream flow due to increased interception for municipal usage or from the effects of climate change. Introduction of nonnative fish into the stream could also wipe out the damselfly population. The population is vulnerable due to the low number of individuals and lack of genetic representation.

NLTAA Rationale for Insects: The Rota blue damselfly's habitat is afforded some protection from human impact by its remote and relatively inaccessible location. Because of the remote and inaccessible nature of the damselfly's habitat and stream's natural source of spring water, the damselfly is very unlikely to be exposed to the surface water pollutants. There are no wastewater dischargers on the island of Rota, which further limits the chances of pollutant exposure to the damselfly.

Ammonia: Additional protection is afforded to the Rota blue damselfly because toxicity test data (mortality, immobility, loss of equilibrium) for aquatic insects was incorporated into EPA's 2013 nationally recommended criteria for ammonia. The damselfly (*Enallagma* sp.), reviewed in toxicity tests, is of the same order Odonata as the Rota blue damselfly and had a SMAV of 164.0 mg TAN/L which is well above the nationally recommended criteria of 17 mg TAN/L.

Cadmium: EPA considered but did not ultimately include LC50 values for damselfly (*Enallagma sp.*) when creating the cadmium criteria because the pH was made to be artificially low as part of the study. LC50 values for the unused studies were 7,050 µg/L, 8,660 µg/L, and 10,660 µg/L at pH levels of 3.5, 4.0, and 4.5 respectively. These LC50 values are well above the acute criteria at 1.8 µg/L and chronic criteria of 0.72 µg/L.

Selenium: Toxicity studies that were collected when creating the national selenium criteria show that invertebrates are relatively insensitive to selenium compared to fish. Therefore, the fish whole-body concentration limits in the criteria are expected to be generally protective of invertebrates as well as fish. Dragonfly, damselfly, mayfly and midge information was included in the analysis of the selenium criterion.

Tributyltin (TBT): Since no toxicity data is available for the damselfly, toxicity data for mosquito larva will be used as a surrogate to understand the impacts of TBT. The mosquito larva toxicity data was considered in setting the national criteria. Mosquito larva showed acute toxicity at a concentration of 10.2 µg/L. This value is well above the national criteria set at 0.46 µg/L.

Nonylphenol: Since no toxicity data is available for the damselfly, toxicity data for the midge and dragonfly nymph will be used as surrogates to understand the impacts of nonylphenol. The midge (2nd instar), *Chironomus tentans*, showed acute toxicity to nonylphenol at concentration 160 µg/L. The dragonfly (nymph), *Ophiogomphus* sp., showed acute toxicity at concentration 596 µg/L. Both of these values were considered in setting the national acute criterion at 28 µg/L, which is meant to be protective of the most sensitive species *Hyalella azteca.* The midge

(*Chironomus tentans*) showed chronic toxicity at concentration 61.82 µg/L. This information was used in setting the national chronic criterion at 6.6 µg/L.

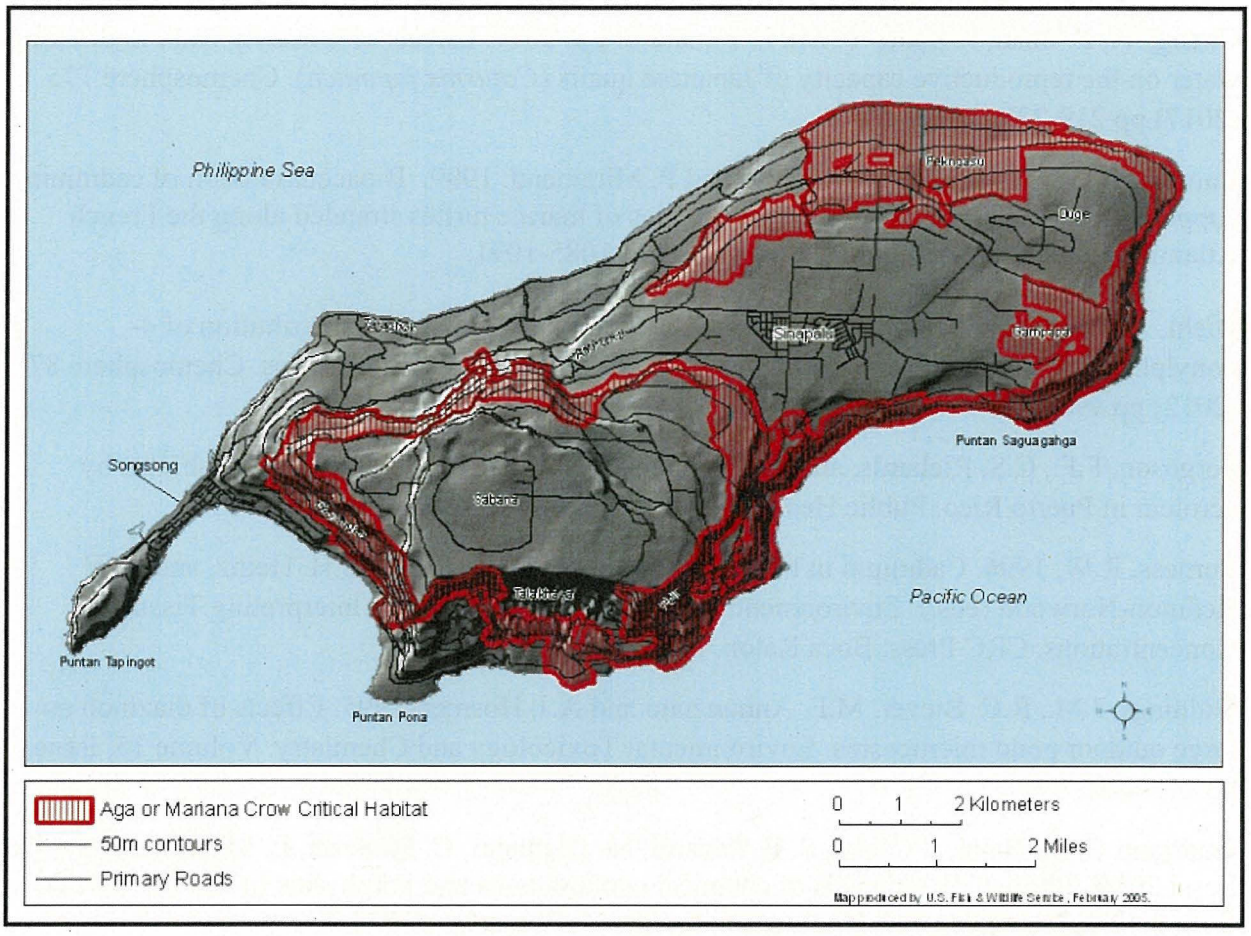
Carbaryl: In one laboratory experiment, damselfly larvae were exposed to carbaryl until the adult damselflies merged. The highest concentration which did not affect emergence was 10 ppb (Hardersen and Wratten, 1998). The LC_{50} values for *Cinygma* sp. (mayflies) are 848 µg/L, 220 µg/L, and 165 µg/L for 15, 30, and 60 minute exposure times respectively. *Calineuria californica* (stonefly) did not have 50% mortality rates after 15 or 30 minute exposure intervals. After 60 minutes of exposure, the stonefly had an LC_{50} value of 1,139 µg/L (Peterson and Jepson, 2009). The EPA national carbaryl criteria is 2.1 µg/L for acute and chronic exposures. The national criteria are expected to be protective of insects because these levels are below any of the concentrations shown to have lethal effect on insects.

Acrolein: EPA concludes that there will be no effect of acrolein on damselflies in relation to this action because the CNMI BECQ pesticide office confirmed that there is no reported use or import of acrolein on the islands (Shai, 2018). Information has been included for background information: The National Biological Survey reports that insects are comparatively resistant to acrolein compared to other animals. Adult fruitflies (*Drosophila melanogaster*) tolerated 3,700,00 µg Acrolein/L in culture medium (U.S. DOI, 1994). An EPA study on the toxicity of pesticides to water fleas determined that the maximum acceptable acrolein concentration for *Daphnia magna* is between 16.9 to 33.6 µg/L. The 48-h EC_{50} for *Daphnia magna* is 0.051 mg/L. The 48-h LC_{50} for midges is 0.151 mg/L (Holcombe et al, 1987). The EPA national acrolein criteria is 3 µg/L for acute and chronic exposure. The national criteria are expected to be protective of insects because these levels are below any of the concentrations shown to have a lethal effect on insects.

Diazinon: EPA concludes that there will be no effect of diazinon on damselflies in relation to this action because the CNMI BECQ pesticide office confirmed that there is no reported use or import of diazinon on the islands (Shai, 2018). Information has been included for background information: The LC_{50} value of diazinon to the damselfly *Lestes congener* is 50 µg/L. In a simulated aquatic field study, Odonates were not significantly reduced even at the highest exposure level (70-d average concentration 443 µg/L) (Giddings et al, 1995). The EPA national diazinon criteria is 0.17 µg/L for acute and chronic exposure. The national criteria are expected to be protective of insects because these levels are far below any of the concentrations shown to have any effect on insects.

VI. Critical Habitat

Figure 1. Designated Critical Habitat for Aga, Island of Rota, Commonwealth of the Northern Mariana Islands.



Critical habitat for the Mariana Crow was designated on Rota in 2004 (USFWS, 2005). For the aga, approximately 2,552 hectares (6,033 acres) were designated on Rota (Figure 1). EPA's action will have no effect on designated Critical Habitat for the Mariana Crow because the designated critical habitat for this species is not aquatic habitat, and the proposed action is unlikely to result in any alteration of these critical habitat areas that would result in the adverse modification of the critical habitat.

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