ENVIRONMENTAL CONTAMINANTS IN AQUATIC RESOURCES FROM THE COLUMBIA RIVER

Final Report

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On- and Off-Refuge Investigation

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ABSTRACT

The Columbia River is an important resource for fish and wildlife, and a number of National Wildlife Refuges (NWRs) were established along the river to protect migratory birds, species listed under the Endangered Species Act, and habitats necessary for the survival of these species. Fish and wildlife are exposed to environmental contaminants entering the Columbia River from point and nonpoint sources. Even when released in small concentrations, some contaminants can biomagnify and harm top level predators, and can impact species using NWR lands. We collected sediment, invertebrates, fish, and eggs of piscivorous and non-piscivorous birds in 1990 and 1991 within various river segments to determine contaminant concentrations, compare concentrations within river segments, identify concentrations in biota that exceed guidance or reference levels, evaluate the magnitude of exceedances using hazard quotients (HQs), and derive biomagnification factors (BMFs) for persistent, bioaccumulative compounds. BMFs were used to develop target fish concentrations (TFCs), or the concentrations in fish estimated to be protective of upper trophic level species such as bald eagles (*Haliaeetus leucocephalus*). We collected samples in the lower Columbia River below Bonneville Dam (four river segments including three NWRs), at Umatilla NWR and above McNary Dam, and in the lower Willamette River near Portland. We found most organochlorine (OC) pesticides were below detection in sediment and biota. However, similar to previous and concurrent studies, the pesticide transformation products DDE and DDD were the most commonly detected and most elevated compounds in biota from both rivers. DDE was detected in all fish samples during both years of the study, and in nearly all samples of clams and bird eggs. Polychlorinated biphenyls (PCBs), represented as total Aroclor PCBs or by summing individual congeners, were commonly found in fish and bird egg samples, but were rarely detected in sediment or invertebrates. PCBs and DDE in most fish samples exceeded mean concentrations reported in nationwide comparison studies, and exceeded estimated guidance values for the protection of avian predators. Concentrations of DDE and total PCBs exceeded estimated no-observable adverse effect levels (NOAELs) in some eggs of double-crested cormorants (*Phalacrocorax auritus*) and Caspian terns (*Sterna caspia*) in the lower river segment. Mercury was detected in all invertebrates and birds eggs, and in most fish sampled. In invertebrates, mercury was below estimated guidance values for the protection of avian invertebrate predators, but some fish samples exceeded these guidance values. Mercury in eggs of some piscivorous birds in the lower river segments exceeded values associated with impaired reproduction in sensitive individuals. Most dioxin and furan congeners were near or below detection in sediment and invertebrates, but were commonly detected in fish and bird eggs. Nearly all fish sampled contained 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF) in excess of guideline values derived in this study or other studies for the protection of bald eagles or other avian predators. TCDD and TCDF exceeded estimated NOAELs in eggs of some piscivorous birds, particularly double-crested cormorants. BMFs derived based on data from Columbia River fish and bald eagle eggs were fairly consistent among river Segments 1 to 3 in the lower river, and the combined BMFs for the three segments were 113 for total PCBs, 75 for DDE, 2.8 for mercury, 16 for TCDD, and 2 for TCDF. The TFC values derived from the BMFs were 0.06 μg/g for total PCBs, 0.04 μg/g for DDE, 0.20 μg/g for mercury, 0.9 pg/g for TCDD, and 7.5 pg/g for TCDF. Although bioaccumulative contaminants were near or below detection limits in sediment and invertebrates, our results document biomagnification of some OC compounds to concentrations likely resulting in adverse impacts to piscivorous birds. Results did not indicate that individual river segments differed in their contribution to the contaminant concentrations observed in biota. This trend indicates that the river receives contaminants from numerous widespread sources, and that contaminants were evenly distributed in biota. The role of bed sediment in contaminant transfer to biota in the river is unknown, and additional information is needed to characterize this role and to develop better management strategies for bed sediment disturbance. We recommend a basin-wide strategy to better control release of bioaccumulative contaminants to the river and minimize impacts to fish-eating birds, to monitor changes in OC contaminants over time, and to better address contaminant uptake from sediment sources.

INTRODUCTION

The Columbia River lies within the second largest river basin in the United States, draining 255,000 square miles (Fox et al. 1984, Simenstad et al. 1990). The river is exposed to a variety of contaminants through municipal and industrial permitted discharges (Rosetta and Borys 1996), atmospheric deposition, urban and industrial nonpoint pollution, accidental spills of oil and hazardous materials, runoff from agricultural and forested areas, and contaminants associated with accelerated population growth and development along the banks of the river and its tributaries. The lower Columbia River (from Bonneville Dam at river mile 146 to the mouth) alone receives discharges from eight major municipal wastewater treatment facilities, 24 industrial facilities (including aluminum smelters, pulp and paper plants, wood products facilities, and chemical manufacturers), and also discharges from a variety of upriver sources (Tetra Tech 1992a). Eleven bleached-kraft or sulfite pulp and paper mills discharge into the Columbia River system, including one in Canada, one in Idaho, four in Washington, and three in Oregon. Five of these facilities discharge into the lower Columbia River (Tetra Tech 1994), as do several other mills using a mechanical thermal process. Most of the pulp and paper facilities have used the elemental chlorine process in the past, but many have recently converted to the chlorine dioxide process, thus minimizing discharges of chlorinated dioxins and furans. Contaminants from all these sources enter the river and have the potential to threaten aquatic resources.

The lower Columbia River and estuary provides essential breeding and wintering habitat for migratory birds and species listed as threatened or endangered under the Endangered Species Act. Numerous species of waterfowl, shorebirds, and seabirds winter along the lower river or use the river's resources during migration. Threatened or endangered birds and mammals in the area include the bald eagle (*Haliaeetus leucocephalus*), brown pelican (*Pelecamus occidentalis*), and Columbia white-tailed deer *(Odocoileus virginianus*). East Sand and Rice Islands, located near the mouth of the river, support the largest currently active colony of double-crested cormorants (*Phalacrocorax auritus*) on the Pacific coast (Carter et al. 1995) and the largest breeding colony of Caspian terns (*Sterna caspia*) in North America, although recently most terns have been relocated to East Sand Island (Collis et al. 1999, 2001). East Sand Island also supports a large brown pelican rookery. Bald eagles nest throughout the lower river to just above Bonneville Dam, and Columbia white-tailed deer inhabit some islands in the river and the Julia Butler Hanson National Wildlife Refuge (NWR). The Columbia River is a valuable anadromous waterway, providing nursery and rearing habitat for the numerous salmonids in the basin. Many islands within the Lewis and Clark NWR in the lower river provide nursery areas for juvenile salmonids, and serve as a freshwater to saltwater transition zone for anadromous fish. Federally listed species of fish in the lower Columbia River include bull trout (*Salvelinus confluentus*), chinook salmon *(Oncorhynchus tshawytscha*), steelhead trout (*O. mykiss*), and chum salmon (*O. keta*). Many of these fish and wildlife species depend on the river for foraging, breeding, and rearing during some or all stages of their life cycle, and therefore are exposed to contaminants entering the river from anthropogenic sources. Moreover, fish and wildlife using habitat on NWRs could be threatened if contaminants are found within refuge boundaries, or in the backwater rearing areas around refuge islands. Refuges that could be impacted by contaminants include Umatilla NWR near McNary Dam in the middle Columbia River reach, and Ridgefield, Lewis and Clark, and Julia Butler Hansen NWRs located below Bonneville Dam.

Several persistent and bioaccumulative contaminants, primarily organochlorine (OC) pesticides, polychlorinated biphenyls (PCBs), dioxins, furans, and some metals, such as mercury, have been found in Columbia River fish and wildlife at hazardous concentrations. Some OC compounds such as DDE, a transformation product of the pesticide DDT, and PCBs have been found in piscivorous birds, mammals, and fish from the Columbia River (Henny et al. 1981, 1984, Schmitt et al. 1985, Anthony et al. 1993, Blus et al. 1998, Elliott et al. 1999a). PCB

concentrations in mammals such as mink (*Mustela vison*) and river otter (*Lutra canadensis*) exceeded levels shown to be associated with reproductive impairment in mink (Henny et al. 1981, Elliott et al. 1999a). Poor reproductive success has been documented in bald eagles nesting along the lower Columbia River, and elevated concentrations of dioxin, furans, DDE, and PCBs have been found in bald eagle eggs (Anthony et al. 1993, U.S. Fish and Wildlife Service 1999a). Fish collected from the lower Columbia River had dioxin concentrations exceeding human health guidelines (U.S. Environmental Protection Agency 1986, 1991a,b; U.S. Fish and Wildlife Service 1994). In 1991, the U.S. Environmental Protection Agency (EPA) restricted the discharge of allowable dioxin to the Columbia River through the establishment of a Total Maximum Daily Load (TMDL) to protect aquatic resources. EPA formally consulted with the U.S. Fish and Wildlife Service under Section 7 of the Endangered Species Act on whether the TMDL would protect bald eagles. The resulting Biological Opinion documented the need for additional data regarding dioxin bioaccumulation in the lower Columbia River to better identify the threats to bald eagles nesting along the river (U.S. Fish and Wildlife Service 1994). The present study was initiated partly in response to these data needs.

This study was undertaken to determine if persistent, bioacumulative compounds are present at concentrations hazardous to fish and wildlife inhabiting NWRs and other locations in the Columbia River. The objectives of this investigation were to 1) determine concentrations of environmental contaminants in sediment, aquatic invertebrates, fish, and bird eggs within various segments of the Columbia River (segments were designated based on different physical and hydrologic characteristics); 2) compare contaminant concentrations within river segments; 3) compare concentrations in biota to guidance or reference levels to identify primary contaminants of concern and resources at risk; 4) compare concentrations in biota to previous and concurrent studies in the river and elsewhere; and 5) derive biomagnification factors and target fish concentrations for persistent, bioaccumulative compounds. Information collected in this investigation will support continuing efforts to evaluate contaminant conditions on NWRs along the Columbia River. Results will be used by state and federal agencies to better evaluate the water quality in the basin and to develop strategies to address contaminant conditions in the river.

METHODS

Study Areas

Sediment, invertebrate, fish, or bird egg samples were collected from the Columbia River in Oregon and Washington in 1990 and 1991 (Figures 1-6). Sampling occurred in the lower Columbia River between the mouth and Camas Slough (Figures 1-5); in the middle river region near McNary Dam at Umatilla NWR and Crescent Island (Figure 6); and in the Willamette River near Portland (1990 only) (Figures 1 and 5). Study areas within these regions (listed from the mouth to upriver sites) included Baker Bay, Cathlamet Bay, around various islands within the Lewis and Clark NWR, in Elochoman Slough and beach area at Julia Butler Hansen NWR, along the shorelines near industrial areas at Longview and St. Helens, in Lake River at Ridgefield NWR, Camas Slough, the Willamette River downstream of Portland, Umatilla NWR, and on Crescent Island near Wallula (Figures 1-6). The lower Columbia River study areas were within river segments designated under the Bi-State Lower Columbia River Water Quality Program (Bi-State Study) (Tetra Tech 1992b). Tetra Tech (1992b) segmented the lower river between the mouth and Bonneville Dam (RM 146) based on distinct hydrologic and physical characteristics that influence sediment and contaminant transport and fate. The lower river was first divided into two distinct zones; a sediment sink or deposition zone from RM 0 to 37 (estuary and river transition reach), and a transfer zone from RM 37 to 146 where sediment inflow can equal the sediment outflow and confluences of major tributaries are the primary influences on the hydrodynamics of the river. Within these two zones, the lower river was further divided into

four segments and 14 subsegments based on specific and hydrologic characteristics (Tetra Tech 1992b). The four major segments used in the Bi-State Study that corresponded to our study sites include:

Segment 1 (RM 0-37; Figure 2) Estuary and Transition Region, mouth of the Columbia River to Tenasillahe Island, including the study sites at Baker Bay (between RM 2-6) and Cathlamet Bay (RM 19-21) and Lewis and Clark NWR (between RM 21-37);

Segment 2 (RM 37-72; Figure 3) Intermediate Region, Tenasillahe Island to Cowlitz River, including study sites at Julia Butler Hansen NWR (between RM 37-47) and Longview (between RM 64-72);

Segment 3 (RM 72-102; Figure 4), River Flow Region, Cowlitz River to the Willamette River, including study sites at St. Helens (between RM 79-87) and Ridgefield NWR (between RM 87-102);

Segment 4 (RM 102-146; Figure 5) River Flow Region, Willamette River to Bonneville Dam, including the study site at Camas Slough (between RM 111-121).

In addition to these study segments in the lower river associated with the Bi-State Study, samples also were collected in 1991 from the middle river region below McNary Dam within Lake Umatilla at Umatilla NWR (RM 274-286) and at Crescent Island (RM 319) near Wallula (Umatilla Segment; Figure 6), and in 1990 from the Willamette River downstream of Portland (Portland Segment; RM 3-6, Figure 5).

Sample Collection and Processing

A total of 274 samples was collected in 1990 and 1991 from the study area and analyzed for chemical constituents, including 73 samples of fish and avian eggs in 1990 and 201 samples of sediment, invertebrates, fish, and avian eggs in 1991 (Tables 1 and 2). Information for each sample including sample number and type, collection location, sample composite mass, type of chemical analysis, and percent moisture and lipid are presented in Appendix A. All samples except avian eggs were processed at the collection site and transferred in a cooler on wet or dry ice to the Oregon Fish and Wildlife Office (OFWO) in Portland. Avian eggs were transferred whole on wet ice and processed at the OFWO. Sample processing for individual matrices is described in detail below. All samples were stored at -20° C prior to shipment to an analytical laboratory.

Fish samples collected in 1990 (Table 1) included 26 composite samples of common carp (*Cyprinus carpio*), peamouth chub (*Mylocheilus caurinas*), sucker (*Catostomus* spp.), northern pikeminnow (*Ptychocheilus oregonensis*), smallmouth bass (*Micropterus dolomieu*), or largemouth bass (*M. salmoides*), which were collected in September by electroschocking, seining, or hook and line fishing. Fish species were collected to represent different feeding groups, consisting of primarily herbivorous fish (carp and sucker), three predacious species (bass and pikeminnow), and one omnivorous species (peamouth chub). Fish were collected within Cathlamet Bay, at Longview upstream and downstream from the industrial area (RM 61-68), along the shoreline at St. Helens (RM 85-88), within Camas Slough downstream from the industrial area (RM 119-121), and in the Willamette River between the Multnomah Slough and St. Johns Bridge (RM 3-6; Table 1, Figures 1-5). Mass and total length of fish were recorded, and individual fish were wrapped in aluminum foil and placed in double plastic bags along with other fish of the same species from the site. One composite sample was prepared for each species (except suckers) captured at a site, and each sample consisted of one to three fish of similar length and mass (Table 3). For suckers, multiple individuals of up to three species within the same genus were occasionally combined in the same composite sample. Sucker species

included largescale sucker (*Catostomus macrocheilus*), bridgelip sucker *C. columbianus*), or longnose sucker *C. catostomus*). It was assumed that the three sucker species in the genus *Catostomas* would have similar feeding behavior and have similar exposure opportunities and metabolic processing, and therefore body-burden concentrations would be equivalent among the three species. Not all fish species were found or collected at each site, and not all composite samples were analyzed for the same group of chemical constituents (Table 3).

Eggs were collected from May to June in 1990 from birds nesting on two islands within the Columbia River. Twenty-eight eggs were collected from western or glaucous-winged gulls (samples could include eggs from western gulls [*Larus occidentalis*], glaucous-winged gulls [*L. glaucescens*], or hybrids of the two species), Caspian terns, and double-crested cormorants nesting in the lower river on Rice Island within the Lewis and Clark NWR (Figure 2), and 19 eggs were collected from ring-billed gulls (*L. delawarensis*), Forster's terns (*Sterna forsteri*), and Caspian terns from Crescent Island in the Umatilla Segment (Table 1, Figure 6). Eggs were collected by hand, and only one egg per nest was collected during site visits. At the OFWO, each egg was cut along the equator, emptied into a chemically-cleaned glass jar, staged for embryonic development, examined for gross deformities, and weighed prior to freezing. Length, width, whole egg mass, and sample mass (with eggshell removed) were recorded for individual eggs.

In 1991, samples of surface sediment, fish, invertebrates, or bird eggs were collected and analyzed for chemical constituents from the lower Columbia River sites within Baker and Cathlamet Bays, around various islands within the Lewis and Clark NWR (RM 20-35), in Elochoman Slough and beach area at the Julia Butler Hansen NWR, along the shoreline at Longview (RM 61-68), in Lake River at Ridgefield NWR, and in Camas Slough (RM 119-121; Figures 2-5). Samples also were collected around various islands within the Umatilla NWR (RM 274-286; Figure 6).

Surface sediment was collected in shallow, depositional areas from all eight study areas between August and November in 1991. River discharge data that could impact water quality and sediment transport during the sampling period were described during a concurrent reconnaissance investigation (Tetra Tech 1993a). Three separate composite samples were obtained at three different locations within each study area, resulting in 24 total composite samples (Table 2). At each sample location, three grab samples were collected within approximately 30 cm of the surface to form a composite. The three grab samples were collected with a stainless steel spoon or trowel, mixed in a stainless steel pan, and transferred into a chemically-cleaned glass jar. Samples were not sieved and visual inspection indicated they were primarily fine-grained materials, although grain-size analysis was not conducted. Sediment sampling equipment was decontaminated between sites to prevent cross contamination of samples by washing with detergent, followed by rinses with deionized water and acetone.

Invertebrate samples were collected primarily from July to November in 1991, although Corbicula clam (*Corbicula manilensis*) samples from the Umatilla site were obtained in January of 1992. Forty-six samples of *Corophium* (*Corophium* spp.), Corbicula clam, Macoma clam (*Macoma* spp.), and crayfish (*Pacifastacus sp.*) were collected and analyzed from the study areas (Table 2). Invertebrates were represented at all eight study areas, but not all species were sampled or found at every site (Table 2). *Corophium* were collected and analyzed from two lower river sites, Corbicula clams were obtained at all sites except Baker Bay, Macoma clams were only obtained at Baker Bay, and crayfish were collected at all sites except Baker Bay and Umatilla NWR (Table 2). One to three composite samples of each species captured at a site were prepared and analyzed; samples were a composite of hundreds of *Corophium*, 12 to 16 Macoma clams, 12 to 23 Corbicula clams, or one to five crayfish (Table 4). *Corophium* were collected along the beach by placing surface sediment from the water-sediment interface into a metal sieve and transferring retained individuals into chemically-cleaned glass jars. Corbicula

and Macoma clams were collected by hand or removed from the sediment with a hand tool, discarding the clam shell, and placing the tissue directly into glass jars. Crayfish were collected from backwater areas using minnow traps containing cat food or commercial fish bait. Mass and length measurements were collected on individual crayfish, and a composite sample of whole crayfish (including the exoskeleton) of similar size was prepared at each site.

Fish were collected between July and December in 1991 at the Columbia River study areas. Fifty-two composite samples of common carp, sucker, peamouth chub, and mountain whitefish (*Prosopium williamsoni*) were collected within Cathlamet Bay, near various islands of the Lewis and Clark NWR, in Elochoman Slough at the Julia Butler Hansen NWR, at Longview near the industrial area, in Lake River at Ridgefield NWR, within backwater areas of Camas Slough downstream of a pulp mill and industrial area, and at the Umatilla NWR in Lake Umatilla (Table 2, Figures 2-6). Mountain whitefish were collected only from the Umatilla NWR, and no fish samples were collected from the Baker Bay site. Fish were collected by electroshocking, seining nets, or by hook and line fishing. Hook and line fishing was used predominately in the lower river study areas (e.g., Cathlamet Bay) where electroshocking was ineffective due to salinity. One to four composite samples were prepared for each species captured at a site, and each sample consisted of one to six fish of similar length and mass (Tables 2 and 4). Not all fish species were found or collected at each site, and not all composite samples were analyzed for the same group of chemical constituents (Table 4). Fish sample processing, transfer, storage, and shipment were similar to methods used for fish samples in 1990.

Seventy-nine eggs were collected from two non-piscivorous and five piscivorous bird species between mid-April and early June in 1991. Eggs of the non-piscivorous species, mallard (*Anas platyrhynchos*) and Canada goose (*Branta canadensis*), were collected only from study areas in the lower river region. Mallard eggs were collected from East Sand Island in Baker Bay and from Rice and Miller Sands Islands within the Lewis and Clark NWR (Table 2, Figure 2). Canada goose eggs were obtained within the Baker Bay study area at East Sand Island, within the Lewis and Clark NWR at Pillar Rock, Fitzpatrick Island, and Miller Sands Island (Table 2, Figure 2). Canada goose eggs were also collected from Hump, Crimms, and Walker Islands, which were considered part of the Longview site (Table 2, Figure 3). Eggs from piscivorous birds were collected from the following lower and middle river study sites: ring-billed gull and Forster's tern eggs from Crescent Island (Umatilla Segment); Western/glaucous-winged gull and double-crested cormorant eggs from East Sand Island in Baker Bay and Rice Island within Lewis and Clark NWR; and Caspian tern eggs from Rice Island and Crescent Island (Table 2, Figures 2 and 6). Egg collection and processing methods were similar to methods used in 1990.

Analytical Methods

Organochlorine pesticides and total PCBs

A total of 24 sediment and 164 tissue samples from 37 invertebrates, 66 fish, and 61 eggs were analyzed for OC pesticides and total PCBs at four analytical laboratories: Patuxent Analytical Control Facility (PACF) in Patuxent, Maryland; Geochemical and Environmental Research Group (GERG) in College Station, Texas; North Coast Laboratories (NCL) in Arcata, California (subcontracted by Alta Analytical Laboratory [Alta] in Eldorado Hills, California); and Mississippi State Chemical Laboratory (MSCL) in Mississippi State, Mississippi (Table 5). The OC pesticide analysis included para, para- (p,p'-) and ortho, para- (o,p'-) isomers of DDT, DDD, and DDE, but only the p,p'-isomers are reported here unless otherwise noted. Total PCBs were determined as Aroclor PCBs at all laboratories except GERG, which conducted a congener-specific PCB analysis and summed about 77 congeners, including co-eluting congeners, to represent total PCBs. A summary of analytical methods used and the sample types analyzed by each laboratory is listed in Table 5.

All sediment samples were analyzed at PACF. Sample preparation and analyte extraction from sediment followed the methods of Nash and Harris (1972) and Nash et al. (1973). Analytes were extracted using Soxhlet apparatus and the extract shaken out with water in a separatory funnel as a cleanup step. Co-eluting OC pesticides and PCBs were separated by silica gel fractionation, and analytes were quantified by capillary gas chromatography (CGC) with an electron capture detector (ECD). The detection limit for these procedures ranged from 0.01 to 0.05 µg/g for OC pesticides and 0.05 µg/g for PCBs.

Analytical methods for the preparation, extraction, and cleanup of tissue samples were similar among the four laboratories and followed the methods of Cromartie el al. (1975) and MacLoed et al. (1985) with minor revisions of Brooks et al. (1989) and Wade et al. (1988). Briefly, a tissue sample was extracted under a solvent using Soxhlet apparatus, and the extract purified by silica/alumina and/or Florisil column chromatography to isolate the pesticide/PCB fraction. At PACF, this fraction was further purified by high performance liquid chromatography (HPLC) to remove interfering lipids. Additional cleanup steps included transferring the extract to silica gel chromatography to separate PCBs from other OCs, and to improve separation of endrin from dieldrin. Quantitation of analytes was performed by gas-liquid chromatography (GLC)/ECD or CGC/ECD at specific laboratories (Table 5). OC pesticides or total Aroclor PCBs were confirmed by gas chromatography/mass spectrometry (GC/MS) at some laboratories in at least 10 percent of the samples (Table 5).

Total mercury

A total of 116 tissue samples from nine invertebrates, 58 fish, and 49 eggs were analyzed for mercury concentrations (sediment was not analyzed for mercury). Tissue samples were analyzed at PACF, GERG, Environmental Trace Substances Laboratory (ETSL) in Rolla, Missouri, Hazleton Environmental Services, Inc., (HES) in Madison, Wisconsin, and NCL (subcontracted by Alta) (Table 5). Sample analysis primarily followed Monk (1961) or EPA method 245.5 with minor revisions (U.S. Environmental Protection Agency 1980). Samples were homogenized and digested with concentrated sulfuric and nitric acids in a water bath, or by nitric-reflux digestion. Mercury was reduced to the elemental state and quantified by a modification of the method of Hatch and Ott (1968), using a cold-vapor atomic absorption spectroscopy. Six Caspian tern eggs collected in 1990 from the Lewis and Clark NWR and Umatilla sites were quantified by inductively coupled plasma-atomic emission spectroscopy as part of a metals scan (Table 5). The differences between the methods used for the tern eggs and other samples are primarily reflected in detection limit differences. However, detection limits for both methods in this study were similar (about 0.05 µg/g). A summary of analytical methods for mercury and the sample types analyzed by each laboratory are listed in Table 5.

Dioxins and furans

A total of 146 samples including eight sediment, 29 invertebrate, 57 fish, and 44 eggs were analyzed for 17 congeners of polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), or for only the 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF) congeners. The dioxin and furan congeners and abbreviations used in this report are listed in Table 6. Samples were analyzed at the following laboratories: Triangle Laboratories (TLI), Research Triangle Park, North Carolina; Pacific Analytical (PA), Carlsbad, California; Midwest Research Institute (MRI), Kansas City, Missouri; U.S. Geological Survey, Biological Research Division, Columbia Environmental Research Center (CERC), Columbia, Missouri; and Radian Analytical Services (Radian), Austin, Texas. Analytical methods used and sample types analyzed by each laboratory for dioxins and furans are summarized in Table 5.

Methods for extraction, cleanup, fractionation, and determination of dioxins and furans followed contract specifications and methodologies outlined by EPA methods 8280A, 1613, and 1613A. Methods were similar among all laboratories, although quantification methods varied slightly

between years. Samples were extracted according to matrix-specific extraction and cleanup procedures to eliminate interferences. Sample extracts were purified using 1) column chromatography using a sulfuric acid silica gel/potassium silicate and then a sulfuric acid silica gel/silica gel; 2) alumina, silica gel, and AX-21 activated carbon on silica; or 3) a four-column cleanup procedure consisting of potassium silicate/coarse acidified silica gel, acidified silica gel, neutral alumina, and carbon. At CERC, analytes were separated from the purified extract by HPLC Porous Graphite Carbon and isolated into fractions. Most laboratories eluted the PCDD/PCDF fraction through basic alumina for removal of potential co-contaminants (polychlorinated diphenyl ethers [PCDPEs] and residual polychlorinated napthalenes and PCBs) (Table 5).

For the fish and eggs collected in 1990, analytes were determined at Radian by EPA method 8280A, and at CERC (Lodge 1990, Gale 1991, Echols et al. 1997) using high resolution gas chromatography-low resolution mass spectrometry (HRGC/LRMS) and monitoring five sequential mass windows of 12 selected ions during the chromatographic separation. For 1991 samples, all laboratories used EPA method 1613 and 1613A involving HRGC/high-resolution mass spectrometry (HRMS), capable of performing selected ion monitoring (SIM) at resolving powers of at least 10,000 at 10 percent valley definition (Tondeur 1987, U.S. Environmental Protection Agency 1990). Both the HRMS and LRMS can produce comparable results, but the HRMS method has greater selectivity for PCDDs and PCDFs versus interferences than does the LRMS. The lower limit of sensitivity for TCDD and TCDF was approximately 1 pg/g. Detection limits for other congeners ranged from 1 to 9 pg/g.

Quality Assurance/Quality Control

Due to financial and contractual limitations, multiple laboratories were used to determine contaminant concentrations in samples over the 2-year project. Even though similar analytical methods for the same group of analytes were used at each laboratory, differences in equipment, personnel, and procedural modifications specific to the laboratory resulted in different detection limits or analyte recoveries. These differences are a source of variation that can influence data interpretation, although it is expected that variation attributed to differences in laboratory methods would be greatest for values at or near detection. To help identify the magnitude of this variation source, we evaluated quality control (QC) information such as procedural blanks, duplicates, and matrix spike samples for each individual laboratory.

For analysis of OC pesticides, total PCBs, and mercury, the accuracy of analytical results was measured by spike recoveries, and duplicate samples were analyzed to evaluate precision of analytical results. Average spiked matrix recoveries considered acceptable were 80 to 120 percent. Duplicate results were considered valid if the average, relative percent difference between duplicates was 1) 200 percent for average analyte concentrations at zero to two times the detection limit; 2) 17.3 percent for concentrations at two to 10 times the detection limit; or 3) 8.6 percent for concentrations greater than 10 times the detection limit.

Recovery and duplicate results for OC pesticide, total PCB, and mercury were within specified ranges, with few exceptions. Recoveries of HCB, mirex, alpha chlordane, and beta-, delta-, and gamma-BHC in tissue results from some laboratories were outside specified limits (primarily below the lower limit). However, concentrations of these chemicals in samples were generally near or below detection at all laboratories, or were identified in Table 5 and listed in tabulated results as estimates. Contaminant concentrations in blank samples were below detection.

For the dioxin and furan methods, additional QC sample analyses were performed because of the low detection limits required in the analysis and the potential interferences caused by co-eluting PCDPEs and other co-contaminants. Procedural internal standards were added at the beginning of sample preparation to determine whether the method was in control based on acceptable recoveries of the standards throughout the cleanup procedure. Instrument internal standards

were added to samples after sample preparation, and just prior to analysis, to indicate that the sample extract was delivered on-column to the detector (i.e., to evaluate the success of the injection and that the instrument was working properly under the analytical conditions) and provide the reference by which to estimate the quantities of the procedural internal standards. The ratio of the procedural internal standard to the instrument internal standard quantifies the recovery of the procedural internal standards, measures the efficiency of the extraction and cleanup procedures, and can be used to correct for any losses throughout the analysis. Also, ^{37}Cl-labeled procedural internal standards were added at an intermediate point in the cleanup at those laboratories using Method 1613 (Table 5). Each set of samples was analyzed along with a procedural blank and duplicate, and samples analyzed by CERC included a matrix blank, fortified matrix blank, and positive control sample material containing bioincorporated native compounds. At CERC, positive identification and quantitation of a particular congener or group of co-eluting isomers in the PCDD and PCDF analysis was determined under the following criteria: 1) the peak areas for the signals from the two principal ions must be greater than three times the background noise (S/N>3); 2) for congeners with isotopically labeled analogs, the peaks (monitored for quantitation for the native and corresponding labeled ions) must occur at retention times within ±3 seconds, but when labels are not available peaks must occur at relative retention times within 0.5 percent; and 3) for two principal ions responses, the ion ratio must be within the acceptable range (±15 percent). These ion ratios were determined experimentally for the system during calibrations, compared with the theoretical values, and were tracked for quality assurance. The range of ion ratios exceeded the QC range (±15 percent) for some samples due to difficult matrix effects, but these were within 20 percent and manual inspection of the ion cluster was used to verify any suspected analyte. At all laboratories, average spiked matrix recoveries considered acceptable were 25 to 125 percent for dioxins and furans.

For samples analyzed specifically for 2,3,7,8-TCDD and -TCDF, identification was based on their elution at their exact retention time and the simultaneous detection of the two most abundant ions in the molecular ion region. Individual congeners were quantified using a multipoint calibration curve for each homologue, during which each calibration solution was analyzed at least once. Identification of dioxins and furans was based on a comparison of the ratios of the integrated ion abundance of the molecular ion species to their theoretical abundance ratios, and a second column was used to confirm which dioxin/furan congener was present. Chromatography columns used in quantification included a DB-5, DB-Dioxin, or RTX-200 column, and detections of the 2,3,7,8-TCDF isomer were confirmed using a DB-225 confirmation column when interfering PCDPEs or other tetrachlorinated dibenzofurans were observed in chromatographic peaks (Table 5). The PCDPEs interfere with the determination of PCDFs, and the more highly chlorinated congeners of the PCDPEs elute in the same GC/MS window as the less chlorinated PCDFs. During MS ionization, hexachlorinated PCDPEs can lose two chlorines, resulting in a tetrachlorinated ion having the exact mass of the molecular ion of TCDF. This process affects both high and low resolution MS methods.

Several samples analyzed for TCDD and TCDF failed QC criteria. At one laboratory, 67 samples collected in 1991 and analyzed for TCDD and TCDF had poor procedural internal standard recoveries, elevated detection limits, or interference with PCDPEs (see Table 5 for QC notes and Appendix B for a list of all samples affected). These samples did not pass QC limits and samples with sufficient material remaining were reanalyzed. Reanalysis consisted of additional cleanup of sample extracts by processing through Method 1613 alumina and carbon column cleanup and reanalysis, or sample re-extraction and reanalysis (Table 5). There were insufficient funds or insufficient sample material remaining to analyze 11 samples that initially failed QC limits. These 11 samples were excluded from the data set (Appendix B).
Three of the 11 samples excluded were Corophium samples listed in Appendix B which had no analysis conducted for any contaminant and were excluded from the 274 samples described in Tables 2 and 4.

The reanalysis procedures improved recovery and detection limits and data were qualified as useable for 56 of the 67 samples (Appendix B). TCDF results for some of the 56 samples were reported as estimated maximum possible concentrations when interfering PCDPEs were present and second-column confirmation was not performed or not effective in resolving interferences. The reanalysis incorporated the RTX-200, DB-5, and DB-225 columns for TCDD and TCDF analysis. Separation of TCDF in sample extracts on the DB-225 confirmation column proved worse than on the RTX-200 column with respect to PCDPE interference. In these instances, results from the DB-5 column for TCDF were lowest and presented in this report. All results from the RTX-200 column only were flagged as estimated maximum possible concentrations in the tabulated results due to possible diphenyl ether interference. Appendix B reports the original, intermediate, and final results for all samples reanalyzed.

Data Analysis

All concentration data were reported as dry weight for sediment and wet or fresh weight for tissues. Concentrations were reported in parts per million (ppm or μg/g) for all analytes except dioxins and furans, which were reported as parts per trillion (ppt or pg/g). Egg volume was estimated based on length and breadth measurements of the analyzed egg, and analyte concentrations were adjusted for moisture and lipid loss using these volume estimates (Stickel et al. 1973) and are presented as fresh weight.

For species with at least two samples per location, geometric means were calculated as a measure of central tendency in the data, and to minimize the influence of outlying concentrations in small data sets. Arithmetic mean or median measures of central tendency would result in equal or slightly more elevated mean values when outlying values are present, thus the geometric mean provides a more conservative approach to expressing the central tendency of the data. Chemical concentrations below detection limits were assigned a value of one-half the detection limit for determining geometric means, provided the majority of values were above detection limits. Difference in means among sites were not compared statistically for a species due to inadequate sample size at one or more locations, or an insufficient number of detectable concentrations. Therefore, mean and maximum concentrations were compared across sites using relative percent differences as an indication of trends of higher concentrations at particular sites or among river segments. Concentrations in fish and bird eggs also were compared between years for an individual species when sufficient data were available.

Geometric mean and maximum contaminant concentrations in sediment and biota were compared to 1) reference values from nationwide sampling efforts; 2) guidance values including estimated no-observable-adverse-effect levels (NOAELs) or lowest-observable-adverse-effect-levels (LOAELs) derived from referenced laboratory or field studies; or 3) concentrations considered protective of predators consuming contaminated prey (Table 7). Concentrations in fish were compared to concentrations found previously in various species from the Columbia River and reported in nationwide studies including the National Contaminant Biomonitoring Program (NCBP) (Schmitt et al. 1990, Schmitt and Brumbaugh 1990) and the National Chemical Residue Study (NCRS) (U.S. Environmental Protection Agency 1992). The frequency of detection of selected contaminants, the number of samples exceeding reference values or protective guidelines, and sites where exceedances occurred are also reported.

Concentrations in sediment and fish also were compared to those reported during a concurrent reconnaissance investigation as part of the Bi-State Study. During this reconnaissance investigation, Tetra Tech (1993a, 1994) collected sediment, crayfish, and fish from various river segments below Bonneville Dam in 1991 and 1993. In 1991, sediment, crayfish (*Pacifastacus leniusculus*), carp, sucker, and peamouth chub were collected primarily in or along the main channel of the river during a period of very little rainfall and low river flow conditions (Tetra Tech 1993a). In 1993, additional sediment, carp, and sucker samples were collected in an

attempt to gather information specifically from sloughs and backwater areas during a period of intermittent rainfall and moderate flow conditions (Tetra Tech 1994). Collection methods and formulation of composite samples during the Bi-State Study were similar to methods used in our study. Concentrations reported in the Bi-State Study as µg/kg (ppb) were converted to µg/g (ppm) to facilitate comparisons to our results.

To better understand trophic transfer of contaminants in the lower Columbia River, we derived apparent biomagnification factors (BMFs) (Braune and Norstrom 1989) to evaluate transfer of selected OC compounds and mercury between prey fish and bald eagle eggs. Contaminant concentrations were determined in lower Columbia River bald eagle eggs in 1994 and 1995 by the U.S. Fish and Wildlife Service (1999a). Apparent BMFs from prey fish to bald eagle egg were derived as the ratio of the geometric mean of a contaminant in the eagle egg (GM EGG) to the geometric mean of the prey fish concentrations (GM FISH) based on the equation

$$BMF_{fish \div BE\ egg} = [GM\ EGG] / [GM\ fish]. \qquad (1)$$

Bald eagles nesting along the lower Columbia River are resident year-round and all of their diet comes from the Columbia River (U.S. Fish and Wildlife Service 1999a). The eagles primarily consume fish, but their diet also includes piscivorous birds, non-piscivorous birds, and a very small proportion of small mammals (Watson et al. 1991). Therefore, the total BMF represents a field diet normalized to forage fish equivalents, given that eagles also forage on nonfish prey (primarily piscivorous and non-piscivorous birds). For this analysis, it was assumed that any piscivorous birds consumed by the eagles also would be receiving contaminants from eating the same fish stocks from the river, and the contaminant concentrations in prey fish did not change between 1991 and 1995. Another assumption of this model is that the organochlorine contaminants are in steady-state conditions between various tissues in the river.

For the BMF calculation, we used fish samples collected in 1991 and determined a geometric mean for sucker, carp, and peamouth chub within segments one to three, as eagle eggs were collected only within these sections. All fish collected and analyzed were within the size range (<60 cm) that included 94 percent of the fish captured by bald eagles along the lower Columbia River (Watson et al. 1991). As described by equation 1, the total BMF was derived within each segment by dividing the geometric mean of a contaminant in the eagle egg by the geometric mean of the fish within a segment. A single BMF was also determined for the three segments combined. To better compare variability in BMFs, we used data for carp, sucker, and peamouth from the Bi-State Study only (Tetra Tech 1993b,c), and eagle egg data from U.S. Fish and Wildlife Service (1999a), to derive BMFs and made separate comparisons within segments (our fish data were excluded when deriving this BMF). We also derived a target fish concentration (TFC), or the estimated contaminant concentration in prey fish that would be considered protective of bald eagles regardless of the proportion of birds consumed in the diet, by the equation

$$TFC_x = NOAEL_{BE\ egg} / BMF_{fish \div BE\ egg} \qquad (2)$$

where X is a particular contaminant, $NOAEL_{BE\ egg}$ is a concentration of contaminant X in the egg considered protective of bald eagle embryos, and the $BMF_{fish \div BE\ egg}$ is derived from equation 1. Estimated NOAELs for bald eagle eggs used in equation 2 for total PCBs, DDE, and mercury were based on literature values (Table 7). NOAELs used for TCDD and TCDF were based on reference concentrations in eggs of bald eagles reproducing successfully in coastal British Columbia (Elliott et al. 1996b). We assumed the reference values to be suitable guidance for this assessment for comparison purposes. Actual NOAELs for bald eagles have not been calculated individually for TCDD and TCDF and contributions from other dioxin-like compounds should be evaluated before making decisions based on results from TCDD and TCDF alone. We had insufficient contaminant information in prey fish to compare to bald eagle NOAELs derived for

groups of dioxin-like compounds, and therefore the NOAELs used for TCDD and TCDF in our evaluation could under- or overestimate actual threshold values. TFCs were determined within each segment and for segments one to three combined, and were determined based on the BMFs from the Bi-State data for comparison.

To better evaluate the relative magnitude of exceedances of concentrations in tissue over reference or threshold values, we used a hazard quotient (HQ) similar to the approach defined by Giesy et al. (1995). The HQ approach was based on the equation

$$HQ = [Tissue] / [NOAEL_{tissue}] \qquad (3)$$

where [Tissue] is the contaminant concentration in the tissue for a species and $[NOAEL_{tissue}]$ is the estimated NOAEL, reference, or guidance value obtained from the literature for the species or a similar species sampled (Table 7). An HQ was derived for each composite sample per species for each contaminant (total PCBs, DDE, mercury, TCDD, and TCDF). The arithmetic mean HQ was then reported for all fish and bird eggs collected in a given year, and for each species within a group. For bald eagles, HQs were reported as the ratio of the geometric mean of each contaminant in all eggs collected from the river over the NOAEL for that contaminant.

RESULTS

Sediment

Organochlorine pesticides and total PCBs

OC pesticides or transformation products were detected at two locations in sediment samples. One sample at Julia Butler Hansen NWR contained DDE at 30 µg/kg, and one sample at Umatilla NWR contained DDD at 20 µg/kg. Total PCBs, and all other OC pesticides, were below detection limits in all sediment samples (Table 8). Mercury was not evaluated in sediment.

Dioxins and furans

Dioxins and furans were detected in sediment samples from all locations, but most congeners were only slightly above the detection limits (Table 9). The highest dioxin concentrations were found in one sample from Lewis and Clark NWR, and this was the only sample where TCDD was detected. The hepta- and octa-substituted dioxin congeners were elevated well above detection limits in all samples. Most furans were not detected or were below one pg/g, although more elevated furan concentrations were found in the Lewis and Clark NWR sample. TCDF was found above detection in Cathlamet Bay, Lewis and Clark NWR, Julia Butler Hansen NWR, and Umatilla NWR samples, and was highest in the Lewis and Clark NWR sample. The octa-substituted dioxin and furan appeared to be the most elevated congener, although concentrations were estimated due to matrix interferences or blank contamination during analysis.

Invertebrates

Organochlorine pesticides, total PCBs, and mercury

Concentrations of total PCBs and OC pesticides were near or below detection in most invertebrate samples (Table 10). Compared to other invertebrates, total PCBs in Corbicula clam and crayfish samples from the Julia Butler Hansen NWR were the most elevated OCs detected (Table 10). Of the OC pesticides, DDE was the most commonly detected contaminant in invertebrates, and was found in 80 percent of Corbicula clam samples (Tables 10 and 11). DDE was detected at all sites in Corbicula clam, and was highest (six to nine times greater than the detection limit) at the Julia Butler Hansen NWR (Table 10). Macoma clam, sampled only at Baker Bay, had low concentrations of DDE, and crayfish from Lewis and Clark NWR and

Ridgefield NWR had similar concentrations of both DDE and DDT (Table 10). DDD was only detected in Corbicula clam at Julia Butler Hansen and Umatilla NWRs. One sample of Corbicula clam at the Julia Butler Hansen NWR was the only sample to contain other OC pesticides, but most values were near the detection limits (Table 10). *Corophium*, sampled only at Cathlamet Bay, did not contain OC pesticides or total PCBs above the detection limits.

Mercury was only analyzed in Corbicula clam samples from the Julia Butler Hansen NWR and Longview sites, and in crayfish from the Julia Butler Hansen NWR (Table 10). All samples from these sites contained mercury, and concentrations in the clam samples were very similar between the sites. Mercury was much higher in the crayfish samples from Julia Butler Hansen NWR than the clam samples (Table 10).

Dioxins and furans

Concentrations of most dioxin and furan congeners were near or below detection limits in invertebrate samples, although not all samples were analyzed for the same congeners and not all species were found or sampled at all sites (Table 12). Most composite samples were analyzed only for the 2,3,7,8-tetra-substituted congeners, and results for *Corophium* and Macoma clam were only available for one site. In addition, results from Corbicula clam samples at two sites, Julia Butler Hansen NWR and Longview, did not meet quality control criteria and were excluded from the results.

Concentrations of TCDD were detected infrequently, whereas TCDF, OCDD, and 1,2,3,4,6,7,8-HpCDD were the most commonly detected congeners (Table 12). TCDD was detected in one sample of *Corophium* from the Lewis and Clark NWR at 1.4 pg/g, in crayfish samples from Cathlamet Bay at 1.2 pg/g, and from Longview at 0.3 pg/g. In contrast, TCDF was found in all invertebrate samples at all sites except in one Corbicula sample from Lewis and Clark NWR. The highest concentration (10 pg/g) of TCDF was found in one Corbicula clam sample from Cathlamet Bay, although this value was an estimate of the maximum possible concentration in the sample due to interference with co-eluting diphenyl ethers. Mean concentrations of TCDF in *Corophium*, Corbicula clam, and crayfish were relatively similar at all sites where these matrices were analyzed. The geometric means of TCDF in crayfish were most elevated at the Julia Butler Hansen NWR (4.4 pg/g) and Longview (3.6 pg/g), but results were not available to compare for clams and *Corophium* tissues at these two sites. OCDD was the most elevated congener detected in the two clam samples at all sites sampled, but the congener was below or near detection limits in crayfish sampled at the same or additional sites. Likewise, 1,2,3,4,6,7,8-HpCDD was elevated in clam tissue from all sites sampled except Lewis and Clark NWR, where detection limits were elevated for this sample (Table 12). This congener was below detection in crayfish from all sites sampled.

Fish

Organochlorine pesticides, total PCBs, and mercury

Fish samples were obtained from five sites in 1990, although not all species were collected from all sites (Table 13). Most fish samples analyzed in 1990 contained primarily five OC pesticides or transformation products, PCBs (reported as total PCBs), and mercury (Table 13). The OC pesticides and transformation products above detection limits included DDT, DDE, DDD, chlordane, and trans-nonachlor. PCBs and DDE were the most common and most elevated OC compounds, and were detected in 87 and 100 percent of the fish, respectively (Table 11). Mercury was analyzed in only a few fish samples, and was above detection in four of seven samples (Table 11). Other OC pesticides were at or below detection limits (Table 13).

DDE was detected in all 1990 fish samples at all locations, ranging from 0.07 μg/g in largemouth bass at St. Helens to 0.65 μg/g in peamouth chub from Cathlamet Bay (Table 13). DDE concentrations in the herbivorous fish (sucker and carp) were similar, and other predacious

species (bass and pikeminnow) had concentrations within the range of, or slightly below, the nonpredatory fish. Concentrations in carp and sucker were highest in river segments near the mouth and at the Portland site (carp only), and were much lower in upriver Segments 3 and 4. In contrast, concentrations in pikeminnow increased four-fold from Segments one to three. The peamouth sample from Segment 1 (Cathlamet Bay) had the highest concentration of DDE (0.65 µg/g) in any species, followed by pikeminnow from St. Helens (0.37 µg/g), and sucker from Cathlamet Bay (0.34 µg/g).

DDT was detected in relatively few fish samples and was highest in sucker from Cathlamet Bay (Table 13). Detectable concentrations were relatively similar within species across all sites. DDT was detected less frequently in fish samples than DDD or DDE and was below detection limits in both carp and pikeminnow, but was present in all sucker samples. DDT was only slightly above detection in sucker from Longview and St. Helens, in largemouth bass from Longview, and in smallmouth bass from the Portland site. DDD concentrations in various species were similar at all locations. DDD was above detection limits in all samples except one carp from Camas Slough, and was highest (0.08 µg/g) in pikeminnow from St. Helens and smallmouth bass from the Portland site. Other OC pesticides were slightly above detection limits in most samples, with the highest concentrations found in species at the following locations: (1) total chlordanes in smallmouth bass from the Portland site; (2) chlordane in peamouth chub from Cathlamet Bay; and (3) trans-nonachlor in smallmouth bass from the Portland site (Table 13).

PCBs (reported as total PCBs) were detected in all fish except one carp sample from Camas Slough and one pikeminnow sample from Cathlamet Bay (Table 13). PCBs ranged up to 1.03 µg/g in sucker at Cathlamet Bay. PCB concentrations in sucker and carp sampled in 1990 followed a similar pattern as the DDE concentrations; PCBs were highest in the lower river segments, declined progressively moving upriver, and were not detected in the most upriver carp sample at Segment 4 (Camas Slough). In contrast, pikeminnow did not have PCBs above detection limits at Cathlamet Bay. The predatory fish species sampled had concentrations within the upper ranges of the nonpredatory fish, but did not contain the most elevated concentrations.

Total mercury was found in just over half the fish sampled in 1990 (Tables 11 and 13), ranging from 0.21 to 1.1 µg/g in samples with detectable concentrations. Mercury was below detection in carp from the Portland site and Camas Slough, and in pikeminnow from Cathlamet Bay. Mercury was highest (1.1 µg/g) in pikeminnow from St. Helens.

In 1991 fish samples, carp, sucker, and peamouth chub were collected within most river segments including the Umatilla segment. In addition, mountain whitefish were collected from Umatilla. No fish samples were collected from Baker Bay. The three fish species (carp, sucker and peamouth chub) contained DDT, DDE, DDD, dieldrin, cis-nonachlor, trans-nonachlor, total PCBs, and mercury above detection limits (Table 14). Whitefish from Umatilla also contained these compounds above detection, except for total PCBs and trans-nonachlor (Table 14). Total PCBs, DDE, and mercury were the most elevated of this group of contaminants.

Similar to the 1990 results, DDE was detected in 100 percent of the fish sampled (Table 11). All four fish species sampled in 1991 had concentrations of DDE well above detection limits and at relatively similar concentrations among species and sites (Table 14). In carp, the most elevated geometric mean occurred in samples from Umatilla (Table 14). One carp sample from Umatilla had a maximum concentration of 0.47 µg/g, nearly double the concentration in any other fish sample. Whitefish from Umatilla also had some of the highest DDE concentrations compared to other fish. Sucker, sampled at every site, had the most elevated geometric mean (0.10 µg/g) in samples from the Ridgefield site, although the maximum concentration (0.13 µg/g) was in a sample from the Longview site. In contrast, peamouth chub from Cathlamet Bay had the highest geometric mean (0.24 µg/g) compared to any of the fish species sampled. Unlike the previous

year, DDE in carp was relatively similar among upriver segments and highest at Umatilla, and concentrations in sucker were similar among all segments and highest at Ridgefield, Umatilla, and Cathlamet Bay. Concentrations of DDE in peamouth were most elevated in samples from Cathlamet Bay compared to other river segments, but concentrations at this site were not as elevated as observed in 1990.

DDT was near detection limits in most fish samples, and was detected less frequently than either DDE or DDD. DDT rarely was detected in carp, but was at or above detection limits in all sucker samples except one sample from Camas Slough (Table 14). Peamouth chub had DDT in samples from Lewis and Clark NWR, Longview, and Ridgefield, but was not found in samples from Cathlamet Bay, Julia Butler Hansen NWR, and Umatilla. Whitefish samples from Umatilla had the highest mean concentration of DDT than in other fish species. DDD was found in at least one sample in all species at all sites except sucker at Lewis and Clark NWR and at Camas Slough, and was comparable to concentrations in fish the previous year sampled (Tables 13 and 14). However, most concentrations were at or slightly above the detection limits. The most elevated geometric means for DDD were found in peamouth chub samples from Cathlamet Bay and Julia Butler Hansen NWR, although the maximum concentration among all fish was in a carp sample from Umatilla. Dieldrin and cis-nonachlor were present slightly above detection limits in many of the samples, whereas these compounds were not present or were at detection limits in 1990 samples (Tables 13 and 14). Other OC pesticides were at or below detection limits (Table 14).

Total PCBs were detected in relatively few fish (29 percent of the samples) in 1991 compared to 1990 (Table 11). Total PCBs were not above the detection limits in any sucker samples from any location, or in whitefish from Umatilla (Table 14). In carp, sampled only at four sites, total PCBs were detected in 67 percent of the samples (Table 11). The most elevated mean value (0.11 µg/g) was found at Longview, although the maximum concentration (0.32 µg/g) was found in a carp sample from Umatilla. Almost half of the peamouth chub samples contained total PCBs (Table 11). Total PCBs were most elevated in peamouth from Cathlamet Bay; samples at this site had a geometric mean of 0.29 µg/g, which was more than double the mean for any other species. One peamouth sample at Cathlamet Bay had a maximum value of 0.54 µg/g, higher than that found in any other fish sample. In contrast, total PCBs were below detection in all peamouth samples at Lewis and Clark NWR, Ridgefield NWR, and at Umatilla, and were found in only one sample at Longview (Table 14).

Total mercury was found in nearly all (94 percent) of the fish samples (Table 11), and was only below detection in two sucker samples from Umatilla and in one peamouth chub sample from Longview (Table 14). Mercury in fish with detectable concentrations ranged from 0.04 to 0.18 µg/g, and concentrations were much lower than the range of detectable concentrations in fish from 1990. Geometric means were very similar among species and sites, although the mean in peamouth chub from the Longview site was three times lower than the means in the other fish species at Longview (Table 14). The highest geometric mean occurred in carp and sucker from Longview, although the maximum concentration (0.18 µg/g) occurred in a carp sample from Umatilla. Concentrations in whitefish from Umatilla were similar to concentrations observed in most peamouth and carp samples at the site (Table 14).

Dioxins and furans

Of the fish species collected in 1990, only carp and northern pikeminnow were analyzed for dioxins and furans from the five locations sampled. The congeners TCDD, 1,2,3,4,6,7,8-HpCDD, OCDD, and TCDF were well above detection limits in both species from most sites (Table 15). TCDD and TCDF were detected in both species at all sites, except TCDD was not found in either fish from Portland (Table 15). The highest TCDD and TCDF concentrations (9.0 pg/g and 83 pg/g, respectively) were found in pikeminnow from the St. Helens location. Most

other dioxin and furan congeners were at or below detection limits, although numerous congeners were consistently above detection in carp samples from the Longview site.

Of the 1991 fish samples, only carp, peamouth chub, and sucker were analyzed for dioxins and furans. Multiple composite samples of each species were analyzed for the 2,3,7,8-tetra substituted congeners, whereas only one composite sample of peamouth or sucker per site were analyzed for the other dioxin and furan congeners. TCDD was detected in 77 percent of the samples (Table 11). The geometric mean for TCDD was most elevated (11 pg/g) in carp from the Umatilla site, whereas the geometric means for carp at the other sites were much lower and ranged from 0.9 pg/g to 2.1 pg/g (Table 16). Within the lower river below Bonneville Dam, peamouth had the highest mean and maximum concentrations of TCDD at Cathlamet Bay, and TCDD in sucker was highest (mean and maximum values) at the Longview site (Table 16).

TCDF was found in nearly all (94 percent) of the fish sampled, although diphenyl ether compounds interfered with analysis and results for many samples were estimated as maximum possible concentrations (Tables 11 and 16). For carp, the highest estimated geometric mean (35 pg/g) and maximum (110 pg/g) concentrations of TCDF were from Umatilla (Table 16). Maximum estimated TCDF concentrations in peamouth chub occurred at Ridgefield, and estimated concentrations in sucker were greatest at Umatilla (Table 16).

Few samples of peamouth or sucker contained 2,3,7,8-substituted dioxin and furan congeners other than TCDD and TCDF (Table 16). Other dioxin and furans above detection limits included: OCDD in peamouth from Cathlamet Bay, Ridgefield, and Umatilla, and in sucker from Cathlamet Bay, Julia Butler Hansen NWR, Ridgefield, and Camas Slough; 1,2,3,7,8-PCDF in peamouth and sucker from Ridgefield; and 1,2,3,4,6,7,8-HpCDF in sucker from Cathlamet Bay (Table 16).

Bird Eggs

Organochlorine pesticides, total PCBs, and mercury

Eggs were collected in 1990 within the Lewis and Clark NWR on Rice Island, and at Umatilla on Crescent Island (Figures 2 and 6). Eggs from three species of piscivorous birds were sampled at each location. Total PCBs, DDE, DDD, dieldrin, HCB, beta BHC, heptachlor epoxide, chlordane, oxychlordane, alpha-chlordane, trans-nonachlor, and endosulfan-I were above detection limits in one or more eggs from Rice or Crescent Islands in 1990, although chlordane and endosulfan-I were not analyzed in samples from Crescent Island (Table 17). Total PCBs and DDE were the most elevated compounds in eggs from both sites, whereas other chemicals were only slightly above detection. Total PCBs were detected in 25 (93 percent) of the bird eggs and were most elevated in cormorant eggs from Rice Island, with a geometric mean of 3.35 µg/g and a maximum value of 6.53 µg/g (Tables 11 and 17). Mean total PCBs in the other species at the two sites were similar (ranging between 1.11 and 1.88 µg/g), except in ring-billed gulls at Umatilla where concentrations were low and ranged from <0.5 to 0.31 µg/g (Table 17). Concentrations of DDE were detected in 25 (93 percent) of the bird eggs collected (Table 11). The highest geometric mean (2.31 µg/g) and maximum value (4.12 µg/g) of DDE were for Caspian terns from Crescent Island. Mean DDE was relatively similar among the other species at the two islands (Table 17).

In 1991, eggs from two non-piscivorous and four piscivorous bird species were collected and analyzed for total PCBs and OC pesticides. Eggs of non-piscivorous birds only were collected in the lower river segments below Bonneville Dam. In non-piscivorous birds, total PCBs, DDT, DDE, total-BHC, and total chlordane were above detection limits, and total PCBs and DDE had the highest values compared to other OC pesticides (Table 18). Total PCBs were detected in nine (82 percent) of the non-piscivorous bird eggs sampled (Table 11). Total PCBs in Canada goose eggs were highest at the Lewis and Clark NWR (Table 18). Mallard eggs had similar total

PCB concentrations between Baker Bay and Lewis and Clark NWR samples, and total PCBs in most samples exceeded concentrations found in goose eggs at both sites (Table 18). Concentrations of DDE were detected in 10 (91 percent) of the non-piscivorous bird eggs sampled (Table 11). Concentrations of DDE followed a similar pattern in mallard and goose eggs as the PCB concentrations; mallard egg DDE concentrations were higher than in goose eggs, and the highest concentrations were at the Lewis and Clark NWR site (Table 18). Other OC pesticides were at or slightly above the detection limits (Table 18).

In piscivorous birds, concentrations of total PCBs, DDT, DDE, DDD dieldrin, endrin, total-BHC, heptachlor epoxide, total chlordanes, oxychlordane, alpha-chlordane, and cis- and trans-nonachlor were above detection limits in one or more samples (Table 19). However, total PCBs and DDE were well above detection limits in every sample (Table 11), and were the most elevated compounds analyzed (Table 19). The geometric mean (6.07 µg/g) and maximum value (10.8 µg/g) for total PCBs was highest in cormorants from Rice Island. Likewise, the mean and maximum values for DDE (5.31 µg/g and 9.88 µg/g, respectively) were highest in cormorants from this same location. The lowest PCB concentrations were found in Caspian terns from Crescent Island, and the lowest DDE values were in western/glaucous-winged gulls from East Sand Island (Table 19). A number of other OC pesticides were elevated well above detection limits in individual eggs of some species, including: (1) dieldrin in individual cormorant eggs from East Sand and Rice Islands, and in an egg from a ring-billed gull at Crescent Island; (2) endrin in a cormorant egg from Rice Island; (3) total-BHC in eggs of Caspian terns at Rice and Crescent Islands; (4) heptachlor epoxide in all eggs from ring-billed gulls at Crescent Island; (5) total chlordanes in nearly all species at all sites; (6) oxychlordane in cormorants from Rice Island and in ring-billed gulls from Crescent Island; (7) cis-nonachlor in one cormorant egg from Rice Island; and (8) trans-nonachlor in eggs of ring-billed gulls from Umatilla (Table 19).

Mercury was detected in all eggs of piscivorous and non-piscivorous birds (Table 11). In 1990, concentrations were similar among species (Table 20). The geometric mean and maximum values in the 1990 eggs were highest (0.72 and 0.89 µg/g, respectively) in Caspian terns eggs from Crescent Island. In 1991, mercury was highest in cormorants from East Sand Island, although concentrations in cormorants and Caspian terns from Rice Island were elevated compared to other samples as well. Mercury concentrations in ring-billed gulls at Crescent Island were low and only slightly above concentrations observed in non-piscivorous birds (mallard and Canada goose), which had concentrations near the detection limits (Table 20).

Dioxins and furans

Eggs were collected from four piscivorous bird species in 1990 on Rice or Crescent Islands. TCDD was detected in nine (82 percent) eggs analyzed in 1990 (Table 11). TCDD was found in all eggs except for ring-billed gull and Forster's tern samples from Crescent Island, although the Forster's tern samples had elevated detection limits and were not comparable to the other samples (Table 21). TCDD was highest in cormorant samples from Rice Island, with a geometric mean of 34 pg/g and a maximum value of 44 pg/g. The cormorant TCDD mean was nearly five times higher than mean TCDD in eggs of other species (Table 21). Mean TCDD was higher in Caspian terns from Crescent than Rice Island (Table 21). Other dioxin congeners were predominantly below detection limits except for the following: 1,2,3,7,8-PCDD was detected in most samples except ring-billed gull; 1,2,3,6,7,8-HxCDD was found in at least one sample from all locations and in all samples of gulls from Crescent Island and Caspian terns from Rice Island; 1,2,3,4,6,7,8-HpCDD was found in all samples of gulls from Rice Island and in one ring-billed gull egg from Crescent Island; and OCDD was found well above detection limits in all samples from all locations (Table 21). TCDF was detected in nine (82 percent) of the 1990 eggs, but was not found in western/glaucous-winged gull, and was in only one ring-billed gull sample from Crescent Island (Tables 11 and 21). TCDF concentrations were similar among Caspian tern and cormorant eggs (Table 21). Other furan congeners were primarily near or below detection limits.

In 1991, eggs were collected from East Sand Island and Rice Island in the lower Columbia River, and from Crescent Island at Umatilla. Eggs were analyzed for the 2,3,7,8-tetra substituted congeners only. TCDD was detected in 24 eggs or 80 percent (Table 11). TCDD was highest in western/glaucous-winged gulls at Rice Island, with a geometric mean of 8.6 pg/g and a maximum value of 22 pg/g (Table 22). The lowest concentrations were found in ring-billed gulls and Forster's terns at Crescent Island (Table 22). Both the cormorant and gull egg geometric means for TCDD were slightly elevated at Rice Island compared to East Sand Island, although the maximum concentration (24 pg/g) was found in one cormorant egg from East Sand Island (Table 22). The geometric mean for TCDD in Caspian tern eggs was slightly higher from Rice Island compared to Crescent Island. TCDF was detected in 20 (67 percent) of all bird eggs in 1991 (Table 11). Geometric means for TCDF were generally near detection limits, and the highest concentrations were in Caspian tern eggs from Rice Island (Table 22). Concentrations in cormorant eggs were slightly higher at Rice Island compared to East Sand Island, and Caspian tern egg concentrations were higher at Rice Island compared to Crescent Island (Table 22). TCDF was primarily below detection in Forster's terns and ring-billed gull eggs from Crescent Island.

Contaminants Within River Segments

The percentage of detections of selected OC compounds (total PCBs, DDE, TCDD, and TCDF combined by sample matrix) most commonly found in biota from the Columbia River was similar within a particular matrix sampled (Figure 7). In sediment, the percentage of detections was relatively similar over all segments, although no detections were found in Segment 4. Invertebrates revealed nearly the same percentage of detections across all segments. Fish sampled in 1990 in Segments 2 and 3 had the highest percentage of detections for any sample matrix, although sample sizes were relatively small. Fish analyzed in 1991 had a lower percentage of detection than fish sampled in 1990. In 1991, there was a greater percentage of detection in Segments 1 to 3 compared to Segment 4 and at Umatilla (Figure 7). Bird eggs sampled in both 1990 and 1991 showed nearly the same detection pattern; eggs sampled in 1990 and 1991 had identical percentage of detections within a site, and higher percentages of detections were found in Segment 1 compared to Umatilla (Figure 7).

The percentage of detections of some individual OC compounds (all sediment and biota sample results combined within a segment) showed a declining trend among some segments (Figure 8). Total PCBs were primarily detected in combined samples from Segment 1 and Umatilla, and showed a declining trend in samples from Segment 2 to 4 (Figure 8). A similar pattern exists for TCDD. The percentage of DDE detections was nearly identical from Segments 1 to 4, and highest at Umatilla. In contrast, the percentage of TCDF detections increased from Segment 1 to 3, and was lowest in Segment 4 and Umatilla.

Biomagnification Factors (BMFs)

The mean apparent total BMFs from forage fish to bald eagle eggs for total PCBs and DDE were higher than the other contaminants evaluated (Table 23). Total PCBs had the highest apparent BMFs at all river segments compared to other chemicals. However, the BMFs for total PCBs varied quite markedly among the three segments evaluated, ranging from 90 for Segment 2 to 155 for Segment 3. The BMF for DDE in Segments 1 and 3 were similar, and Segment 2 was highest (Table 23). The BMFs for total mercury, TCDD, and TCDF were relatively consistent among segments (Table 23). Total mercury and TCDF had the lowest BMFs.

TFCs, or the concentrations estimated in fish that would be protective of bald eagles eating fish, were derived for total PCBs, DDE, mercury, TCDD, and TCDF for Segments 1 to 3 along the river (Table 24). TFCs for DDE and total PCBs were similar, even though the BMFs for these two chemicals were quite different. In contrast, the TFC for TCDD was much lower than for

TCDF, which reflects the much lower BMF value for TCDF even though the same NOAEL reference values were used for these two chemicals. Concentrations of these chemicals in most fish samples from the river exceeded the TFC values (Table 11).

DISCUSSION

Sediment

Organochlorine pesticides and total PCBs

Very few sediment samples contained detectable concentrations of OC pesticides or total PCBs. Similarly, OC pesticides and total PCBs were below detection limits or detected only in low frequencies in sediment collected in 1991 and 1993 from the lower Columbia River during the Bi-State Study (Tetra Tech 1993a, 1994). In our study and the Bi-State Study, DDT compounds (DDT, DDD, and DDE) were the most frequently detected of the OC pesticides and transformation products analyzed; DDE was detected in 4 of 54 samples collected from depositional areas in 1991 (Tetra Tech 1993a) and in 5 of 15 samples collected from backwater areas in 1993 (Tetra Tech 1994). The detected DDE concentrations in the samples from both years ranged from 0.5 to 6 µg/kg (Tetra Tech 1993a, 1994); concentrations which were well below the detection limits in our study. Sediment DDE concentrations in the Bi-State Study occurred primarily at Coal Creek at RM 58, St. Helens at RM 85, Camas Slough at RM 118, and Beacon Rock at RM 142. Tetra Tech (1993a, 1994) also found only three sediment samples containing total PCBs, primarily as Aroclor 1248 (7.3 µg/kg from Carrolls Channel at RM 11 and 6.8 µg/kg from Burke Slough at RM 81) and Aroclor 1254 (85 µg/kg from Longview at RM 63). Other studies have documented total PCBs at a number of locations ranging from 20 µg/kg in Cathlamet Bay (Fuhrer and Horowitz 1989) to 30 µg/kg in Baker Bay (Fuhrer and Rinella 1983). As in our study, there were no clear spatial trends seen with OC pesticides or total PCBs in sediment in the Bi-State Study (Tetra Tech 1993a, 1994).

In our study, a sediment sample from the Julia Butler Hansen NWR was the only one to exceed the lower ten percentile of concentrations associated with biological effects (Long and Morgan 1990) for DDE (Table 11), which indicates invertebrates could be impaired at this site. Most other values were below those considered to impair benthic invertebrates, although concentrations could bioaccumulate and have impacts higher up the food chain.

Dioxins and furans

Although few sediment samples were analyzed for dioxins and furans, the compounds were present at all eight study sites. Only one sample contained the most toxic dioxin congener, TCDD, at concentrations slightly above detection limits. The sample was collected at Lewis and Clark NWR; TCDD was below detection at all other sites. Two congeners, 1,2,3,4,6,7,8-HpCDD and OCDD, were present at all sites, and the congeners 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, TCDF, and OCDF were present at the majority of sites. Concentrations of many of the congeners were near detection limits, or were estimated due to poor resolution during analysis. In the Bi-State reconnaissance studies, dioxins and furans were among the most frequently detected compounds in sediment, although most were below 1 pg/g (Tetra Tech 1994). In contrast to our study, TCDD was detected in nearly all (18 of 20) of the depositional sediment sampled in the 1991 Bi-State Study (Tetra Tech 1993a). However, TCDD was not detected in the 15 backwater samples collected in 1993 (Tetra Tech 1994). Similarly, TCDF was detected in all 20 samples collected in 1991, but not in any of the 15 backwater samples (Tetra Tech 1993a, 1994). Concentration ranges for TCDD and TCDF in the 1991 samples were 0.07 to 0.35 pg/g and 0.06 to 3.23 pg/g, respectively (Tetra Tech 1993a). Similar to the present study, the highest dioxin and furan congener concentrations found by Tetra Tech (1994) were for 1,2,3,4,6,7,8-HpCDD, OCDD, and OCDF, which ranged from 0.9 to 188, 6.8 to 1,480, and 1.19 to 128 pg/g, respectively. OCDD was the most elevated congener in both our study and the Bi-State Study.

Distinct spatial differences in concentrations in sediment for dioxins and furans were not readily discernable in either our study or the Bi–State Study. Information regarding guidance levels for dioxins and furans in sediment are unavailable, and it is unclear if concentrations are high enough to impact benthic organisms. However, dioxins and furans in sediment could bioaccumulate in biota and possibly impact upper trophic level species.

Invertebrates

Organochlorine pesticides, total PCBs, and mercury

Concentrations of most OC pesticides and transformation products were below detection limits in invertebrate samples. DDE was the most commonly detected OC transformation product, occurring in 54 percent of the invertebrate samples. DDE was detected in nearly all clam samples but was detected much less frequently in crayfish. DDT was not detected in clam samples, yet both DDE and DDT were present in crayfish samples from Lewis and Clark and Ridgefield NWRs at concentrations near detection limits. Presence of DDT in tissues may indicate more recent exposure to this pesticide at the two locations. Concentrations of DDE in crayfish and clam samples collected from multiple locations did not show discernable patterns or trends, primarily because concentrations were near detection limits. However, Corbicula clams sampled at the Julia Butler Hansen NWR had DDE concentrations well above detection limits (up to 0.09 µg/g) and values in all clam samples from this site greatly exceeded all other invertebrate samples. In addition, the only detection of DDE in sediment samples occurred at the Julia Butler Hansen NWR. In contrast, concentrations in crayfish from the Julia Butler Hansen NWR were below detection. Guidance values for the protection of fish and wildlife that consume invertebrates contaminated with OC compounds are unavailable. However, Corbicula clams are commonly harvested in the beach area at Julia Butler Hansen NWR and consumed by people (Al Clark, Refuge Biologist, U.S. Fish and Wildlife Service, pers. comm.), and further characterization of DDE and other contaminants in clams in this area is warranted.

Relatively few studies have evaluated contaminant concentrations in invertebrate species in the lower Columbia River. Crayfish from the lower Columbia River were sampled in 1991 and 1993 by Tetra Tech (1993a, 1994). Similar to our study, the authors found DDE to be the most commonly detected OC pesticide or transformation product in crayfish; DDE was detected in 30 of 33 samples and ranged from 0.003 to 0.017 µg/g. DDE concentrations were highest (up to 0.14 µg/g) in samples collected between RMs 90 and 124. DDE was found in a higher percentage of crayfish samples in the Bi-State Study than in our study, due to the much lower reporting limits in the Bi-State Study. As in our study, Tetra Tech (1994) reported that other DDT compounds were much less prevalent than DDE in crayfish; DDT was found in one sample out of 33 at 0.003 µg/g, and DDD was detected in 2 of 33 crayfish samples at 0.01 µg/g.

Total PCBs were present above detection limits in only two (5 percent) of the invertebrate samples. Total PCBs (calculated as the sum of congener PCBs) were only present in one Corbicula clam and one crayfish sample from the Julia Butler Hansen NWR site, and the maximum concentration exceeded 1 µg/g in the clam sample. Total PCB concentrations at this site appeared to be higher than in samples from other sites. However, PCBs from the Julia Butler Hansen NWR were analyzed and totaled as congener PCBs, whereas PCBs from the other sites were analyzed as Aroclor PCBs, so the results among the sites are not directly comparable. The Aroclor PCBs were not above detection in any sample from other sites. Similarly, Tetra Tech (1994) reported no detections of Aroclor PCBs in any of 33 crayfish samples collected in 1991 and 1993. In sediment samples, total PCBs were below detection and could not be compared to the invertebrate samples.

Mercury was detected in all invertebrate samples, although samples of only two clams and one crayfish were analyzed. Concentrations in the crayfish sample were within the range of concentrations (0.012-0.081 µg/g) detected in 32 of 35 crayfish samples collected from the lower

Columbia River by Tetra Tech (1994). Concentrations in clams from our study, and in crayfish in both our study and the Bi-State Study (Tetra Tech 1993a, 1994), were below concentrations (< 0.10 µg/g) in various invertebrate species considered representative of uncontaminated freshwater areas (Huckabee et al. 1979). Also, concentrations in both studies were below concentrations in food items considered protective of avian species (Eisler 1987), as represented by their corresponding HQ values of well below one (Table 11). Mercury was not evaluated in sediment samples and could not be compared to invertebrate concentrations.

Dioxins and furans

Few dioxins and furans were above detection limits in invertebrate samples, and no sites or species appeared more contaminated than others. TCDD was above detection limits in only 3 (10 percent) of the invertebrate samples, and was not detected in clam samples. TCDD was present in *Corophium* from the Lewis and Clark NWR at 1.4 pg/g, which is the only site that also had TCDD in sediment. In contrast, TCDF was detected in 28 (97 percent) of the invertebrate samples and ranged up to a maximum, estimated concentration of 10 pg/g in a Corbicula clam sample at Cathlamet Bay. Geometric means of TCDF in invertebrates were similar across sites, although crayfish at the Julia Butler Hansen NWR and Longview sites had higher means than in crayfish or invertebrates at other locations. TCDF also was found in most (63 percent) of the sediment samples collected. Dioxins and furans other than TCDF were rarely detected in invertebrate samples, with the exceptions of congeners 1,2,3,4,6,7,8-HpCDD (present in clams from most sites but not crayfish) and OCDD (present in clams from all sites and in crayfish from 50 percent of the sites sampled). Similar to the sediment results, OCDD was the most elevated congener in invertebrate samples.

Very little information is available regarding dioxin and furan concentrations in invertebrates from the lower Columbia River, and guidance values for the protection of fish and wildlife that consume invertebrates contaminated with dioxin and furans are unavailable for comparison. Crayfish (tail meat only) from Lake River, a side channel to the lower Columbia River near a wood treating facility at Ridgefield, had <0.01 pg TCDD/g and 0.01 pg TCDF/g on a dry weight basis (Foster et al. 1999). Tetra Tech (1994) found TCDD ranging from 0.27 to 1.0 pg/g in 15 of 27 crayfish sampled in 1991 and 1993. TCDD was detected at similar concentrations (0.3 and 1.2 pg/g) but with much less frequency in our study. The higher frequency of detection by Tetra Tech (1994) probably resulted from lower reporting limits. In our study, TCDF was present in all 17 crayfish samples ranging from 0.8 to 5.0 pg/g. Similarly, all 27 crayfish collected by Tetra Tech (1994) contained TCDF, although maximum concentrations were higher and ranged from 0.63 to 12.4 pg/g. The pentachloro- through octachloro-dibenzo-*p*-dioxins and dibenzofurans were primarily below the detection limits of 1.0 pg/g in our study, with the exception of OCDD, which ranged from <2.0 to 4.1 pg/g. In contrast, Tetra Tech (1994) found higher concentrations of these congeners in 27 crayfish samples, which included the following congeners: 1,2,3,4,6,7,8-HpCDD (0.42-5.21 pg/g for 11 samples); OCDD (1.62-79.1 pg/g for 14 samples); 1,2,3,7,8-PCDF (0.11-1.02 for eight samples); 2,3,4,7,8- PCDF (0.20-3.05 pg/g for 12 samples); 2,3,4,6,7,8-HxCDF (0.21-7.26 pg/g for 11 samples); 1,2,3,4,6,7,8-HpCDF (0.27-5.2 pg/g for eight samples); and OCDF (0.42 to 1.24 pg/g for six samples).

Fish

Organochlorine pesticides, total PCBs, and mercury

Most OC pesticides were at or below detection limits in fish sampled in 1990 and 1991. Low concentrations or low detection frequency for most OC pesticides were also reported for sucker, carp, and peamouth sampled from the lower Columbia River during the Bi-State Study in 1991 and 1993 (Tetra Tech 1994) as well as other fish species from the river (Schmitt et al. 1990, U.S. Environmental Protection Agency 1992). Similar to previous studies on fish from the Columbia River (Schmitt et al. 1990, Tetra Tech 1994, Foster et al. 2001a,b), the OC pesticide transformation products DDE and DDD were the most commonly detected and most elevated of

this group of contaminants. DDE was detected in all fish samples collected during both years of our study. Concentrations of the three DDT-related contaminants appeared higher in fish sampled in 1990 compared to 1991. In addition, DDT was present slightly above the detection limits in many species and was present in every river segment, indicating the pesticide still enters the system in its parent form. Similar to results from the Bi-State Study (Tetra Tech 1994) and results from white sturgeon (*Acipenser transmontanus*) liver samples from the Columbia River (Foster et al. 2001a), concentrations of OC pesticides or transformation products were not consistently elevated in any particular species or location. In contrast, Foster et al. (2001b) found DDE in white sturgeon gonad tissue was significantly higher in samples collected in the pool behind The Dalles Dam ($\bar{0}$=4.38 µg DDE/g wet weight, n=11) than in samples from the lower estuary ($\bar{0}$=1.45 µg DDE/g wet weight, n=7).

Concentrations of DDE reported in whole-body fish sampled from 1987 to 1989 by the U.S. Environmental Protection Agency (1992) during the NCRS were very similar to our 1990 results, with some exceptions. The DDE concentration in sucker sampled in our study at the St. Helens site was nearly identical to the concentration found in sucker at St. Helens during the NCRS (0.08 µg/g). However, our results in sucker from Longview was more than twice the concentration reported in sucker in the NCRS (0.11 µg/g). Although sucker were not analyzed at Camas Slough in our study, the concentration in sucker collected at the site during the NCRS (0.13 µg/g) was similar to the concentration we found in carp from the site, and was nearly half the value we observed in pikeminnow. At the Portland site in the NCRS, a composite carp sample had a slightly higher DDE concentration (estimated at 0.33 µg/g) than we found in carp in Portland. DDD and DDT concentrations were not reported for fish in the NCRS.

Concentrations of DDE reported by Tetra Tech (1994) in 1991 and 1993 samples ranged from 0.03 to 0.18 µg/g in 17 of 34 largescale sucker samples, 0.02 to 0.10 µg/g in 9 of 11 carp samples, and 0.08 to 0.48 µg/g in 7 of 10 peamouth samples (collected in 1991 only) from the lower Columbia River. These concentrations were very similar to those we found in the same species collected from the lower river segments in 1991, but were below most concentrations in fish collected in 1990. Although DDE concentrations were detected in all fish samples during both years of our study, Tetra Tech (1994) reported finding DDE in only 50 percent of sucker, 82 percent of carp, and 70 percent of the peamouth samples. Concentrations of DDT and DDD reported by Tetra Tech (1994) in largescale sucker, carp, and peamouth also were within the range we found. However, DDT was detected less frequently in carp and more frequently in peamouth in our study, which in part may reflect the lower detection limits for these compounds reported in the Bi-State Study.

Concentrations of DDE in all individual fish samples from 1990 exceeded the nationwide median concentration of 0.058 µg/g reported for various species sampled during the NCRS (U.S. Environmental Protection Agency 1992). In addition, the nationwide geometric mean of 0.19 µg/g (Schmitt et al. 1990) was exceeded for all species except pikeminnow at Cathlamet Bay and Longview; carp, sucker and largemouth bass at St. Helens; smallmouth bass at the Portland site; and carp at Camas Slough. The geometric means of the 1991 fish exceeded the NCRS median for all species at all sites except sucker from Lewis and Clark NWR, Julia Butler Hansen NWR, and Camas Slough, and in carp from Longview. Concentrations or geometric means for peamouth at all sites exceeded the national median reported in the NCRS. In contrast, geometric means for DDE at only one site (peamouth chub at Cathlamet Bay) exceeded the national geometric mean of 0.19 µg/g for various fish species reported by Schmitt et al. (1990), although concentrations in numerous individual samples exceeded this national mean.

All fish samples at all sites collected in 1990 contained DDE concentrations above the TFC guidance value considered protective of lower Columbia River bald eagles (Table 11; see equations 1 and 2 in the *Data Analysis* for derivation of TFCs), based on data collected from this study and U.S. Fish and Wildlife Service (1999a). Eight of the 15 fish samples also exceeded

the New York State Department of Environmental Conservation (NYSDEC) value of 0.2 µg/g considered protective of piscivorous fish and wildlife (Newell et al. 1987). At least one sample of all species sampled except smallmouth bass exceeded the NYSDEC value (Table 11). The HQ value (see equation 3) indicated that the average fish sampled in 1990 was six times the value in fish considered protective of bald eagles (Table 11), but most fish were at the level of hazard (HQ=1) for the NYSDEC protective value. The species exhibiting the greatest hazards to bald eagles based on high HQ values were peamouth chub (HQ=16) and sucker (HQ=6).

In the 1991 fish samples, DDE concentrations in 86 percent exceeded the TFC (Table 11). Only a few samples of sucker and carp were below the TFC, and all sites had concentrations in fish that exceeded the TFC for at least one species (Table 11). Fish posed a hazard to eagles that was an average of three times the protective TFC value, with the highest threats from mountain whitefish (HQ=4) and carp and sucker (HQ=3) (Table 11). Only five samples (carp from Umatilla and peamouth from Cathlamet Bay and Julia Butler Hansen NWR) exceeded the NYSDEC value for protection of piscivorous fish and wildlife, and average hazard to predators eating fish was below one based on the NYSDEC value (Table 11).

Results from the NCRS for total PCBs in fish samples were notably different than our results from 1990 for the same sites. In the NCRS study, concentrations of total PCBs in sucker from St. Helens, Longview, and Camas Slough were 0.13, 0.18, and 0.09 µg/g, respectively (U.S. Environmental Protection Agency 1992). Concentrations in sucker in our 1990 study were double the value of the NCRS results at St. Helens, and over three times the value from Longview. Sucker were not sampled at Camas Slough in our study, but concentrations in carp from the site were below detection and pikeminnow had a concentration (0.13 µg/g) slightly greater than the NCRS sucker value. In contrast, carp sampled in the Portland area in the NCRS study had a total PCB concentration of 2.04 µg/g (U.S. Environmental Protection Agency 1992), which was nearly nine times greater than concentrations found in carp and almost three times greater than what was found in smallmouth bass from the same area in our study. Total PCBs in 1990 fish samples were somewhat similar to the range found in fish samples during the Bi-State Study (Tetra Tech 1993a, 1994), although maximum values for sucker in the Bi-State Study (2.7 µg/g) greatly exceeded values for sucker in our study. Also, concentrations in peamouth (up to 0.11 µg/g) from the Bi-State Study were generally lower than concentrations in our study.

In 1991 fish samples, PCBs were most elevated in peamouth from Segment 1 (Cathlamet Bay), but at other sites concentrations among species were similar or PCBs were not detected. Total PCBs in carp and peamouth in our 1991 study were generally similar to concentrations in the Bi-State Study (Tetra Tech 1994), although peamouth concentrations from Cathlamet Bay were nearly double the range found in the Bi-State Study (total PCB concentrations were 0.04-0.27 µg/g in 7 of 11 carp sampled in 1991 and 1993, and 0.03-0.11 µg/g in all 10 peamouth sampled in 1991) (Tetra Tech 1993a). In contrast, total PCBs were not detected in any sucker sampled during our 1991 study, but were detected in nearly every largescale sucker sample in the Bi-State Study. PCB concentrations of selected congeners were very low in liver and gonad tissue samples from white sturgeon sampled at various Columbia River sites, including within the lower estuary and at upriver dam sites (Foster et al. 2001a,b).

Total PCBs were detected in 1990 samples of sucker and other species at higher concentrations than the 1991 samples (Tables 13 and 14). Variations in how total PCBs were calculated (sum of individual congeners versus Aroclor analysis) could have influenced concentration results between years or between studies. For example, total PCBs reported as the sum of individual congeners were detected in all suckers sampled in our 1990 study at concentrations up to 1.03 µg/g. In the Bi-State Study, total PCBs (reported primarily Aroclor 1254) were detected in 1991 and 1993 samples including 33 of 34 largescale suckers (0.03-2.7 µg/g), whereas Aroclor 1260 was detected less frequently (10 of 34 sucker samples) and in lower concentrations (0.03-0.13 µg/g) during the same sampling event. In our study, the congener PCB analysis had lower

detection limits (0.01 µg/g) compared to the Aroclor PCB analysis (0.05 µg/g), so there are more detections by summing the congeners. Although some differences between years could be explained by different methods of calculations for total PCBs, it is unclear why Aroclors 1254 and 1260 were detected in 1991 suckers collected by Tetra Tech (1994) and not detected in suckers collected in 1991 during our study.

Concentrations of total PCBs in all individual fish samples from 1990 exceeded the nationwide median concentration from the NCRS of 0.208 µg/g (U.S. Environmental Protection Agency 1992) at all sites except for pikeminnow at Cathlamet Bay, largemouth bass at St. Helens, and carp and pikeminnow from Camas Slough. In contrast, fish sampled in 1991 only exceeded the NCRS median value for total PCBs in peamouth chub at Cathlamet Bay and one carp sample at Umatilla. Schmitt et al. (1990) reported a nationwide geometric mean of 0.21 µg/g for Aroclor 1254, 0.15 µg/g for Aroclor 1260, and 0.39 µg/g for total PCBs for fish of various species sampled in 1984. Many individual samples from 1990 fish in our study exceeded even the highest nationwide means, yet very few of the fish sampled in 1991 exceeded these nationwide values.

Most fish (13 of 15) sampled from all sites in 1990 contained total PCBs above the TFC considered protective of lower Columbia River bald eagles, and exceeded the value of 0.11 µg/g (Newell et al. 1987) considered protective of piscivorous fish and wildlife (Table 11). HQs were very high in 1990 fish, ranging from four to 12 for the TFC-based HQ and two to seven for the NYSDEC-based HQs. The greatest hazard to fish-eating predators came from smallmouth bass and peamouth chub (Table 11). In the 1991 samples, total PCBs in 67 percent of the carp samples and 44 percent of the peamouth samples exceeded the TFC, and 42 percent of the carp and 38 percent of the peamouth samples exceeded the NYSDEC value derived by Newell et al. (1987). Sucker and whitefish were the only fish not having concentrations exceeding these values (Table 11). The magnitude of exceedances in 1991 fish was much lower than the in previous year, with carp and peamouth having the highest HQ (double the protective TFC value).

Total mercury concentrations were quite variable among fish in 1990, ranging from <0.07 to 1.1 µg/g. Mercury exceeded a nationwide geometric mean of 0.10 µg/g (Schmitt and Brumbaugh 1990) in four of the seven samples with detectable concentrations. In contrast to the 1990 samples, mercury concentrations were relatively similar among fish species and consistent across sites in 1991. Mercury was present in 48 of 51 samples in 1991, maximum values did not exceed 0.23 µg/g, and concentrations in many fish samples were below the nationwide geometric mean (Schmitt and Brumbaugh 1990). In 1990 fish, mercury results indicated there was a trend toward higher concentrations of mercury in predatory fish (peamouth and pikeminnow) compared to the nonpredatory fish such as carp (as exemplified by the increasing HQ values in the more predatory fish), whereas 1991 samples did not show much difference between nonpredatory fish (sucker and carp) and predatory fish (peamouth and whitefish).

The NCRS reported median mercury concentrations in sucker as 0.05 µg/g at St. Helens, 0.36 µg/g at Wauna, 0.05 µg/g at Longview, and below detection limits at Camas (U.S. Environmental Protection Agency 1992). Sucker were not sampled for mercury in 1990 in our study, but the 1991 values for most sucker were within the range of the NCRS median concentrations. An exception was the high median concentration (0.36 µg/g) of mercury reported by the NCRS at the Wauna site. This concentration at Wauna was higher than any sample collected in our study in 1991, but more similar to concentrations in our pikeminnow samples in 1990 from nearby Longview (0.39 µg/g), St. Helens (1.1 µg/g), and Camas Slough (0.32 µg/g). Carp collected from the Portland site in the NCRS had mercury concentrations at 0.1 µg/g (U.S. Environmental Protection Agency 1992), whereas carp from the Portland site collected in 1990 in our study were <0.07 µg/g. In the Bi-State Study, mercury was found in all 34 largescale sucker samples from 0.022 to 0.264 µg/g, in 9 of 10 carp from 0.056 to 0.166 µg/g, and in all 10 peamouth samples from 0.054 to 0.23 µg/g (Tetra Tech 1993a). Concentrations in

fish sampled during our 1990 and 1991 study were within the ranges reported in the Bi-State Study, with the exception of the elevated concentrations found in pikeminnow at the Longview and St. Helens sites in 1990.

Total mercury concentrations in 40 percent of the fish sampled during both years in our study exceeded the level of 0.1 µg/g (Eisler 1987) in food items considered protective of avian species. The average hazard to fish predators was three times this protective level in 1990 fish, and northern pikeminnow posed the greatest hazard of up to five times the protective level (Table 11). Fish concentrations in 1990 averaged three times greater than the mercury TFC level derived to protect bald eagles. In 1991 fish, the mercury HQ did not exceed one for either the 0.01 µg/g protective level or the TFC, indicating fish concentrations were mostly at the protective level or below (Table 11). However, mercury did exceed the 0.01 µg/g protective level during both years of the study in at least one sample of each species at all locations except the Portland site. Nearly all samples exceeded the critical value (threshold above which risk could be expected for certain segments of piscivorous bird populations) derived by the Great Lakes Water Quality Initiative of 0.02 µg/g for methylmercury (as reviewed by Yeardley et al. 1998). The total mercury analysis may result in greater concentration results compared to a methylmercury analysis, but mercury in fish tissue is predominantly (95 - 100 percent) methylmercury (Bloom 1992).

Results from our study did not indicate mercury in fish was a threat to lower Columbia River bald eagles, as concentrations in most fish did not exceed the TFC of 0.2 µg/g and the corresponding HQ values were primarily at one or below (Tables 11 and 24). Results from the NCRS, Bi-State Study, and our study indicate that mercury is consistently found in samples at all locations, and may be more available to fish in the areas near Wauna, St. Helens, and Longview. This segment of the river was identified by Rosetta and Borys (1996) as receiving high mercury suspended sediment loading, primarily as a result of discharges from numerous point sources and sewage releases including pulp and paper mills located Wauna, St. Helens, and Longview. High loading of mercury in this area from regulated point discharges could have contributed to the higher concentrations found in the fish species present in the area. Non-point sources of mercury in Oregon include natural cinnabar deposits and, secondarily, atmospheric deposition (Allengil et al. 1995; Buhler et al. 1973 as cited in Newell et al. 1996).

Dioxins and furans

Dioxins and furans were detected relatively frequently and at all sites in fish sampled in 1990 and 1991. Dioxins and furans also were commonly detected in various fish species reported in the NCRS (U.S. Environmental Protection Agency 1992) and in carp collected near a wood treating facility and a bleached kraft pull mill in the lower Columbia River (Foster et al. 1999). Concentrations (rounded to two significant digits) of TCDD and TCDF, respectively, in sucker from the NCRS were 2.8 and 16 pg/g at Wauna, 5.2 and 28 pg/g at Longview, 2.6 and 11 pg/g at St. Helens, and 2.3 and 16 pg/g at Camas. TCDD and TCDF concentrations in sucker in the NCRS were relatively similar to our results in 1990 for carp and pikeminnow in the lower river. However, TCDD and TCDF in pikeminnow from St. Helens in our study were much greater (9.0 pg/g) than in sucker samples at the same site in the NCRS. In addition, TCDD in carp from Portland in the NCRS was much higher (2.9 pg/g) than carp concentrations (<1.0 pg/g) from the Portland site in our study, but TCDF concentrations were similar (4.1 pg/g in the NCRS and 5.0 pg/g in our study).

The congeners most commonly detected and elevated in sucker from the lower Columbia River in the NCRS (excluding OCDD and OCDF, which were not evaluated) were TCDD, TCDF, and 1,2,3,4,6,7,8-HpCDD; other congeners were below 1 pg/g in sucker (U.S. Environmental Protection Agency 1992). In contrast, nearly all congeners in the NCRS were above 1 pg/g or elevated compared to other samples in carp from the Portland site, including TCDD; TCDF; 1,2,3,7,8-PCDD; 1,2,3,6,7,8-HxCDD; 1,2,3,7,8,9-HxCDD; 1,2,3,4,6,7,8-HpCDD; 2,3,4,7,8-

PCDF; 1,2,3,4,7,8-HxCDF; 2,3,4,6,7,8-HxCDF; and 1,2,3,4,6,7,8-HpCDF (U.S. Environmental Protection Agency 1992). The difference in accumulation patterns between the Portland carp and the Columbia River sucker in the NCRS study indicates the fish in the two rivers are exposed to the compounds from different sources. However, both carp and pikeminnow from the Portland site in our study had much lower values of dioxin and furan congeners, and the concentrations were similar to fish from some of the lower Columbia River sites.

During the Bi-State Study, dioxins and furans were the most frequently detected organic compounds in fish and were widely distributed throughout the lower river, although detections were much more common in fish during the main channel study (Tetra Tech 1993a) compared to the backwater study (Tetra Tech 1994). In these studies, TCDD was detected in 14 of 28 largescale sucker at concentrations ranging from 0.49 to 1.56 pg/g, in five of seven carp ranging from 1.28 to 2.1 pg/g, and in all seven peamouth (sampled in 1991 only) from 1.44 to 4.41 pg/g. TCDF was found in 27 of 28 largescale sucker from 1.6 to 11.4 pg/g, in all seven carp ranging from 3.6 to 12.2 pg/g, and in all seven peamouth ranging from 22.2 to 58.8 pg/g (Tetra Tech 1994). Peamouth chub had the highest concentrations of TCDD and TCDF (Tetra Tech 1994). The concentrations of TCDD and TCDF in sucker, carp, and peamouth sampled from the lower river in our study in 1991 were very close to the Bi-State Study ranges, although our maximum TCDD and TCDF concentrations were observed in carp samples from Umatilla. Likewise, concentrations of the penta- through octa- chlorinated dioxins and furans were similar between the studies, but the lower reporting limits used in the Bi-Sate Study resulted in a much greater frequency of detection for these compounds.

Foster et al. (1999) found dioxins and furans in whole body carp collected in 1991 from a lower Columbia River side channel (Lake River) near a wood treating facility (WTF), and in the main stem near Wallula, Washington (around river mile 305 to 315) near a bleached kraft pulp mill (BKM). Mean dry weight concentrations of TCDD and TCDF in four carp near the WTF were 1.0 and 2.8 pg/g, respectively, and from the BKM were 4.7 pg/g and 22.1 pg/g, respectively (Foster et al. 1999). Mean dry weight concentrations of TCDD and TCDF in three composite carp samples collected in 1991 in our study from Lake River at the Ridgefield NWR site were higher (3.7 pg TCDD/g and 11.9 pg TCDF/g) than in carp sampled in from the WTF site. Carp (n=3 composite samples) sampled downstream from Wallula at RM 274 to 286 in our study also contained higher mean concentrations of TCDD and TCDF (48 and 147 pg/g dry weight, respectively) than the BKM carp sampled by Foster et al. (1999). However, the TCDF values in our study near Wallula are suspect due to interference with co-eluting diphenyl ethers, and are likely overestimated.

Distinct differences in dioxin and furan concentrations among sites were not apparent. Similarly, Tetra Tech (1993a) found that dioxin and furan tissue concentrations downstream of paper mills were not substantially elevated above those measured at other sites in the river (Tetra Tech 1993a). However, Foster et al. (1999) found significantly higher concentrations of TCDF, but not TCDD, in carp samples from the mill site near Wallula compared to the wood treating site in the lower river. In our 1990 samples, concentrations were relatively similar across sites, although carp sampled at Longview showed consistently elevated concentrations of numerous dioxins and furans compared to fish at other sites. Likewise, sucker from Longview in the NCRS study had the most elevated concentrations of TCDD and TCDF compared to sucker from other sites (U.S. Environmental Protection Agency 1992). However, our 1990 congener concentrations in pikeminnow at the Longview site were more similar to concentrations in pikeminnow and carp from the other sites. In addition, this pattern of higher concentrations at Longview was not observed in fish sampled in 1991 in our study, although congeners other than TCDD and TCDF were not analyzed in carp sampled in 1991.

In comparison to other studies, our 1991 results revealed the highest values for TCDD and TCDF reported for any fish species on the Columbia River. These values (12 and 33 pg/g for

TCDD and estimated concentrations of 25 and 110 pg/g for TCDF) were found in two composite carp samples from Umatilla, a site that was not sampled in other investigations except by Foster et al. (1999), who also found elevated dioxins and furans in carp sampled just upstream of Umatilla. In addition, very high TCDF concentrations were present in 1991 samples of carp and peamouth from all sites along the river, which were higher than reported in previous investigations. However, TCDF for most carp and peamouth samples was estimated as a maximum possible concentration due to interfering compounds in the tissue matrix (see Tables 5 and 16), so the results are likely inflated and should be considered as high estimates. Tetra Tech (1994) experienced similar problems with the TCDF analysis and qualified five of their fish sample results as estimated due to high matrix spike recoveries and interferences during analysis. It is unknown why TCDD and TCDF were elevated in the carp samples from the Umatilla Segment, as other fish species sampled at Umatilla did not exhibit such high concentrations. Two carp samples at this site exhibited high lipid concentrations (up to 14.5 percent) compared to other fish (see Appendix A), which indicates concentrations of lipophilic contaminants would be higher in these samples. Also, one carp within one of the three composite samples weighed over 5 kg, which was nearly five times as much as the other fish in the composite sample (Table 4). The composite sample containing the most elevated concentrations of OC compounds included this single fish, which likely contributed a much greater concentration of OC compounds due its size and age compared to the other fish in the composite.

In 1990 fish, seven samples (78 percent) of carp and pikeminnow contained TCDD an average of five times higher than TFC value of 0.9 pg/g considered protective of bald eagles consuming fish in the lower Columbia River, and an average of four times the dietary NOAEL (Giesy et al. 1994) of 0.6 pg/g derived from Lake Huron fish fed to chickens and considered protective of bald eagles in the Great Lakes (Table 11). TCDF also exceeded the TFC in seven fish samples (78 percent) and exceeded the Great Lakes dietary NOAEL in eight samples (89 percent) (Table 11). In 1991, nearly all fish samples containing detectable concentrations of TCDD exceeded both the TFC and the dietary NOAEL for protection of bald eagles, with pikeminnow having the greatest HQ or posing the greatest hazard to fish predators (Table 11). All fish samples with detectable TCDF concentrations appeared to exceed the dietary NOAEL considered protective of bald eagles in the Great Lakes and most samples exceeded the TFC (Table 11), but the actual concentration of TCDF in some samples was unknown due to matrix interference. Samples exceeded at least one guideline value at all sites where fish were collected (Table 11).

Bird Eggs

Organochlorine pesticides, total PCBs, and mercury

DDE was the most frequently detected of the OC pesticides in bird eggs; most other pesticides were near or below detection limits. Wet weight concentrations (unadjusted for moisture loss) of these contaminants in the 1991 Caspian tern eggs collected from Crescent Island during our study were previously reported by Blus et al. (1998). DDE was detected in all piscivorous bird eggs in 1990 except for one cormorant egg and one Caspian tern egg, in all piscivorous bird eggs collected in 1991, and from nearly all (10 of 11) non-piscivorous bird eggs in 1991 (Table 11). In the piscivorous birds sampled in 1990, mean DDE was low and similar among cormorant, Caspian tern, and gull species sampled from Rice Island, whereas concentrations were much higher in eggs from Caspian terns and ring-billed gulls from Crescent Island. Caspian tern eggs from Crescent Island had the highest DDE concentrations of all eggs sampled in 1990. Concentrations of OC pesticides and total PCBs in the 1990 eggs of Forster's terns in our study were similar to wet weight concentrations in 1991 eggs of Crescent Island Forster's terns reported by Blus et al. (1998), although total PCBs were slightly higher in the 1990 eggs. DDE concentrations in most bird eggs in 1990 were similar to concentrations in great blue heron (*Ardea herodias*) eggs collected from lower Columbia River colonies in 1994 and 1995 (Thomas and Anthony 1999), but the 1991 values of DDE in terns and cormorants were higher.

The non-piscivorous birds (mallard and Canada goose), sampled in 1991 had the lowest concentrations of DDE compared to the other birds, although concentrations in mallard in 1991 were similar to concentrations observed in some piscivorous bird eggs from Rice Island in 1990. Canada goose eggs had the lowest DDE concentrations, which reflects the species' herbivorous diet. In 1991, DDE was highest in cormorant eggs from Rice Island, followed by Caspian tern eggs from Crescent Island. The U.S. Fish and Wildlife Service (1999b) compared cormorant eggs between Rice Island and East Sand Island from 1990 to 1995 and found no significant difference in DDE concentrations except in 1995 when DDE was higher in Rice Island eggs. DDE was frequently detected in fish sampled in Segment 1 and the upriver reaches at Umatilla, indicating the contaminant is readily available to fish-eating birds and is likely biomagnified in the food chain. However, it is unknown why DDE concentrations were so low in eggs from the three piscivorous bird species sampled at Rice Island in 1990. Much higher DDE concentrations were observed in these three species in 1991, and in double-crested cormorant eggs collected from the island in subsequent investigations (U.S. Fish and Wildlife Service 1999b).

Total PCBs were detected in nearly all eggs, including most eggs of non-piscivorous birds (Table 11). Only two eggs from ring-billed gulls in 1990, and two eggs from Canada goose in 1991, did not have detectable concentrations of total PCBs. The non-piscivorous birds had the lowest concentrations of total PCBs compared to piscivorous birds, with concentrations in eggs similar to fish sampled in 1991. Double-crested cormorants from Rice Island had the most elevated concentrations of total PCBs during both years of the study, and the geometric mean in 1991 was up to three times higher than other species. In 1991, double-crested cormorant egg concentrations appeared higher in samples from Rice Island compared to cormorants from East Sand Island, and this difference was reported as significant for the 1991 samples and in cormorant eggs collected in subsequent years from both islands (U.S. Fish and Wildlife Service 1999b). Caspian tern egg concentrations were similar between Rice and Crescent Island samples in 1990, but concentrations were much higher in nearly all of the tern eggs from Rice Island than Crescent Island in 1991. Great blue heron eggs collected from the lower Columbia River in 1994 and 1995 (Thomas and Anthony 1999) had total PCB concentrations lower than or similar to values in cormorants, terns, and gulls nesting outside of Rice Island. The cormorants, terns, and gull species sampled within Segment 1 from the lower river (East Sand Island and Lewis and Clark NWR) and the upriver region at Umatilla showed substantial bioaccumulation of total PCBs, even though fish sampled from the same river reaches revealed little total PCB contamination. This suggests that small amounts of PCBs in fish, even at levels near or below detection, could accumulate and possibly impact upper trophic level species.

Total PCBs in three eggs from double-crested cormorants collected from Rice Island in 1990, and three eggs collected in 1991, exceeded estimated NOAELs based on egg lethality in cormorant eggs (Tables 7 and 11) (Tillitt et al. 1992, Yamashita et al. 1993). Concentrations of DDE in one Caspian tern egg in 1990, and in five Caspian tern and four cormorant eggs in 1991, exceeded the range of values associated with embryo death and reproductive impairment related to shell structure in common terns in Alberta (Fox 1976) (Table 11). Average HQs for these samples did not exceed one. Average HQs for all other bird species were below one for DDE and total PCBs in both years (Table 11). In non-piscivorous birds (mallard and goose), egg concentrations of total PCB or DDE did not appear to pose a hazard based on the available guidance values (Table 11).

All bird eggs sampled contained mercury, although piscivorous birds had much higher concentrations than non-piscivorous birds. The highest mercury values were found in cormorant and Caspian tern samples from the lower river (Segment 1) in 1991. In contrast to the results for DDE and total PCBs, cormorants nesting on East Sand Island near the mouth of the river at Baker Bay had the maximum contaminant concentrations. This indicates that mercury may be deposited and more available near the mouth of the river, whereas the OC contaminants could be more evenly distributed throughout the river. However, mercury in fish did not show consistent

trends in the lower river, and fish were not collected from Baker Bay. Mercury concentrations in a number of eggs from piscivorous birds were within the range of, or exceeded, the concentrations in eggs (Eisler 1987) associated with impaired reproduction in various bird species (Table 11). These samples included: (1) four Caspian tern eggs (two each from Rice and Crescent Islands) in 1990; (2) two western/glaucous-winged gulls (one each from Rice and East Sand Islands) in 1991; (3) six eggs from Caspian terns (three each from Crescent and Rice Islands) in 1991; and (4) six cormorant eggs (three each from Rice and East Sand Islands) in 1991 (Table 11). Double-crested cormorant and Caspian terns sampled in 1991 exhibited the greatest threat from mercury with HQ values double the protection levels for these species (Table 11). Most other species did not have HQs that exceeded one. Hazard from mercury concentrations in eggs of non-piscivorous birds were below levels of concern (Table 11).

Dioxins and furans

Most species of colonial nesting birds accumulated dioxins and furans, particularly TCDD, although concentrations in ring-billed gulls at Umatilla were rarely above detection limits. Similarly, Thomas and Anthony (1999) reported elevated concentrations of various dioxins and furans, especially TCDD, in eggs of great blue herons collected from the lower Columbia River in 1994 and 1995. Previous studies reported abnormalities in developing heron or tern embryos that could be associated with dioxin-like contaminants, but deformity rates were low and relationships to contaminants were inconclusive (Blus et al. 1998, Thomas and Anthony 1999).

Cormorants from Rice Island in 1990 had the highest egg concentrations of TCDD compared to any other species sampled in the river, yet cormorant eggs sampled in 1991 from the same location were well below the 1990 values. Higher TCDD concentrations in 1990 were not apparent in other bird species sampled at Rice Island; TCDD was similar in Caspian tern eggs between years, and was higher in 1991 gull eggs compared to 1990. The difference in cormorant results could be attributable to differences in analytical methods used to quantify TCDD and TCDD. As noted in Table 5, TCDD and TCDF in 1990 cormorant eggs were sampled using HRGC/LRMS, which has different selectivity and is more prone to interferences than is the HRGC/HRMS method used to analyze cormorant eggs in other years. Although QC limits were acceptable for the method for these samples, we considered the 1990 cormorant values as suspect data which could be overestimated.

Maximum TCDD concentrations occurred in cormorant eggs during both years of the study; one sample from Rice Island in 1990 and the other from East Sand Island in 1991. Ring-billed gulls were the only species with egg concentrations of TCDD below 1 pg/g in 1990 and 1991. Although high TCDD concentrations were observed in Caspian tern samples from Crescent Island, TCDD was more consistently detected at higher concentrations within the lower Columbia River at Rice Island.

TCDF accumulated in colonial nesting birds to a lesser degree than TCDD. Egg concentrations in 1990 were relatively low, although one Forster's tern egg had an estimated concentration of 50 pg/g. Eggs collected in 1991 from birds other than Caspian terns were below 1 to 2 pg/g. In Caspian tern eggs, TCDF was present at similar concentrations between sites and years. The relatively low TCDF values in eggs are in direct contrast to the exceptionally high TCDF concentrations in most fish samples from this study, although TCDF in many fish samples were estimated due to interference with diphenyl ethers. Kubiak et al. (1989) reported little bioaccumulation of TCDF in Forster's terns in the Great Lakes, indicating that the colonial nesting birds have the ability to metabolize TCDF compounds.

The penta- through octa- chlorinated dioxins were detected relatively infrequently, with 1,2,3,7,8-PCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,4,6,7,8-HpCDD, and OCDD most common in 1990 eggs (eggs collected in 1991 were only analyzed for TCDD and TCDF). Concentrations of the penta- through octa- chlorinated dioxins were detected at similar or higher concentrations in fish

sampled in 1990, although values in the carp sample from Longview were well above the bird egg concentrations. Aside from OCDD, the penta- through octa- chlorinated dioxins were not detected in fish sampled in 1991, and the penta- through octa- chlorinated furans were detected in only three eggs from colonial nesting birds in 1990. In contrast, fish sampled during this study had highly elevated TCDF concentrations, but most other furan congeners were below detection. It appears that the penta- through octa- chlorinated dioxins and furans other than OCDD are not transferred to higher tropic levels, or are metabolized by colonial nesting seabirds.

In 1990, estimated TCDD concentrations in three cormorant eggs, and TCDF in two cormorant eggs, from Rice Island were above the NOAELs for dioxin-like compounds measured as TCDD-equivalents (TCDD-EQs) recommended by Giesy et al. (1994) in the Great Lakes to protect double-crested cormorants (Table 11). HQs in 1990 eggs were only above one for the cormorant samples for TCDD. In 1991, TCDD in eight (27 percent) of the eggs analyzed exceeded NOAEL levels for TCDD-EQs (Table 11). Seven of these samples were double-crested cormorant eggs (four from Rice Island and three from East Sand Island), and one was from a western/glaucous-winged gull from Rice Island (Table 11). The cormorant HQ values were double the NOAELs, but average HQs for other species were below one (Table 11). The TCDF concentration in one egg sample in 1991 from a Caspian tern at Rice Island exceeded the TCDD-EQ NOAEL values (Giesy et al. 1994), but TCDF in other samples was below these values and average HQs were less than for all species sampled (Table 11). The contribution of individual dioxins, furans, or planar PCBs toward the overall dioxin-like activity (TCDD-EQs) was not determined due to lack of sufficient congener-specific results. Therefore, if these contributions are included, the resulting concentration in an egg could exceed the NOAEL guidance values for species other than cormorants.

Contaminants Within River Segments

Fish and bird eggs had the greatest detection frequencies of DDE, total PCBs, TCDD, and TCDF compared to invertebrates and sediment, yet results did not indicate that some individual river segments contributed disproportionately more than others to the overall loading or body burdens of these contaminants (Figure 7). Some individual contaminants were more common in various river segments when all sampling matrices were combined within a river segment (Figure 8). For instance, total PCBs and TCDD were more common in Segment 1 and at Umatilla, whereas DDE was more evenly detected among all river segments. In contrast, TCDF was found most commonly in Segments 2 and 3, and least in Segment 4 and Umatilla. These results suggest that most OC contaminants are evenly distributed in fish and wildlife in the river, and no individual river segment contributes more contaminants into the system than other segments. Therefore, contaminants likely enter the system from numerous locations or tributaries along the river, and the hydrodynamic and transport processes that differentiate the river segments have minimal influence on contaminant distribution and uptake. However, the number of samples used in this analysis was not consistent across all river segments, and this could influence the magnitude of detection frequencies and slightly bias the observed trends in the results.

Other studies also have reported inconsistent results when attempting to associate contaminant burdens to particular river reaches. The Bi-State Study found no clear spatial trends in concentrations of OC pesticide, total PCBs, and mercury contaminants in the lower Columbia River (Tetra Tech 1993a, 1994). For dioxins and furans, the Bi-State Study reported that concentrations were roughly similar at all sites, although sites within the Lewis and Clark NWR typically had more detections and had the highest concentrations in comparison to other sites. Results from semi-permeable membrane devices (SPMDs) deployed in the river in 1997 and 1998 indicated dioxins, furans, PCBs, OC pesticides, and polyaromatic hydrocarbons were prevalent throughout the Columbia River basin, with the highest concentrations associated with the Portland-Vancouver urban area (McCarthy and Gale 2001). High concentrations of these

contaminants were found at the mouths of tributaries, but tributary discharge could not account for the total contaminant loading in the mainstem and sources other than tributaries were considered important. Distinct areas of contamination in the Columbia River mainstem outside the Portland-Vancouver area could not be clearly isolated, but SPMDs were not deployed below RM 39 (McCarthy and Gale 2001).

Biomagnification Factors

Site-specific BMFs were derived with empirical data of chemical concentrations in forage fish (carp, peamouth, and suckers) relative to the chemical concentrations in bald eagle eggs collected from the same river segments as the fish (see equation 1 in the *Data Analysis* section). These site-specific BMFs were also derived from data collected in the Bi-State Study (Tetra Tech 1993b,c) for comparative purposes. Total BMFs for most river segments in our study were very similar to those calculated using the Bi-State fish samples for mercury, TCDD, and TCDF, but different for total PCBs and DDE (Table 23). In all river segments, the BMFs for total PCBs in our study were higher than the Bi-State BMFs, and our BMFs were lower for DDE. These differences were primarily a result of skewed data for DDE and total PCBs in either the Bi-State data or our data when results of the three fish species sampled were combined within a study. Specifically, the 1991 Bi-State fish sample results included numerous sucker samples that were below detection limits for DDE, whereas DDE in our study exceeded detection limits in all fish species. For total PCBs, all fish samples in the Bi-State Study were above detection, whereas the results in our study included many values below detection for all suckers and some other fish samples. The values included in the combined data within either study that were below detection resulted in a lower overall mean for the fish samples, and a higher BMF for a particular compound. Therefore, the actual BMFs for DDE and total PCBs may be somewhere between the values reported for our study and the Bi-State Study. Consequently, TFC values for total PCBs and DDE reported here are the average of TFCs calculated in the Bi-State study and our study, which resulted in values of 0.06 µg/g for total PCBs and 0.04 µg/g for DDE. In contrast to the differences in DDE and total PCB TFCs between the studies, the TFCs for TCDD, TCDF, and mercury derived using the Bi-State data were very similar to those derived using our data.

BMFs were similar and within an order of magnitude among segments for most compounds evaluated, but varied among segments for total PCBs (Table 23). Bald eagle diets have been evaluated for birds nesting in Segment 1 (Watson et al. 1991) but the diet of birds nesting in upriver segments has not been evaluated and could be different due to greater abundance of migratory and resident birds available at the mouth of the river. A higher percentage of birds in the diet could influence BMF values for eagles at nests located near the mouth, but for most of the compounds the data indicate similar BMF values among the various segments. This supports earlier work on lower Columbia River bald eagles nesting in Segment 1 that indicate fish are a primary component of the diet, especially during the breeding season (Watson et al. 1991).

Braune and Norstrom (1989) derived apparent BMFs for OC compounds transferred from forage fish to the herring gull (*Larus argentatus*) and herring gull eggs in the Great Lakes. The authors determined that BMFs from forage fish to egg for DDE, total PCBs, and TCDD were 32, 34, and 21, respectively. These BMF values are lower than our results for the same compounds, and may reflect species differences or the higher trophic status and more diverse diet of the bald eagle compared to the strictly piscivorous diet of the gull. The authors did not report a forage fish to egg BMF for TCDF because the compound was not detected in the gull eggs. BMFs from whole body forage fish to whole body gull were 85 for DDE, 93 for total PCBs, 32 for TCDD, and 1.3 for TCDF. Our results indicate that forage fish to egg BMFs for total PCBs and DDE are much higher in the lower Columbia River food chain than in the Lake Ontario food chain, and are more similar to the BMFs for forage fish to whole body gull. In contrast, the BMF value for TCDD from forage fish to egg was very similar between the two studies.

Henny et al. (2003) derived BMFs from forage fish to osprey (*Pandion haliaetus*) egg in the Willamette River, Oregon, and found values of 87 for DDE, 11 for total PCBs, 10 for TCDD, and 0.42 for TCDF. The BMF from fish to osprey egg for DDE and TCDD are similar to values found from forage fish to eagle in our study, but the osprey BMFs for PCBs are lower (Table 23). Differences in deriving total PCBs in fish and eggs in the studies may account for some of the differences observed between osprey and eagle BMFs, as total PCBS were reported based on summation of congeners for the osprey and reported as Aroclor PCBs for eagles. Both studies revealed a low potential for TCDF to bioaccumulate from fish prey to bird eggs, although the BMF for TCDF was about five times higher than for osprey (Table 23).

Thomas and Anthony (1999) found variability in field-derived BMFs from forage items to great blue heron eggs among colonies on the lower Columbia and Willamette Rivers. Forage BMFs for DDE, total PCBs, TCDD, and TCDF were low for all great blue heron colonies except at Karlson Island in the lower Columbia River where values were quite similar to BMFs found in our study. In the heron study, forage items consisted of prey collected below nest trees. These forage items experienced some degree of dessication, so the BMFs may not be directly comparable to the BMFs derived in our study which were based on fish captured live from the river.

The TFCs derived for the protection of bald eagles consuming prey fish were similar to guidance values reported in other studies, with some exceptions (Tables 7 and 11). TFCs for total PCBs and DDE were much lower than guidance derived for these chemicals to protect piscivorous birds in New York (Newell et al. 1987). The NYSDEC value was two and four times higher for total PCBs and DDE, respectively. In contrast, the TFC derived for TCDD was very similar to the guidance value for TCDD-EQs (Tables 7 and 11). However, the TFC derived from our data did not include contributions of other dioxin-like constituents and should only be used as a guidance value to evaluate TCDD concentrations independently of other dioxin-like compounds. The mercury TFC was about double the guidance considered protective of avian species in other studies (as reviewed by Eisler 1987), which reflects a greater sensitivity of some avian predators to mercury compared to bald eagles. However, the mercury TFC derived in our study of 0.2 µg/g was similar to the EPA fish tissue criterion for methylmercury of 0.3 µg/g (U.S. Environmental Protection Agency 2001), which suggests that bald eagles could be a good surrogate to humans as an indicator of mercury impacts to water quality in the Columbia River.

SUMMARY

In this investigation, we evaluated persistent, bioaccumulative contaminants in sediment, invertebrates, fish, and eggs of piscivorous and non-piscivorous birds collected in 1990 and 1991 from various locations in the lower Columbia River below Bonneville Dam, in the middle Columbia River at Umatilla, and at one location in the lower Willamette River at Portland. Four NWRs were included among the sampling locations to determine if contaminants threatened natural resources using these important protected areas. Contaminant concentrations (geometric means and maximum values) were compared across sites and river segments for indications of spatial differences, and the frequency of detection of selected contaminants was compared within a sample matrix. In addition, the number of samples exceeding reference or estimated guidance values, the magnitude of the exceedances as measured by HQs, and the locations where exceedances occurred were identified. We also derived BMFs and TFCs to evaluate trophic transfer of contaminants in the food chain.

Few sediment or invertebrate samples collected from depositional areas in our study or in concurrent studies contained OC pesticides or total PCBs, and spatial trends in concentrations were not apparent. DDE was the most commonly detected chemical in sediment and was detected in nearly all Corbicula clam samples. The highest concentration of DDE in Corbicula,

and the only detection of DDE in sediment that exceeded guidance values, occurred at the Julia Butler Hansen NWR beach area. Elevated concentrations of total PCBs were found in Corbicula clams from this site as well, but not in sediment. Sediment and invertebrate concentrations of dioxins and furans were near or below detection limits, and detectable concentrations were most common at the Julia Butler Hansen and Lewis and Clark NWRs. Guidance or protection levels for clams or clam predators for OC compounds are unavailable for comparison. Mercury was detected in all invertebrate tissues sampled, but was below estimated guidance values for the protection of avian predators.

Similar to the sediment and invertebrate results, most OC pesticides were infrequently detected in fish, and DDE was the most commonly detected compound. Total PCBs also were commonly detected in fish, but were primarily below detection in sediment and invertebrates. For unknown reasons, total PCBs were conspicuously below detection in all sucker samples collected in 1991, even though all sucker sampled in 1990 and in a concurrent study contained total PCBs.

Guidance values for the protection of avian predators such as bald eagles were exceeded in all fish sampled for DDE, and in nearly all fish with detectable total PCB concentrations. Exceedances in fish ranged up to 16 times the protective value for bald eagles in 1990, but did not exceed two for total PCBs or four for DDE in 1991. DDE and PCB concentrations exceeded guidance values at all sites, indicating these contaminants were widespread in the river. DDE in most fish samples, and total PCBs in the 1990 fish samples, exceeded mean concentrations reported in nationwide comparison studies. However, few fish sampled in 1991 exceeded the nationwide means for total PCBs. DDT also was present in a number of species within every river segment sampled, indicating the pesticide still enters the river in its parent form.

Mercury was found in nearly all fish sampled from the river, although less than half the samples exceeded guidance values for the protection of avian predators. Average HQs in fish were three times the value estimated to protect fish-eating species in 1990, but HQs did not exceed one in 1991. Hazard quotients were much higher in the predatory fish than fish at lower trophic levels in 1990, but no difference was observed in 1991 fish. Mercury in fish in our study and concurrent studies indicated that the element was most prevalent in fish near Wauna, St. Helens, and Longview.

Dioxins and furans, especially TCDD and TCDF, were found in all species of fish sampled, but differences in concentrations among sites were not apparent. Nearly all fish with detectable concentrations of TCDD and TCDF exceeded guideline values derived for the protection of bald eagles in the Great Lakes, and the majority of samples exceeded TFCs derived in this study for the protection of bald eagles in the lower Columbia River. Carp sampled in 1991 from the Umatilla site had the highest concentrations of TCDD, and the highest estimated values of TCDF, for any fish species sampled on the Columbia River. It is unclear why the carp samples were so elevated, as other fish species at this site did not contain similarly high concentrations. High lipid values and large mass of fish within the composite sample from this site could be partly responsible for the high concentrations of the lipophilic contaminants.

Contaminant concentrations in eggs of most species of piscivorous birds sampled were much greater than in species lower in the food chain, whereas concentrations in non-piscivorous bird eggs were within the range of concentrations found in fish. As in other tissues sampled, DDE was the most frequently detected compound, and total PCBs were detected in nearly all samples of piscivorous and non-piscivorous birds. Some concentrations of DDE exceeded estimated NOAELs at Rice and East Sand Islands in double-crested cormorant eggs, and at Rice and Crescent Islands in Caspian tern eggs. Total PCBs exceeded NOAELs for nearly half the double-crested cormorant eggs at Rice Island. Mercury was found in eggs of all birds, and exceeded estimated guidance values for some eggs of Caspian terns at Rice and Crescent Islands, and in eggs of double-crested cormorants and western/glaucous-winged gulls at Rice and East

Sands Island. However, average HQs for birds species rarely exceeded one for most species, indicating most values are near the protective values. Dioxins and furans, especially the tetra-substituted congeners, were present in the majority of piscivorous bird eggs collected (these compounds were not evaluated in non-piscivorous bird eggs). TCDD exceeded estimated NOAELs in most double-crested cormorant eggs from Rice and East Sand Islands, and in one western/glaucous-winged gull egg from Rice Island. TCDF exceeded estimated NOAELs in one Caspian tern egg from Rice Island and in two double-crested cormorant eggs from Rice Island. Concentrations in bird eggs were generally at or slightly above protective levels, which indicates that some individuals of Caspian terns, double-crested cormorants, and western/glaucous winged gulls have been (or continue to be) impacted by bioaccumulative compounds.

BMFs derived from lower Columbia River carp, peamouth, and sucker data were fairly consistent among river Segments 1 (RM 0-37), 2 (RM 37-72), and 3 (RM 72-102). However, BMFs for DDE and total PCBs were different from the BMFs derived using data on the same fish species collected during the concurrent Bi-State Study. The differences in BMF values between the studies were attributed to skewed data resulting from numerous below-detection values for total PCBs in sucker in our study and for DDE in sucker from the Bi-State Study. The actual BMFs for total PCBs and DDE were estimated to fall between our values and the Bi-State values. The BMFs calculated for TCDD were similar to BMFs from prey to herring gull eggs in the Great Lakes, but the Great Lakes BMF values were much lower for DDE and total PCBs. Separate BMFs derived from our data and data from the Bi-State Study were used to estimate TFC values, or the concentration in prey fish considered protective of lower Columbia River bald eagles. The resulting TFCs in fish were 0.06 µg/g for total PCBs, 0.04 µg/g for DDE, 0.20 µg/g for mercury, 0.9 pg/g for TCDD, and 7.5 pg/g for TCDD. TFCs derived from our fish data for total PCBs and DDE were much lower than protective guidance levels published for these compounds in other studies, but the TFCs derived for TCDD were very similar to guidance levels published elsewhere. The TFCs for mercury and TCDF were higher than protective levels in fish reported elsewhere.

The OC compounds detected, when compared within river segments, did not indicate that individual river segments contributed disproportionately to the overall loading or body burdens of these contaminants. This indicates that the river receives contaminants from numerous sources spread throughout the river, and the contaminants are evenly distributed in biota. Sample size was limited for some species or animal groups at some locations, and these results could be evaluated more completely with more comparable sample sizes across locations. However, previous and concurrent studies also reported no clear spatial trends in contaminants in sediment or fish from the lower Columbia River reaches.

CONCLUSIONS

Although OC contaminants were primarily below detection limits in sediment and in organisms lower in the Columbia River food chain, our results clearly indicate contaminants are transferred and biomagnified between trophic levels. Most invertebrate and fish species do not carry body burdens of contaminants that would be associated with direct impacts to individuals of the species, but concentrations in some piscivorous birds such as Caspian terns, double-crested cormorants, and bald eagles exceeded effect thresholds. In other studies along the river (Henny et al. 1981, 1996, Elliott et al. 1999a), concentrations of bioaccumulative compounds were implicated in impacts to mammalian predators such as mink and river otter. Various investigations have not established sediment in the lower Columbia River as a source or sink for contaminants, and it remains unclear exactly how the biota are exposed to bioaccumulative compounds, or if water or suspended concentrations play a greater role in trophic transfer than bed sediment.

A possible reason for the lack of OC compounds in sediment but elevated concentrations in tissue could be that the organic carbon, silts, and clays often associated with contaminants are rare or absent even in the depositional areas. OC contaminants are typically associated with the organic carbon fraction within fine-grained sediments or suspended sediments (especially the silt- and clay-sized fractions), and these sediments are commonly flushed into depositional or low energy areas. Deposit feeders and benthic invertebrates in these areas, such as clams, typically consume the finer materials (<100 μm fraction) and would be exposed to associated contaminants (Fuhrer and Horowitz 1989).

In the Columbia River, numerous authors have reported a trend of increasingly finer-grained sediments toward the mouth of the estuary, and these sediments deposit primarily in protected peripheral bays and channel bottoms of the mid to upper estuary (Hubbel and Glenn 1973, Sherwood et al. 1984, Tetra Tech 1993a). Contaminants associated with fine-grained materials and organic carbon would most likely be found in these depositional areas. However, clay-sized materials (most often associated with contaminants) are rarely found even in these shallow environments in the Columbia River, and sediments throughout the lower river were generally low in organic carbon (primarily <2 percent; Hedges et al. 1984). The low organic carbon and minimal silt- and clay-sized fractions, even in these shallow areas, do not provide many surfaces for attachment of organic contaminants; therefore, sediment from these areas contain concentrations near or below detection limits. However, any contaminants that are present in these areas, even at low concentrations or concentrations below detection limits, would be readily available to biota because the clays and silts that strongly bind the contaminants are not present or are minimal.

The increased availability of these contaminants means that lower concentrations in sediment would be a greater concern in this area than in other areas with higher contaminant concentrations but with more silts and clays. For example, Tetra Tech (1993a, 1994) suggested that because the toxicity of nonpolar, nonionic organic compounds is related to the organic content of sediment, higher sediment organic carbon would allow for the sorption of organic compounds and the reduction of the toxicity potential of a given sediment contaminant level. Therefore, the relatively low organic carbon content in the lower Columbia River sediments indicates that the organic contaminant concentrations (including contaminant concentrations below detection limits), in general, would be more available and could result in potentially greater toxicological effects in biota. The results of our sampling of depositional materials support the suggestion made by Tetra Tech (1993a), and indicate that further characterization of contaminant concentrations and the organic carbon content, specifically within various grain-sized fractions of depositional sediment in the lower Columbia River, could help determine the true availability of sediment-borne contaminants to organisms, and the degree to which bed sediment acts as a source of OC compounds.

RECOMMENDATIONS

Results of this study revealed that OC contaminants and mercury bioaccumulate in fish and wildlife in the Columbia River, and some of these compounds are biomagnified to levels that can impact piscivorous birds. Fish and wildlife using NWR lands also were exposed to bioaccumulative contaminants, although the refuges are probably not the source of the contaminants. Limiting entry of these contaminants into the Columbia River and its tributaries and minimizing disturbance to sediments contaminated with bioaccumulative compounds would reduce the availability of contaminants to fish and wildlife. However, reducing contaminant release and distribution is a daunting task due the magnitude of the basin, multiple sources of chemicals, and limited knowledge of sediment and contaminant fate and transport. Uses of many OC pesticides and PCBs have been banned since the 1970s. These persistent compounds now enter the river from diffuse, nonpoint sources such as runoff from agricultural and forested lands and hazardous waste sites, and these sources are difficult to control. Mercury, dioxins, and

furans enter the river from point and nonpoint sources, including industrial processes, runoff from contaminated sites, and atmospheric deposition. Point discharges of dioxins and furans were reduced in the 1990s due to changes in the bleaching process made by the pulp and paper industry from the use of elemental chlorine to chlorine dioxide. However, it is unknown if concentrations of dioxins and furans in fish and wildlife have decreased as a result of this conversion. Further reductions in contaminants released into the river are warranted to protect piscivorous birds, but reductions in nonpoint source contributions will be difficult to achieve.

Other contaminant investigations conducted in the Columbia River by the U.S. Fish and Wildlife Service, in cooperation with the Oregon Cooperative Wildlife Research Unit at Oregon State University (U.S. Fish and Wildlife Service 1999a,b; Thomas and Anthony 1999), described contaminant availability in association with river hydrodynamics and provided recommendations for reducing contaminant loading. The U.S. Fish and Wildlife Service (1999a) recommended that "a basin-wide strategy for controlling nonpoint source pollution for agricultural, forested, industrial, and urban areas, along with establishment and enforcement of Water Quality Management Plans to achieve TMDLs (Oregon Department of Environmental Quality 1997), would support efforts to reduce loading of OC pesticides and PCBs into the river. Establishing controls such as buffer zones in riparian areas from agricultural and timber-harvested lands could also reduce OC pesticide-associated soil or sediment particles from entering the Columbia River or its tributaries." Our results from the present study provide additional evidence to support the need to reduce the entry of bioaccumulative contaminants into the river and support recommendations outlined in previously completed studies. In addition, our results show that 1) contaminant concentrations in fish are not protective of bald eagles and some other piscivorous birds; 2) fish should be used to monitor changes in concentrations over time; and 3) target fish concentrations could be used to develop loading strategies for bioaccumulative compounds. Specific recommendations for reducing contaminant exposure to fish and wildlife are listed below. These recommendations are separated into general recommendations and recommendations targeted specifically for National Wildlife Refuge staff. Some of these recommendations have been adapted from previous reports (U.S. Fish and Wildlife 1999a,b).

General Recommendations

1) We propose using site-specific TFCs, or the concentration in fish that would be protective for bald eagles or other sensitive species, as the desired endpoint when determining load allocations for bioaccumulative contaminants in the TMDL process. An example of establishing a target level for methyl mercury for the TMDL process can be found in Hope (2003). The load allocation for a particular river segment should not result in a predicted body burden in fish that would exceed the TFC. The TFCs that resulted from this study for the protection of lower Columbia River bald eagles were 0.06 µg/g for total PCBs, 0.04 µg/g for DDE, 0.20 µg/g for mercury, 0.9 pg/g for TCDD, and 7.5 pg/g for TCDD. Management actions should then be taken to reduce concentrations of certain contaminants in nonpoint source discharges, minimize re-suspension of bed sediment, and reduce suspended sediment in runoff in areas where these chemicals are present and the TFC is exceeded. Periodic collection of whole-body fish for contaminant analysis could then be conducted to evaluate the success of the process, and identify where changes in management actions should occur. Achieving reductions in bioaccumulative contaminants to the proposed TFCs would be protective of bald eagles and other piscivorous birds and mammals lower in the food chain within a particular river segment.

2) Collection of fresh bald eagle eggs for contaminant analysis should occur at periodic intervals to determine trends in contaminant concentrations over time. Bald eagles have been studied in numerous aquatic systems including the Columbia River, and eagle eggs have been ideal indicators to represent biomagnification of OC compounds. The U.S.

Fish and Wildlife Service (1999a) found that DDE and total PCB concentrations have declined in eggs of lower Columbia River bald eagles between the mid-1980s and 1995. In addition, the pulp and paper industry recently changed from using elemental chlorine to chlorine dioxide for bleaching paper at pulp mills along the Columbia River. A similar process change to chlorine dioxide in Canada led to a corresponding decrease in the contaminant burdens in great blue heron eggs (Whitehead et al. 1992, Elliott et al. 1996c). Additional sampling of eagle eggs is needed to evaluate corresponding changes in tissue concentrations as a result of changes in industrial processes, and to gather more information regarding toxicity from mixtures of OC pesticides and dioxin-like compounds.

3) Investigations should be initiated to evaluate the impacts of contaminants on listed species of salmon in the lower Columbia River. Results from this study and others (U.S. Fish and Wildlife Service 1999b) have shown that double-crested cormorants and Caspian terns are exposed to OC compounds from the lower Columbia River, and a large proportion of the diet of these birds consists of juvenile salmonids (Collis et al. 2001). An effective and economical way to evaluate salmonid body burdens is to chemically analyze prey items collected from cormorant and tern nest sites or regurgitated from cormorant and tern nestlings. Prey items should be collected over one or two breeding seasons, identified to species, and individual or composite samples chemically analyzed for bioaccumulative compounds. To minimize analytical chemistry costs, an H4IIE type bioassay, or other suitable bioassay, could be used to assess dioxin-like compounds and establish BMFs between cormorant or tern eggs and salmon prey, similar to studies conducted in the Great Lakes (Jones et al. 1993). Evaluation of juvenile salmonids as prey items will help determine the threats to both salmonids and piscivorous birds from exposure to bioaccumulative compounds.

4) Investigations should continue to further identify river segments that contribute the most to contaminant loading, have a high number of contaminant sources, or contain the highest concentrations in sediment or biota. Currently, only a few studies have been able to identify sections of the river that appear to have a greater contribution of contaminants than other reaches (Henny et al. 1996, McCarthy and Gale 2001). Such studies should be expanded to identify reasons for the higher contributions of contaminants so that management actions can be taken to reduce contaminant loading.

5) An investigation should be conducted to identify organic carbon content and contaminant concentrations in various grain sized fractions of bed sediment, and compare contaminant concentrations among bed sediment, suspended sediment, water, or other abiotic fractions to determine the primary pathway of contaminant transfer to organisms. Various natural and human-induced disturbances can increase suspended sediment or enhance deposition of sediment in backwater areas. Natural events such as flooding (Ludwig et al. 1993), and human activities such as dredging, ship passage, and other bottom-disturbing activities, could resuspend persistent chemicals from sediment and increase contaminant bioavailability to aquatic organisms. However, if the primary transfer media for contaminants is known (e.g., if suspended sediment or water is more important than bed sediment), then some human activities could be better managed or planned to minimize contaminant transport. Currently, areas within the main channel of the lower Columbia and Willamette Rivers are routinely maintained for navigational purposes by dredging, and private parties dredge and maintain connecting channels, ports, marinas, and other areas under a permitting process with the U.S. Army Corps of Engineers. The main navigation channel primarily consists of course-grained materials, yet areas around some docks, marinas, and ports often exhibit deposits of fine-grained sediment containing contaminants, which could be resuspended when disturbed. Material dredged from these areas, and from the lower Willamette River which has a higher proportion of fine

materials such as silts than the Columbia River, is deposited into the flow lane of the lower Columbia River when contamination does not exceed in-water disposal guidelines. It is highly plausible that this disposal process could increase the risk of exposure in aquatic organisms and enhance the potential for biomagnification to higher trophic levels such as river otter and bald eagles. However, these activities could be irrelevant to the overall contaminant loading of the river if suspended sediment or water is identified as the primary contaminant pathway, if redistribution of sediment-sorbed contaminants settling in backwater areas is shown to be of minimal influence compared to other pathways, or if redistribution is not enhanced by human activities compared to natural processes. To identify efficient management actions to control sediment disturbance and redistribution, additional information is needed regarding the specific transfer pathway of contaminants from sediment, suspended sediment, or water to biota.

Recommendations for National Wildlife Refuges

Due to the multiple and diverse sources of contaminants entering the Columbia River that are not associated with refuge operations, specific actions that can be taken by refuge personnel to prevent contamination of fish and wildlife using the refuge are limited. However, we maintain that some management actions supported by the refuge will, in combination with actions taken by state, federal, or other groups described under the "General Recommendations" section above, help to minimize contaminant availability to biota and to monitor changes in contaminant concentrations over time. Some of these recommendations have been identified in a previous U.S. Fish and Wildlife Service report (U.S. Fish and Wildlife Service 1999b).

1) Refuge personnel, in coordination with the U.S. Fish and Wildlife Service's Environmental Contaminants Division and Clatsop County, should further evaluate the beach area near the Julia Butler Hansen NWR to determine if sediment and clams pose a risk to humans or wildlife in the area. Elevated DDE concentrations were found in sediment, and DDE and total PCBs were elevated in Corbicula clam collected from the beach area. The contaminant results are based on only a few samples, so additional samples are needed to clarify concentrations in this area. The beach area is owned and maintained by the County, but this area is commonly used by people and accessed via the refuge for collection of clams.

2) Ensure that adequate buffers exist on any land managed by the refuge that supports agriculture or pasture, or was formerly used for these purposes. Riparian or vegetative buffers should be present between agricultural land and the Columbia River or its tributaries to prevent erosion of soil associated with DDT or its metabolites from entering waterways.

3) Population monitoring or aerial nest counts of nesting cormorants, terns, and bald eagles should continue. In addition, in coordination with the U.S. Fish and Wildlife Service's Environmental Contaminants Division, refuge personnel should continue monitoring contaminants in eggs of piscivorous birds (cormorants and bald eagles nesting on refuge lands) on a periodic basis (e.g., every five years) to more closely examine trends over time. Results of studies by the U.S. Fish and Wildlife Service (1999a,b) indicate contaminants are near or exceed effect-threshold concentrations for cormorants, and exceed threshold values for bald eagles. These species are excellent indicators for monitoring the health of the river and can be used to identify changes in contaminant burdens over time. Contaminant burdens in eggs are responsive to reductions in industrial discharges (Whitehead et al. 1992, Elliott et al. 1996c), natural changes in river conditions such as flooding (Ludwig et al. 1993), and could be sensitive to increased contaminant availability from human activities such as dredging or remediation at hazardous waste sites.

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Table 1. Number of composite, whole-body fish samples and avian eggs collected and analyzed for contaminant concentrations along the Columbia River and Willamette River at Portland in 1990.

	Cathlamet Bay	Lewis & Clark	Longview	St. Helens	Camas Slough	Portland	Umatilla	Total
FISH								
Common carp			2	2	2	2		8
Peamouth chub	1							1
Sucker	1		1	1				3
Northern pikeminnow	2		3	3	2	1		11
Largemouth bass			1	1				2
Smallmouth bass						1		1
EGGS								
Ring-billed gull							5	5
Western gull or hybrid		9						9
Forster's tern							6	6
Caspian tern		9					8	17
Double-crested cormorant		10						10
Total	4	28	7	7	4	4	19	73

Table 2. Number of sediment, invertebrate, fish, and avian egg samples collected and analyzed for contaminants along the Columbia River in 1991.

	Baker Bay	Cathlamet Bay	Lewis & Clark NWR	Julia Butler Hansen NWR	Longview	Ridgefield NWR	Camas Slough	Umatilla	Total
SEDIMENT [a]	3	3	3	3	3	3	3	3	24
INVERTEBRATES [a]									
Corophium		1	2						3
Corbicula clam		2	3	3	3	3	3	3	20
Macoma clam	3								3
Crayfish		3	3	5	3	3	3		20
FISH [a]									
Sucker		3[b]	3	3	3	3	3	3[b]	21
Common carp					3	3	3	3	12
Peamouth chub		4	3	3	3	3		1	17
Whitefish								2	2
EGGS									
Mallard	1		3						4
Canada goose	1		3		3				7
Western gull or hybrid	9		9						18
Ring-billed gull								9	9
Forster's tern								5	5
Caspian tern			9					5	14
Double-crested cormorant	11		11						22
Total	28	16	52	17	21	18	15	34	201

[a] Sediment or biota collected under this matrix group were composited, and the number listed represents the total number of composite samples.

[b] Only two sucker were analyzed for the dioxins and furans at the Lewis and Clark and Umatilla sites, resulting in a total of 19 sucker samples for this chemical group.

Table 3. Number of whole-body fish within a composite sample (pool), and mean length (mm) and mean mass (g) measurements (ranges in parentheses[a]) of individuals within a composite for samples collected from the lower Columbia River and Willamette River at Portland in 1990. Composite samples are grouped by type of chemical analysis. See Appendix A for percent moisture, lipid, and other data for individual samples.

	Cathlamet Bay	Longview	St. Helens	Portland	Camas Slough
TOTAL POLYCHLORINATED BIPHENYLS AND ORGANOCHLORINE PESTICIDES					
Common carp (n=4)[b]					
Pool		1	2	2	3
Length		581	454 (442-466)	463 (460-465)	484 (436-537)
Mass		2436	1540 (1343-1737)	1394 (1331-1457)	1600 (1174-2044)
Peamouth chub (n=1)					
Pool	3				
Length	307 (298-323)				
Mass	275 (269-285)				
Sucker (n=3)					
Pool	1	3	3		
Length	545	431 (391-458)	371 (351-381)		
Mass	893	785 (552-904)	533 (452-607)		
Northern pikeminnow (n=4)					
Pool	3	3	3		2
Length	287 (285-292)	331 (277-431)	463 (453-477)		456 (441-470)
Mass	225 (216-238)	327 (164-633)	848 (677-981)		875 (713-1037)
Largemouth bass (n=2)					
Pool		1	3		
Length		379	214 (207-221)		
Mass		842	165 (146-199)		
Smallmouth bass (n=1)					
Pool				2	
Length				281 (237-325)	
Mass				440 (222-657)	
TOTAL MERCURY					
Common carp (n=2)					
Pool				2	3
Length				463 (460-465)	484 (436-537)
Mass				1394 (1331-1457)	1600 (1174-2044)

Table 3. Continued.

	Cathlamet Bay	Longview	St. Helens	Portland	Camas Slough
Peamouth chub (n=1)					
Pool	3				
Length	307 (298-323)				
Mass	275 (269-275)				
Northern pikeminnow (n=4)					
Pool	3	4	3		2
Length	287 (285-292)	240 (200-276)	336 (225-405)		456 (441-470)
Mass	225 (216-238)	105 (58-152)	349 (95-511)		875 (713-1037)
DIOXINS AND FURANS					
Common carp (n=4)					
Pool		1	2	2	3
Length		545	514 (510-517)	426 (382-470)	473 (422-507)
Mass		2285	1895 (1801-1989)	1238 (959-1517)	1409 (1052-1606)
Northern pikeminnow (n=5)					
Pool	3	3	3	4	2
Length	311 (294-340)	372 (310-453)	514 (503-535)	176 (122-204)	526 (474-578)
Mass	291 (231-390)	459 (238-781)	1154 (976-1438)	45 (15-75)	1201 (858-1544)

[a] Ranges were not available for samples of one fish.
[b] N=total number of composite samples analyzed for this species for all sites.

Table 4. Composite and sample information for invertebrate and whole body fish samples (grouped by chemical analysis type) collected from the Columbia River in 1991. See Appendix A for percent moisture, lipid, and other data for individual samples.

	Baker Bay	Cathlamet Bay	Lewis & Clark NWR	Julia Butler Hansen NWR	Longview	Ridgefield NWR	Camas Slough	Umatilla
TOTAL POLYCHLORINATED BIPHENYLS AND ORGANOCHLORINE PESTICIDES								
Invertebrates								
Corophium[a]								
No. composites[b]		1						
Sample mass[c]		15						
Pool[d]		100s[e]						
Corbicula clam								
No. composites		2	3	3	3	3	3	3
Sample mass		14 (13-16)	32 (31-33)	45 (35-62)	42 (38-49)	48 (35-65)	37 (31-47)	63 (62-65)
Pool		15-16	12	12	16	16	15	18-23
Macoma clam[a]								
No. composites	3							
Sample mass	18 (14-25)							
Pool	12-16							
Crayfish								
No. composites		1	2	3	2	3	2	
Sample mass		110	159 (102-216)	139 (121-166)	144 (130-157)	207 (186-240)	186 (177-194)	
Pool		2	3-4	3-5	3	3-4	4	
Length[f]		113 (111-114)	101 (80-130)	108 (85-138)	107 (80-133)	120 (93-138)[g]	113 (81-133)	
Mass[h]		55 (37-72)	45 (18-122)	38 (17-103)	48 (17-88)	64 (23-105)[g]	46 (16-81)	
Fish								
Sucker								
No. composites		3	3	3	3	3	3	3
Sample mass		1456 (556-2478)	1818 (1683-1890)	1015 (498-1330)	2398 (2133-2656)	1540 (1408-1648)	604 (541-694)	2275 (1781-2666)
Pool		3	3	2-3	3	2-3	1-2	3
Length[f]		355 (167-497)	384 (270-478)	334 (276-415)	446 (400-470)	397 (340-445)	353 (292-389)	410 (344-495)
Mass[h]		485 (40-1129)	606 (286-956)	381 (198-658)	788 (608-914)	578 (418-778)	453 (247-578)	758 (448-1083)
Common carp								
No. composites					3	3	3	3
Sample mass					1197 (970-1644)	1983 (1650-2286)	2580 (2516-2664)	4438 (3526-5000)
Pool					1	2-3	2	1-3
Length[f]					NA[f]	380 (332-455)	465 (450-502)	485 (390-690)[g]
Mass[h]					1197 (970-1644)	744 (452-1309)	1290 (1178-1486)	1902 (1003-5000)

Table 4. Continued.

	Baker Bay	Cathlamet Bay	Lewis & Clark NWR	Julia Butler Hansen NWR	Longview	Ridgefield NWR	Camas Slough	Umatilla
Peamouth chub								
No. composites		3	3	3	3	3		1
Sample mass		236 (238-241)	641 (557-745)	551 (528-581)	496 (117-724)	572 (212-810)		298
Pool		3	5	5	3-6	3-6		2
Length[f]		209 (173-271)	238 (200-278)	236 (197-271)	227 (154-274)	233 (191-300)		248 (185-310)
Mass[h]		79 (47-143)	128 (63-218)	110 (71-173)	99 (29-185)	114 (58-236)		149 (51-247)
Whitefish								
No. composites								2
Sample mass								849 (776-922)
Pool								3-4
Length[f]								288 (148-364)
Mass[h]								243 (21-464)
TOTAL MERCURY (fish samples analyzed for mercury were the same samples used for PCB and pesticides listed above, so only invertebrates are reported below)								
Invertebrates								
Corbicula clam								
No. composites				3	3			
Sample mass				45 (35-62)	42 (38-49)			
Pool				12	16			
Crayfish								
No. composites				3				
Sample mass				139 (121-166)				
Pool				3-5				
Length[f]				108 (85-138)				
Mass[h]				38 (17-103)				
2,3,7,8=TETRACHLORO-SUBSTITUTED DIOXIN AND FURAN (only one sample was analyzed for the other dioxin and furan congeners as listed in Appendix A)								
Invertebrates								
Corophium								
No. composites			2					
Sample mass			23 (22-23)					
Pool			100s[b]					
Corbicula clam								
No. composites		1	2			2	2	2
Sample mass		16	31 (31-32)			54 (43-65)	40 (33-47)	64 (62-65)
Pool		16	12			16	15	20-23

Table 4. Continued.

	Baker Bay	Cathlamet Bay	Lewis & Clark NWR	Julia Butler Hansen NWR	Longview	Ridgefield NWR	Camas Slough	Umatilla
Macoma clam								
No. composites	1							
Sample mass	25							
Pool	12							
Crayfish								
No. composites		3	2	3	3	3	3	
Sample mass		64 (39-110)	181 (145-216)	97 (63-130)	130 (102-157)	207 (186-240)	164 (121-194)	
Pool		1-2	3-4	3-5	2-3	3-4	4	
Length[f]		108 (100-114)	106 (83-130)	94 (62-114)	113 (98-133)	120 (93-138)[g]	108 (81-133)	
Mass[h]		39 (37-42)	52 (21-122)	26 (7-43)	54 (31-88)	64 (23-105)[g]	41 (16-81)	
Fish								
Sucker								
No. composites		3	2	3	3	3	3	2
Sample mass		1456 (556-2478)	1885 (1880-1890)	1015 (498-1330)	2398 (2133-2656)	1540 (1408-1648)	604 (541-694)	2079 (1781-2377)
Pool		3	3	2-3	3	2-3	1-2	3
Length[f]		355 (167-497)	403 (344-478)	334 (276-415)	446 (400-470)	397 (340-445)	353 (292-389)	400 (344-440)
Mass[h]		485 (40-1129)	628 (434-956)	381 (198-658)	788 (608-914)	578 (418-778)	453 (247-578)	693 (448-863)
Common carp								
No. composites					3	3	3	3
Sample mass					1197 (970-1644)	1983 (1650-2286)	2580 (2516-2664)	4438 (3526-5000)
Pool					1	2-3	2	1-3
Length[f]					NA[f]	380 (332-455)	465 (450-502)	485 (390-690)[g]
Mass[h]					1197 (970-1644)	744 (452-1309)	1290 (1178-1486)	1902 (1003-5000)
Peamouth chub								
No. composites		4	3	3	3	3		1
Sample mass		224	641 (557-745)	551 (528-581)	496 (117-724)	572 (212-810)		298
Pool		3-4	5	5	3-6	3-6		2
Length[f]		199 (168-271)	238 (200-278)	236 (197-271)	227 (154-274)	233 (191-300)		248 (185-310)
Mass[h]		69 (42-143)	128 (63-218)	110 (71-173)	99 (29-185)	114 (58-236)		149 (51-247)

[a] Species not analyzed for mercury.
[b] Number of composite samples analyzed for chemical constituents.
[c] Mean mass (g) and (range) of all composite samples analyzed (mean and range not calculated when only one composite sample was analyzed).
[d] Number of individuals within each composite sample. Number appears as a range when composite samples did not consist of the same number of individuals.
[e] Composite sample made up of hundreds of individual *Corophium*.
[f] Mean length (mm) and (range) of all individuals within all composite samples of this species analyzed at an individual site. NA =not available due to lack of information on some individuals.
[g] Mean and range are estimates because length or mass measurements were not available for some individuals within one or more composites.
[h] Mean mass (g) and (range) of all individuals within all composite samples of this species analyzed at an individual site.

Table 5. Comparison of methods used by individual contract laboratories to chemically analyze sediment, invertebrates, fish, and avian eggs collected from the Columbia River in 1990 and 1991.

				Number of samples analyzed by laboratory and analyte group				
Lab[a]	**Catalog[b]**	**Analytes[c]**	**Analysis Methods and Quality Control (QC) Notes[d]**	**Sed.**	**Invert.**	**Fish**	**Eggs**	**Total**
PACF	19	OC	Silica gel separation of pesticides from PCBs. Quantification by CGC/ECD for sediment and 30-m Megabore GLC/ECD for tissue. Confirmation of 10% of samples by GC/MS.	24	17	9	0	50
PACF	16	OC	Silica gel separation of pesticides from PCBs. Quantification by 30-m Megabore GLC/ECD. Confirmation of 10% of samples by GC/MS.		11	32		43
MSCL	6422	OC	Separation by Florisil and silicic acid columns. Quantification by GC/ECD (packed or capillary column).				18	18
GERG	15	OC-PCB	Extracts purified by silica/alumina column and HPLC to remove interfering lipids. Quantification by CGC/ECD. Spike recoveries of beta BHC and HCB were out of QC bounds (<80%) so results were considered estimates for these analytes.		9	10	5[e]	24
GERG	03	OC-PCB	Extracts purified by silica/alumina column and HPLC to remove interfering lipids. Quantification by CGC/ECD.			10	29	39
NCL/ Alta	ALTA	OC	Extraction and cleanup followed FDA PB88-911899 (U.S. Food and Drug Administration 1988). Quantification based on Method 8080 modified for small sample sizes using CGC/ECD with separation on a 30-m, 0.32 micron, DB-1707 capillary column. Identification and quantification of some analytes that co-elute with or near major PCB peaks was problematic due to degraded PCBs in tissues, and detection limits for some analytes were elevated to account for uncertainty. The presence of p,p'-DDD was estimated as within 0.02 and 0.05 µg/g due to co-elution with PCBs in the egg samples. These estimates are noted in tabulated results.			5	9	14

Table 5. Continued.

Lab[a]	Catalog[b]	Analytes[c]	Analysis Methods and Quality Control (QC) Notes[d]	Number of samples analyzed by laboratory and analyte group				
				Sed.	Invert.	Fish	Eggs	Total
TLI	18	PCDD/Fs	Method 1613A, HRGC/HRMS. Hits of TCDF on DB-5 column were confirmed with a DB-225 column for all samples except one tissue and three sediment samples which had TCDF below 1 pg/g on the DB-5 column. Some blank contamination was reported (greatest for OCDD) and noted in tabulated results. The chromatograph peak for 1,2,3,7,8,9 HxCDD was poorly resolved in some sediment samples and flagged as estimated in tabulated results. Ion instabilities caused by quantitative interferences were noted for two analytes in one clam tissues and results were estimated.	7	5			12
MRI	16[b]	PCDD/Fs	Method 1613, HRGC/HRMS. Four-column cleanup with potassium silicate/coarse acidified silica gel, acidified silica gel, neutral alumina column, and carbon column. Hits of TCDF on 60-m DB-5 column confirmed with DB-dioxin column. Both columns agreed well with no interference noted.		6	13	1	20
Radian	6463	PCDD/Fs	Method SW8280A, HRGC/LRMS. Results considered suspect because egg values were higher compared to eggs of the same species analyzed at other laboratories, even though labeled internal recovery standards and other QC results were within acceptable limits. The HRGC/HRMS method used at other laboratories has greater selectivity for PCDD/Fs versus interferences than does the HRGC/LRMC method used at Radian, which could have influenced the results. The tabulated results are reported as estimates.				6	6
TLI	15	TCDD/F	Method 1613A, HRGC/HRMS. Hits of TCDF on DB-5 column confirmed with DB-225 column. All fish samples were listed as estimated maximum possible concentration in tabulated results due to the presence of interfering diphenyl ethers on the DB-225 column. The lower results for fish obtained for TCDF from the DB-5 column were used in this report, and are presented as estimated values in the tabulated results.			6	3[e]	6
TLI	14	TCDD/Fs	Method 1613A, HRGC/HRMS. Hits of TCDF on DB-5 column confirmed with DB-225 column for all samples. Both columns agreed well with no interference noted.				9	9

Table 5. Continued.

Lab[a]	Catalog[b]	Analytes[c]	Analysis Methods and Quality Control (QC) Notes[d]	Number of samples analyzed by laboratory and analyte group				
				Sed.	Invert.	Fish	Eggs	Total
TLI	13	TCDD/Fs	Method 1613A, HRGC/HRMS. Hits of TCDF on DB-5 column confirmed with DB-225 column for all samples. One gull egg had interfering diphenyl ethers on the DB-225 column and the value was reported as an estimated maximum possible concentration in tabulated results.				9	9
PA	18	TCDD/Fs	Method 1613, HRGC/HRMS, with RTX-200 column. Analysis included a four-column cleanup with potassium silicate/coarse acidified silica gel, acidified silica gel, neutral alumina column, and carbon column. Many samples contained diphenyl ether traces and the RTX-200 column was not sensitive in resolving diphenyl ether interferences from TCDF. Poor matrix spike results and diphenyl ether interferences in the original results required reanalysis of all samples except the sediment sample. The additional reanalysis improved resolution and matrix spike results for samples with sufficient material to reanalyze. Reanalysis consisted of additional cleanup of sample extracts by processing through Method 1613 alumina and carbon column and reanalysis, or sample re-extraction and reanalysis. Of 20 samples initially failing QC limits and requiring reanalysis, two samples had insufficient material remaining and the initial results were excluded from the data set, 16 samples were re-extracted (five of which first went through an additional cleanup step and failed QC limits prior to undergoing re-extraction), and two went through additional cleanup only and one of these was excluded from the data set due to failing QC limits and insufficient material remaining for reanalysis. Eighteen samples passed QC limits and were used in the data set. The reanalysis incorporated the RTX-200, DB-5, and DB-225 columns for TCDD and TCDF analysis. Results of TCDF in samples run through a DB-225 confirmation column proved worse than the RTX-200 column with respect to the interference, and in these cases the results from the DB-5 column for TCDF were lowest and presented in this report. All results from the RTX-200 column were flagged as estimated maximum possible concentrations due to possible diphenyl ether interference in the tabulated results. Appendix B reports the original and reanalysis results for all samples in this catalog.	1	5	12		18

Table 5. Continued.

Lab[a]	Catalog[b]	Analytes[c]	Analysis Methods and Quality Control (QC) Notes[d]	Number of samples analyzed by laboratory and analyte group				
				Sed.	Invert.	Fish	Eggs	Total
PA	16[a]	TCDD/Fs	Method 1613, HRGC/HRMS, with RTX-200 column. Analysis included a four-column cleanup with potassium silicate/coarse acidified silica gel, acidified silica gel, neutral alumina column, and carbon column. Many samples contained diphenyl ether traces and the RTX-200 column was not sensitive in resolving diphenyl ether interferences from TCDF. Poor matrix spike results and diphenyl ether interferences in the original results required reanalysis of all samples The additional reanalysis improved resolution and matrix spike results for samples with sufficient material to reanalyze. Reanalysis consisted of additional cleanup of sample extracts by processing through Method 1613 alumina and carbon column and reanalysis, or sample re-extraction and reanalysis. Of the 47 samples initially failing QC limits and requiring reanalysis, eight had insufficient material remaining to reanalyze (one of these had no material left following an additional cleanup step that failed QC limits) and were excluded from the data, 36 were re-extracted (three of which first went through an additional cleanup step and failed QC limits prior to undergoing re-extraction), and three had an additional cleanup step only. Thirty-nine samples passed QC limits and were used in the data set. The reanalysis incorporated the RTX-200, DB-5, and DB-225 columns for TCDD and TCDF analysis. Results of TCDF in samples run through a DB-225 confirmation column proved worse than the RTX-200 column with respect to the interference, and in these cases the results from the DB-5 column for TCDF were lowest and presented in this report. All results from the RTX-200 column were flagged as estimated maximum possible concentrations due to possible diphenyl ether interference in the tabulated results. Appendix B reports the original and reanalysis results for all samples in this catalog.		13	18	8	39

Table 5. Continued.

Lab[a]	Catalog[b]	Analytes[c]	Analysis Methods and Quality Control (QC) Notes[d]	Number of samples analyzed by laboratory and analyte group				
				Sed.	Invert.	Fish	Eggs	Total
CERC	6623	TCDD/Fs PCDD/Fs	HRGC/LRMS, monitoring sequential mass windows of 12 selected ions during chromatographic separation. Cleanup consisted of sulfuric acid silica gel/potassium silicate column, sulfuric acid silica gel/silica gel column, separation by HPLC Porous Graphitic Carbon, and elution through basic alumina to remove diphenyl ethers and co-contaminants.			9	8	17
GERG	15	Hg	Method 245.5 (minor revisions). Digestion by concentrated sulfuric acid and nitric acid. Quantification by AA spectrophotometer.		9	10	5[e]	24
GERG	03	Hg	Method 245.5 (minor revisions). Digestion by concentrated sulfuric acid and nitric acid. Quantification CVAA.				11	11
ETSL	10	Hg	Digestion by nitric-reflux, determination by CVAA.			2	18	20
NCL/ Alta	ALTA	Hg	Digestion by nitric-reflux, determination by CVAA.			5	9	14
PACF	19	Hg	Digestion by sulfuric and nitric reflux, determination by CVAA.			9		9
PACF	16	Hg	Digestion by sulfuric and nitric reflux, determination by CVAA.			32		32
HES	6423	Hg	Determination by ICP as part of elemental scan.				6	6

[a] Laboratories contracted to conduct chemical analyses include 1) Patuxent Analytical Control Facility (PACF) in Patuxent, Maryland; 2) Mississippi State Chemical Laboratory (MSCL) in Mississippi State, Mississippi; 3) Geochemical and Environmental Research Group (GERG) in College Station, Texas; 4) North Coast Laboratories (NCL) in Arcata, California (subcontracted by Alta Analytical Laboratory [Alta] in Eldorado Hills, California); 5) Triangle Laboratories (TLI), Research Triangle Park, North Carolina; 6) Pacific Analytical (PA), Carlsbad, California; 7) Midwest Research Institute (MRI), Kansas City, Missouri; 8) Radian Analytical Services (Radian), Austin, Texas; 9) Columbia Environmental Research Center (CERC), U.S. Geological Survey, Biological Research Division, Columbia, Missouri; 10) Environmental Trace Substances Laboratory (ETSL) in Rolla, Missouri; and 11) Hazleton Environmental Services, Inc., (HES) in Madison, Wisconsin.

[b] Catalog number used to track sample groups sent in to contract laboratories for analysis. Most catalogs are submitted electronically through the U.S. Fish and Wildlife Service's Environmental Contaminant Data Management System (ECDMS).

[c] Analytes include OC (organochlorine pesticide scan including polychlorinated biphenyls [PCBs] measured as Aroclor PCBs); OC-PCB (organochlorine pesticides and individual PCB congeners, with total PCBs reported as summation of congeners); TCDD/F (2,3,7,8-tetraclorodibenzodioxin and furan congeners); PCDD/F (polychlorinated dibenzodioxins and furans); Hg (total mercury).

[d] Analytical method abbreviations are CGC (capillary gas chromatography), ECD (electron capture detection), GLC (gas-liquid chromatography), GC (packed column gas chromatography),HPLC (high performance liquid chromatography), MS/SIM (mass spectrometry/selected ion monitoring), HRGC/LRMS (high resolution gas chromatography/low resolution mass spectrometry), high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS), AA (Atomic Absorption), CVAA (cold vapor atomic absorption), and ICP (inductively coupled plasma). All method numbers are U.S. Environmental Protection Agency methods.

[e] Eggs results previously reported by Blus et al. (1998).

Table 6. Dioxin and furan congeners (abbreviations in parentheses) analyzed in sediment and biota samples collected from the lower Columbia River in 1990 and 1991.

Chlorinated dibenzodioxins:	**Chlorinated dibenzofurans:**
2,3,7,8-Tetra (TCDD)	2,3,7,8-Tetra (TCDF)
1,2,3,7,8-Penta (1,2,3,7,8-PCDD)	1,2,3,7,8-Penta (1,2,3,7,8-PCDF)
1,2,3,4,7,8-Hexa (1,2,3,4,7,8-HxCDD)	2,3,4,7,8-Penta (2,3,4,7,8-PCDF)
1,2,3,6,7,8-Hexa (1,2,3,6,7,8-HxCDD)	1,2,3,4,7,8-Hexa (1,2,3,4,7,8-HxCDF)
1,2,3,7,8,9-Hexa (1,2,3,7,8,9-HxCDD)	1,2,3,6,7,8-Hexa (1,2,3,6,7,8-HxCDF)
1,2,3,4,6,7,8-Hepta (1,2,3,4,6,7,8-HpCDD)	1,2,3,7,8,9-Hexa (1,2,3,7,8,9-HxCDF)
Octa (OCDD)	2,3,4,6,7,8-Hexa (2,3,4,6,7,8-HxCDF)
	1,2,3,4,6,7,8-Hepta (1,2,3,4,6,7,8-HpCDF)
	1,2,3,4,7,8,9-Hepta (1,2,3,4,7,8,9-HpCDF)
	Octa (OCDF)

Table 7. Estimated guidance values for protection of fish and wildlife from exposure to total polychlorinated biphenyls (PCBs), DDE, total mercury, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) and 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF).

	Estimated guidance or protection level (µg/g)	Effect observed at reported concentration including estimated no-observable-adverse-effect-level (NOAELs), lowest-observable-adverse-effect-levels (LOAELs), Target fish concentrations (TFCs), and other effects-based thresholds
TOTAL PCBs		
Sediment	0.0227	Effects range-low (dry weight). The lower tenth percentile of concentrations of total PCBs associated with biological effects (Long and Morgan 1990).
Fish-all species	0.11	New York State Department of Environmental Conservation values for protection of fish-eating fish and wildlife (Newell et al.1987).
	0.06	TFC derived for the protection of bald eagles based on site specific data from the lower Columbia River (U.S. Fish and Wildlife Service 1999a, and this study) and the Bi-State Study (Tetra Tech 1993b,c).
Piscivorous bird eggs		
Gull species	5	LOAEL based on embryonic deformities and egg lethality in herring gull eggs (Weseloh et al. 1991).
Caspian tern	4.2	LOAEL based on embryonic deformities and egg lethality in Caspian tern eggs (Giesy et al. 1994).
Forster's tern	4.5	NOAEL in eggs of the Forster's tern (Kubiak et al. 1989).
Double-crested cormorant	3.5	NOAEL based on egg lethality in double-crested cormorant eggs (Tillitt et al. 1992, Yamashita et al. 1993).
Bald Eagle egg	4.0	Estimated NOAEL based on eagle data from Wiemeyer et al. (1984).
Non-piscivorous bird eggs		
Mallard	105	Lowest observable effect concentration (LOEC) based on eggshell thinning in mallards (Haseltine and Prouty 1980).
p,p -DDE		
Sediment	0.0022	Effects range-low (dry weight). The lower tenth percentile of concentrations of DDE associated with biological effects (Long and Morgan 1990).
Fish-all species	0.2	New York State Department of Environmental Conservation values for protection of fish-eating fish and wildlife (Newell et al. 1987).
	0.04	TFC derived for the protection of bald eagles from site specific data from the lower Columbia River (U.S. Fish and Wildlife Service 1999a, and this study) and the Bi-State Study (Tetra Tech 1993b,c).
Piscivorous birds eggs-all species except bald eagle	3-5	Concentration range associated with embryo death and reproductive impairment related to shell structure in common terns in Alberta (Fox 1976), and associated with eggshell thinning (Heinz et al. 1985) and reduced hatching success (Custer et. al. 1999) in double-crested cormorants.
Bald Eagle eggs	3.6	Estimated NOAEL based on eagle data from Wiemeyer et al. (1993).
Non-piscivorous bird eggs		
Mallard	10-30	Range associated with reduced survival of embryonated eggs or hatchlings of dosed black ducks (*Anas rubripes*) (Longcore et al. 1971).

Table 7. Continued.

	Estimated guidance or protection level (µg/g)	Effect observed at reported concentration including estimated no-observable-adverse-effect-level (NOAELs), lowest-observable-adverse-effect-levels (LOAELs), Target fish concentrations (TFCs), and other effects-based thresholds
TOTAL MERCURY		
Invertebrates	0.1	Concentration in food items considered protective of bird predators (Eisler 1987).
Fish	0.1	Concentration in food items considered protective of bird predators (Eisler 1987).
	0.2	TFC derived for the protection of bald eagles from site specific data from the lower Columbia River (U.S. Fish and Wildlife Service 1999a, and this study).
Bird eggs-all species except bald eagle	0.79-2.2	Concentrations in eggs associated with impaired reproduction in various bird species (Eisler 1987)
Bald eagle eggs	0.5	Estimated NOAEL based on data from Wiemeyer et al. (1984).
2,3,7,8-TCDD		
Fish-all species	6×10^{-7}	Dietary NOAEL (0.6 pg/g) for TCDD-equivalents (TCDD-EQs) derived from Lake Huron fish fed to chickens and considered protective of bald eagles in the Great Lakes (Giesy et al 1994).
	9×10^{-7}	TFC (0.9 pg/g) for TCDD derived from site specific data from the lower Columbia River for the protection of bald eagles (U.S. Fish and Wildlife Service 1999a and this study).
Piscivorous bird eggs		
Gull species	10 x 10-6	Egg NOAEL (10 pg/g) of TCDD-EQs estimated to be protective of herring gulls in the Great Lakes (Giesy et al. 1994).
Caspian and Forster's tern	7.5×10^{-6}	Egg NOAEL (7.5 pg/g) of TCDD-EQs estimated to be protective of Caspian terns in the Great Lakes (Giesy et al. 1994).
Double-crested cormorant	4.6×10^{-6}	Egg NOAEL (4.6 pg/g) of TCDD-EQs estimated to be protective of double-crested cormorants in the Great Lakes (Giesy et al. 1994).
Bald eagle	15×10^{-6}	Reference value estimated as a NOAEL for TCDD based on concentration (15 pg/g) in eggs of bald eagles reproducing successfully along the coast of British Columbia (Elliott et al. 1996b).
2,3,7,8-TCDF		
Fish-all species	6×10^{-7}	Dietary NOAEL (0.6 pg/g) for TCDD-equivalents (TCDD-EQs) derived from Lake Huron fish fed to chickens and considered protective of bald eagles in the Great Lakes (Giesy et al 1994).
	7.5×10^{-6}	TFC (7.5 pg/g) for TCDF derived from site specific data from the lower Columbia River for the protection of bald eagles (U.S. Fish and Wildlife Service 1999a and this study).
Piscivorous bird eggs		
Gull species	10×10^{-6}	Egg NOAEL (10 pg/g) of TCDD-EQs estimated to be protective of herring gulls in the Great Lakes (Giesy et al. 1994).
Caspian and Forster's tern	7.5×10^{-6}	Egg NOAEL (7.5 pg/g) of TCDD-EQs estimated to be protective of Caspian terns in the Great Lakes (Giesy et al. 1994).
Double-crested cormorant	4.6×10^{-6}	Egg NOAEL (4.6 pg/g) of TCDD-EQs estimated to be protective of double-crested cormorants in the Great Lakes (Giesy et al. 1994).
Bald eagle egg	15×10^{-6}	Reference value estimated as a NOAEL for TCDF based on concentration (15 pg/g) in eggs of bald eagles reproducing successfully along the coast of British Columbia (Elliott et al. 1996b).

Table 8. Concentrations (µg/kg dry weight) of total polychlorinated biphenyls (PCBs) and selected organochlorine pesticides[a] in 24 composite sediment samples from the Columbia River in 1991. Each site was represented by three composite samples containing three grab grabs each.

	Baker Bay	Cathlamet Bay	Lewis & Clark NWR	Julia Butler Hansen NWR	Longview	Ridgefield	Camas Slough	Umatilla
Bi-State segment[b]	1	1	1	2	2	3	4	NA
River miles	2-6	19-21	21-37	37-47	64-72	87-102	111-121	274-286
Total PCB	ND[c]	ND	ND	ND	ND	ND	ND	ND
p,p'-DDT	ND	ND	ND	ND	ND	ND	ND	ND
p,p'-DDE	ND	ND	ND	ND - 30[d]	ND	ND	ND	ND
p,p'-DDD	ND	ND	ND	ND	ND	ND	ND	ND- 20[d]

[a] Other organochlorine pesticides were below detection limits and included dieldrin, endrin, HCB, alpha-, beta, and gamma-BHC, alpha- and gamma- chlordane, oxychlordane, heptachlor-epoxide, mirex, cis- and trans-nonachlor, and o,p'-isomers of DDT and transformation products.
[b] Segments correspond to those derived by the Bi-State Water Quality Program (Tetra Tech 1992b). NA=segment designation not available.
[c] Not detected above detection limit. The detection limit was 10 µg/kg dry weight for all organochlorine pesticides and 50 µg/kg dry weight for total PCBs.
[d] Analyte concentration in one of the three composite samples.

Table 9. Concentrations (pg/g dry weight) of dioxins and furans in single composite samples (three sediment grabs per sample) collected from the Columbia River in 1991.

	Baker Bay	Cathlamet Bay	Lewis & Clark NWR	Julia Butler Hansen NWR	Longview	Ridgefield	Camas Slough	Umatilla
Bi-State segment[a]	1	1	1	2	2	3	4	NA
River miles	2-6	19-21	21-37	37-47	64-72	87-102	111-121	274-286
Dibenzo-*p*-dioxins								
2,3,7,8-Tetra	<2.0 [b]	<0.2	0.4	<0.3	<0.2	<0.1	<0.1	<0.2
1,2,3,7,8-Penta		<0.3	0.4	0.3	<0.4	<0.2	<0.2	<0.4
1,2,3,4,7,8-Hexa		<0.3	0.6	<0.4	<0.3	<0.2	<0.2	<0.3
1,2,3,6,7,8-Hexa		1.2	3.0	0.5	0.5	<0.5	0.8	<0.2
1,2,3,7,8,9-Hexa		0.9PR[c]	2.3PR	1.0PR	0.2	<0.4	<0.2	<0.3
1,2,3,4,6,7,8-Hepta		16B[d]	41B	9.1B	13B	8.3B	7.8B	5.3B
Octa		121B	303B	78B	122B	105B	70B	70B
Dibenzofurans								
2,3,7,8-Tetra	<2.0	1.5	3.7	0.9E[e]	<0.9	0.6E	<0.2	0.9
1,2,3,7,8-Penta		0.3	0.5	<0.3	<0.3	<0.2	<0.1	<0.3
2,3,4,7,8-Penta		<0.2	<0.6	<0.2	<0.2	<0.1	0.2	<0.2
1,2,3,4,7,8-Hexa		<0.5	0.9	<0.3	0.3	0.2	<0.1	<0.2
1,2,3,6,7,8-Hexa		0.2	0.4	<0.2	<0.2	<0.1	<0.1	<0.2
1,2,3,7,8,9-Hexa		<0.2	<0.5	<0.3	<0.3	<0.1	<0.1	<0.2
2,3,4,6,7,8-Hexa		0.5B	<0.8	0.4	0.4B	<0.3	0.4	0.3B
1,2,3,4,6,7,8-Hepta		<2.0	5.1	0.7	<1.0	<2.0	0.8	0.4
1,2,3,4,7,8,9-Hepta		<0.2	<0.7	<0.4	<0.4	<0.2	<0.2	<0.3
Octa		5.9	18	<2.0	5.7	2.4	2.3	1.5

[a] Segments correspond to those derived by the Bi-State Water Quality Program (Tetra Tech 1992b). NA=segment designation not available.
[b] Concentration of analyte in one composite sample consisting of three grab samples. A "< " sign indicates value was below specified detection limit.
[c] PR=Chromatograph peak was poorly resolved, and concentration was likely overestimated.
[d] B=Analyte detected in laboratory method blank sample. Blank concentrations were 1.7 and 36 pg/g for the 1,2,3,4,6,7,8-hepta and octa dioxin congeners, respectively, and 0.27 pg/g in the 2,3,4,6,7,8-hexa furan congener. Concentrations in these samples could be overestimated.
[e] E=Result is the estimated maximum possible concentration due to unresolved interfering compounds (confirmation column not performed for this analyte).

Table 10. Geometric mean and range (µg/g wet weight) of total polychlorinated biphenyls (PCBs), selected organochlorine pesticides[a], and total mercury in composite invertebrate samples collected from the Columbia River in 1991. Refer to Table 4 for detailed information on compositing and sample numbers.

	Baker Bay	Cathlamet Bay	Lewis & Clark NWR	Julia Butler Hansen NWR	Longview	Ridgefield	Camas Slough	Umatilla
Bi-State segment[b]	1	1	1	2	2	3	4	NA
River miles	2-6	19-21	21-37	37-47	64-72	87-102	111-121	274-286
No. of samples[c]	0/0/3/0	1/2/0/1	0/3/0/2	0/3/0/3	0/3/0/2	0/3/0/3	0/3/0/2	0/3/0/0
Total PCBs [d]								
Corophium		<0.05 [e]						
Corbicula clam		<0.05	<0.05	<0.01-1.1[f]	<0.01[f]	<0.05	<0.05	<0.05
Macoma clam	<0.05							
Crayfish		<0.05	<0.05	<0.01-0.29[f]	<0.05	<0.05	<0.05	
p,p'-DDT								
Corophium		<0.01						
Corbicula clam		<0.01	<0.01	<0.01[g]	<0.01	<0.01	<0.01	<0.01
Macoma clam	<0.01							
Crayfish		<0.01	<0.01-0.02	<0.01	<0.01	<0.01-0.01	<0.01	
p,p'-DDE								
Corophium		<0.01						
Corbicula clam		0.02 0.02-0.02	<0.01-0.02	0.07[g] 0.06-0.09	0.01 0.01-0.01	0.01 <0.01-0.02	0.02 0.01-0.03	0.01 <0.01-0.03
Macoma clam	0.01 <0.01-0.02							
Crayfish		<0.01	<0.01-0.02	<0.01	<0.01	<0.01-0.01	<0.01	

Table 10. Continued.

	Baker Bay	Cathlamet Bay	Lewis & Clark NWR	Julia Butler Hansen NWR	Longview	Ridgefield	Camas Slough	Umatilla
Bi-State segment[b]	1	1	1	2	2	3	4	NA
River miles	2-6	19-21	21-37	37-47	64-72	87-102	111-121	274-286
No. of samples[c]	0/0/3/0	1/2/0/1	0/3/0/2	0/3/0/3	0/3/0/2	0/3/0/3	0/3/0/2	0/3/0/0
p,p'-DDD								
Corophium		<0.01						
Corbicula clam		<0.01	<0.01	<0.01-0.07[g]	<0.01	<0.01	<0.01	0.01 <0.01-0.01
Macoma clam	<0.01							
Crayfish		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Total mercury								
Corbicula clam				0.008 0.008-0.009	0.007 0.005-0.009			
Crayfish				0.03 0.03-0.04				

[a] Other organochlorine pesticides analyzed were at or below detection limits (unless otherwise noted) and included dieldrin, endrin, HCB, alpha-, beta, and gamma-BHC, heptachlor epoxide, chlordane, oxychlordane, alpha-and gamma-chlordane, mirex, and o,p'-isomers of DDT and transformation products. Aldrin, total-BHC, total chlordane, delta-BHC, heptachlor, and toxaphene were also analyzed in two clam composite samples and one crayfish composite only and were below detection limits. Detection limits were 0.01 µg/g for organochlorine pesticides, 0.01 to 0.05 µg/g for total PCBs, and 0.002 µg/g for mercury.

[b] Segments correspond to those derived by the Bi-State Water Quality Program (Tetra Tech 1992b). NA=segment designation not available.

[c] Number of composite samples for each species in the order *Corophium*/Corbicula clam/Macoma clam/crayfish.

[d] Measured as total Aroclor PCBs unless otherwise noted.

[e] Only the range or a single value was reported when sample size was insufficient to calculate a geometric mean or the majority of samples was below detection. A "<" sign indicates one or more samples was below the detection limit, which is the number listed immediately following the sign. All numbers reported as the maximum value within a range are the actual concentrations found in a sample.

[f] Total PCBs calculated by summation of individual PCB congener concentrations.

[g] One of the three composite samples of Corbicula clam at this site contained other organochlorine pesticides in the following concentrations (µg/g wet weight): o,p'-DDE (0.06), o,p'-DDD (0.03), total chlordane (0.20), total BHC (0.16), cis-nonachlor (0.06), trans-nonachlor (0.04), and mirex (0.05).

Table 11. Frequency of detection and estimated guidance or protection levels for total polychlorinated biphenyls (PCBs), DDE, total mercury, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD), and 2,3,7,8-tetrachlorodibenzofuran (TCDF) in sediment and biota collected from the Columbia River in 1990 and 1991, and from the lower Willamette River at Portland in 1990.

	Frequency of detection[a]	Estimated guidance or protection levels (µg/g)	No. of samples above guidance or protection levels[b]	HQ[c]	Sites where guidance levels were exceeded or, for species without available levels, where chemical was detected (sites in bold indicate multiple guidance or protection levels were exceeded).
Total PCBs [d]					
Sediment	0/24	0.0227 [e]	0		
Invertebrates	2/37	NA [f]		NA	
Corophium	0/1				
Macoma clam	0/3				
Cobicula clam	1/20				JB Hansen
Crayfish	1/13				JB Hansen
Fish-1990	13/15	0.06 [g], 0.11 [h]	13	8 (0.8-17) 4 (0.5-9)	
Sucker	3/3		3	11 (4-17) 6 (2-9)	**Cath Bay, Longview, St. Helens**
Common carp	3/4		3	4 (0.8-7) 2 (0.5-4)	**Longview, St. Helens, Portland**
Peamouth chub	1/1		1	12, 7	**Cath Bay**
N. Pikeminnow	3/4		3	7 (0.8-14) 4 (0.5-7)	**Longview, St. Helens, Camas**
Smallmouth bass	1/1		1	12, 7	**Portland**
Largemouth bass	2/2		2	8 (3-13) 5 (2-7)	**Longview, St. Helens**
Fish-1991	15/51	0.06 [g], 0.11 [h]	14, 11	1 (0.5-9) 0.8 (0.3-5)	
Sucker	0/21		0	<1	
Common carp	8/12		7, 5	2 (0.5-5) 1 (0.3-3)	**Longview, Ridgefield, Camas, Umatilla**
Peamouth chub	7/16		7, 6	2 (0.8-9) 1 (0.5-5)	**Cath Bay, JB Hansen, Longview**
Mountain whitefish	0/2		0	<1	
Piscivorous bird eggs-1990	25/27		3	NA	
West./Glaucous-winged gull	7/7	5 [i]	0	0.3 (0.1-0.4)	
Ring-billed gull	1/3	5 [i]	0	0	
Caspian tern	7/7	4.2 [j]	0	0.4 (0.3-0.8)	
Forster's tern	3/3	4.5 [k]	0	0.3 (0.2-0.3)	
Double-crested cormorant	7/7	3.5 [l]	3	1 (0.5-1.8)	Lew & Clark (Rice I.)

Table 11. Continued.

	Frequency of detection[a]	Estimated guidance or protection levels (µg/g)	No. of samples above guidance or protection levels[b]	HQ[c]	Sites where guidance levels were exceeded or, for species without available levels, where chemical was detected (sites in bold indicate multiple guidance or protection levels were exceeded).
Piscivorous bird eggs-1991	23/23	NA	3	NA	
West./Glaucous-winged gull	6/6	5 [i]	0	0.3 (0.1-0.7)	
Ring-billed gull	3/3	5 [i]	0	0.2 (0.1-0.4)	
Caspian tern	8/8	4.2 [j]	0	0.2 (0.1-0.4)	
Double-crested cormorant	6/6	3.5 [l]	3	1 (0.4-3)	Lew & Clark (Rice I.)
Non-piscivorous bird eggs-1991	9/11				
Mallard	4/4	105 [m]	0	0	
Canada goose	5/7	NA		NA	Baker Bay, Lew & Clark, Ridgefield
p,p -DDE					
Sediment	1/24	0.0022 [e]	1		JB Hansen
Invertebrates	20/37	NA		NA	
Corophium	0/1				
Macoma clam	2/3				Baker Bay
Cobicula clam	16/20				Cath Bay, Lew & Clark, JB Hansen, Longview, Ridgefield, Camas, Umatilla
Crayfish	2/13				Lew & Clark, Ridgefield
Fish-1990	15/15	0.04 [g], 0.2 [h]	15, 8	6 (2-16) 1 (0.4-3)	
Sucker	3/3		3, 2	6 (3-9) 1 (0.5-2)	**Cath Bay, Longview**, St. Helens
Common carp	4/4		4, 2	4 (3-7) 0.9 (0.5-1)	St. Helens, **Longview**, Camas, **Portland**
Peamouth chub	1/1		1	16, 3	**Cath Bay**
N. Pikeminnow	4/4		4, 2	5 (2-9) 1 (0.5-1.9)	Cath Bay, **St. Helens** , Longview, **Camas**
Smallmouth bass	1/1		1, 0	5, 0.9	Portland
Largemouth bass	2/2		2, 1	5 (2-7) 0.9 (0.4-1.5)	St. Helens, **Longview**
Fish-1991	51/51	0.04 [g], 0.2 [h]	44, 5	3 (0.3-12) 0.5 (0.1-2.4)	
Sucker	21/21		16, 0	2 (0.3-3.3) 0.3 (0.1-0.7)	Cath Bay, Lew & Clark , JB Hansen, Longview, Ridgefield, Camas, Umatilla
Common carp	12/12		10, 1	3 (0.3-12) 0.6 (0.1-2.4)	Longview, Ridgefield, Camas, **Umatilla**
Peamouth chub	16/16		16, 4	3 (1-6) 0.7 (0.2-1.3)	**Cath Bay, JB Hansen**, Longview, Ridgefield, Umatilla
Mountain whitefish	2/2		2, 0	4, 0.8	Umatilla

Table 11. Continued.

	Frequency of detection[a]	Estimated guidance or protection levels (µg/g)	No. of samples above guidance or protection levels[b]	HQ[c]	Sites where guidance levels were exceeded or, for species without available levels, where chemical was detected (sites in bold indicate multiple guidance or protection levels were exceeded).
Piscivorous bird eggs-1990	25/27	3-5 [n]	1	0.4 (0-1.4)	
West./Glaucous-winged gull	7/7		0	0.2 (0.1-0.4)	
Ring-billed gull	3/3		0	0.4 (0.2-0.8)	
Caspian tern	6/7		1	0.6 (0-1.4)	Umatilla
Forster's tern	3/3		0	0.2	
Double-crested cormorant	6/7		0	0.4 (0-0.9)	Lew & Clark (Rice Isl)
Piscivorous bird eggs-1991	23/23	3-5 [n]	9	0.9 (0.1-3)	
West./Glaucous-winged gull	6/6		0	0.4 (0.1-0.8)	
Ring-billed gull	3/3		0	0.4 (0.3-0.6)	
Caspian tern	8/8		5	1 (0.3-2)	Lew & Clark (Rice I.), Umatilla (Crescent I.)
Double-crested cormorant	6/6		4	1 (0.4-3)	Lew & Clark (Rice I.), Baker Bay (E. Sand I.)
Non-piscivorous bird eggs-1991	10/11	NA		NA	
Mallard	4/4	10-30 [o]	0	0	
Canada goose	6/7	NA		NA	Baker Bay, Lew & Clark, Ridgefield
Total Mercury					
Invertebrates	9/9	0.1 [p]	0	0.2 (0.1-0.4)	
Cobicula clam	6/6		0	0.1	
Crayfish	3/3		0	0.3 (0.3-0.4)	
Fish-1990	4/7	0.1, 0.2 [p]	4, 3	3 (0.7-11) 2 (0.4-6)	
Common carp	0/2		0	<1	
Peamouth chub	1/1		1, 1	2, 1	Cath Bay
N. Pikeminnow	3/4		3, 2	5 (0.7-11) 2 (0.4-6)	Longview, **St. Helens** , **Camas**
Fish-1991	48/51	0.1, 0.2 [p]	19, 1	0.9 (0.3-2) 0.5 (0.1-1.2)	
Sucker	19/21		8, 1	1 (0.5-2) 0.5 (0.2-1.2)	Lew & Clark, Longview, Ridgefield, Camas
Common carp	12/12		6	1 (0.6-1.8) 0.5 (0.3-0.9)	Longview, Ridgefield, Camas, Umatilla
Peamouth chub	15/16		4	0.8 (0.3-1.4) 0.4 (0.1-0.7)	Lew & Clark, JB Hansen, Ridgefield
Mountain whitefish	2/2		1	1 (0.9-1.1) 0.5 (0.5-0.6)	Umatilla

Table 11. Continued.

	Frequency of detection[a]	Estimated guidance or protection levels (µg/g)	No. of samples above guidance or protection levels[b]	HQ[c]	Sites where guidance levels were exceeded or, for species without available levels, where chemical was detected (sites in bold indicate multiple guidance or protection levels were exceeded).
Piscivorous bird eggs-1990	15/15	0.79-2.2 [p]	4	0.6 (0.2-1.1)	
West./Glaucous-winged gull	4/4		0	0.3 (0.2-0.4)	
Caspian tern	7/7		4	0.8 (0.4-1.1)	Lew & Clark (Rice I.), Umatilla (Crescent I.)
Double-crested cormorant	4/4		0	0.5 (0.4-0.8)	
Piscivorous bird eggs-1991	23/23	0.79-2.2 [p]		1 (0.1-4)	
West./Glaucous-winged gull	6/6		2	0.7 (0.3-1)	Lew & Clark (Rice I.), Baker Bay (E. Sands I.)
Ring-billed gull	3/3		0	0.1 (0.1-0.2)	
Caspian tern	8/8		6	2 (0.8-3)	Lew & Clark (Rice I.), Umatilla (Crescent I.)
Double-crested cormorant	6/6		6	2 (2-4)	Lew & Clark (Rice I.), Baker Bay (E. Sands I.)
Non-piscivorous bird eggs-1991	11/11	0.79-2.2 [p]	0	0	
Mallard	4/4		0	0.1	
Canada goose	7/7		0	0	
TCDD					
Sediment	1/8	NA			Lew & Clark
Invertebrates	3/29	NA		NA	
Corophium	1/2				Lew & Clark
Macoma clam	0/1				
Cobicula clam	0/9				
Crayfish	2/17				Cath Bay, Longview
Fish-1990	7/9	6×10^{-7}, 9×10^{-7} [q]	7, 7	5 (0.8-15) 4 (0.6-10)	
Common carp	3/4		3, 3	4 (0.8-8) 3 (0.6-6)	**Longview, St, Helens, Camas**
N. Pikeminnow	4/5		4, 4	7 (0.8-15) 4 (0.6-10)	**Cath Bay, Longview, St. Helens, Camas**
Fish-1991	37/48	6×10^{-7}, 9×10^{-7} [q]	36, 33	4 (0.7-55) 3 (0.5-37)	
Sucker	14/19		13, 10	2 (0.8-4) 1 (0.6-3)	**Cath Bay, Lew & Clark, JB Hansen, Longview**, **Ridgefield**, Camas, Umatilla
Common carp	9/12		9, 9	9 (0.8-55) 6 (0.6-37)	**Longview, Ridgefield, Camas, Umatilla**
Peamouth chub	14/17		14, 14	3 (0.7-6) 2 (0.5-4)	**Cath Bay, Lew & Clark, JB Hansen, Longview, Ridgefield**

Table 11. Continued.

	Frequency of detection[a]	Estimated guidance or protection levels (µg/g)	No. of samples above guidance or protection levels[b]	HQ[c]	Sites where guidance levels were exceeded or, for species without available levels, where chemical was detected (sites in bold indicate multiple guidance or protection levels were exceeded).
Piscivorous bird eggs-1990	9/11	NA	3	NA	
West./Glaucous-winged gull	2/2	10×10^{-6} [r]	0	0.5 (0.4-0.6)	
Ring-billed gull	0/2	10×10^{-6} [r]	0	<1	
Caspian tern	4/4	7.5×10^{-6} [r]	0	0.9 (0.4-2)	
Double-crested cormorant	3/3	4.6×10^{-6} [r]	3[s]	8[s] (6-10)	Lew & Clark (Rice I.)
Piscivorous bird eggs-1991	24/30	NA	8	NA	
West./Glaucous-winged gull	6/6	10×10^{-6} [r]	1	0.6 (0-2)	Lew & Clark (Rice I.)
Ring-billed gull	2/3	10×10^{-6} [r]	0	0	
Caspian tern	6/6	7.5×10^{-6} [r]	0	0.3 (0.2-0.4)	
Forster's tern	2/5	7.5×10^{-6} [r]	0	0.1 (0.1-0.2)	
Double-crested cormorant	8/10	4.6×10^{-6} [r]	7	2 (0.1-5)	Baker Bay (E Sand I.), Lew & Clark (Rice I.)
TCDF					
Sediment	5/8E	NA			Cath Bay, Lew & Clark, JB Hansen, Ridgefield, Umatilla
Invertebrates	28/29E	NA		NA	
Corophium	2/2				Lew & Clark
Macoma clam	1/1				Baker Bay
Cobicula clam	8/9E				Cath Bay, Lew & Clark, Ridgefield, Camas, Umatilla
Crayfish	17/17				Cath Bay, Lew & Clark, JB Hansen, Longview, Ridgefield, Camas
Fish-1990	9/9	6×10^{-7}, 7.5×10^{-6} [q]	8, 7	49 (8-138) 4 (0.7-11)	
Common carp	4/4		4, 3	20 (8-28) 2 (0.7-2)	**St. Helens, Longview, Camas**, Portland
N. Pikeminnow	5/5		4, 4	73 (18-138) 6 (2-11)	**Cath Bay, Longview, St. Helens, Portland, Camas**
Fish-1991	45/48	6×10^{-7}, 7.5×10^{-6} [q]	45, 29	29 (0.8-183) 2 (0.1-15)	
Sucker	18/19E		18, 8E	11 (0.8-23) 0.9E (0.1-2)	**Cath Bay**, Lew & Clark, JB Hansen, **Longview, Ridgefield**, Camas, **Umatilla**
Common carp	11/12E		11, 5E	31 (0.8-183) 3E (0.1-15)	**Longview,** Ridgefield, **Camas, Umatilla**
Peamouth chub	16/17E		16, 16E	47 (3-107) 4E (0.3-9)	**Cath Bay, Lew & Clark, JB Hansen, Longview, Ridgefield, Umatilla**

Table 11. Continued.

	Frequency of detection[a]	Estimated guidance or protection levels (µg/g)	No. of samples above guidance or protection levels[b]	HQ[c]	Sites where guidance levels were exceeded or, for species without available levels, where chemical was detected (sites in bold indicate multiple guidance or protection levels were exceeded).
Piscivorous bird eggs-1990	9/11	NA	2	NA	
West./Glaucous-winged gull	0/2	10×10^{-6} [r]	0	<10	
Ring-billed gull	1/2	10×10^{-6} [r]	0	0.1 (0.1-0.2)	
Caspian tern	4/4	7.5×10^{-6} [r]	0	0.4 (0.2-0.5)	
Double-crested cormorant	2/3	4.6×10^{-6} [r]	2	0.9 (0.2-1.7)	Lew & Clark (Rice I.)
Piscivorous bird eggs-1991	20/30	NA	1	NA	
West./Glaucous-winged gull	6/6E	10×10^{-6} [r]	0E	0E	
Ring-billed gull	0/3	10×10^{-6} [r]	0	<1	
Caspian tern	6/6	7.5×10^{-6} [r]	1	0.6 (0.1-1.8)	Lew & Clark (Rice I.)
Forster's tern	2/5	7.5×10^{-6} [r]	0	0.1 (0.1-0.3)	
Double-crested cormorant	6/10	4.6×10^{-6} [r]	0	0.2 (0-0.4)	

[a] Number of samples above the detection limits/total number of samples.
[b] Two numbers separated by a comma refers to, respectively, the number of samples exceeding the two guideline values in previous column. A single number indicates only one guideline value was compared, or that all samples exceeded both guidelines listed in previous column.
[c] Average hazard quotient (HQ) and range in parenthesis. The HQ is calculated as the ratio of a contaminant concentration in tissue over the NOAEL or guidance value for tissue, and represents the relative magnitude of exceedance over guidance. The HQ was calculated for each sample and the arithmetic average reported for a group of samples (e.g., all fish) and for all samples of a particular species. If two values are listed in the "Guidance or protection level" column, then two HQs are reported in the "HQ" column respective to the order listed in the guidance column. If a range of guidance values was reported, then only the lowest NOAEL or guidance value was used to calculate an HQ. .
[d] Measured as total Aroclor PCBs or summation of individual PCB congener.
[e] Effects range-low (dry weight). The lower tenth percentile of concentrations of a compound associated with biological effects (Long and Morgan 1990).
[f] Not available. Guidance or protection value was not found in literature for the species within this group, and hazard quotient was not determined.
[g] Target fish concentration (TFC) for the protection of bald eagles derived from site specific data (U.S. Fish and Wildlife Service 1999a, and this study).
[h] New York State Department of Environmental Conservation values for protection of fish-eating fish and wildlife (Newell et al. 1987).
[i] Lowest-observable-adverse-effect-level (LOAEL) based on embryonic deformities and egg lethality in herring gull eggs (Weseloh et al. 1991).
[j] LOAEL based on embryonic deformities and egg lethality in Caspian tern eggs (Giesy et al. 1994).
[k] No-observable-adverse-effect-level (NOAEL) in eggs of the Forster's tern (Kubiak et al. 1989).
[l] NOAEL based on egg lethality in double-crested cormorant eggs (Tillitt et al. 1992, Yamashita et al. 1993).
[m] Lowest observable effect concentration (LOEC) based on eggshell thinning in mallards (Haseltine and Prouty 1980).
[n] Concentration range associated with embryo death and reproductive impairment related to shell structure in common terns in Alberta (Fox 1976), and associated with eggshell thinning (Heinz et al. 1985) and reduced hatching success (Custer et. al. 1999) in double-crested cormorants.
[o] Range associated with reduced survival of embryonated eggs or hatchlings of dosed black ducks (*Anas rubripes*) (Longcore et al. 1971).
[p] Concentrations in food items (0.1 µg/g) such as invertebrates and fish considered protective of birds (Eisler 1987), in eggs (0.79-2.2 µg/g) associated with impaired reproduction in various birds (Eisler 1987), and TFC (0.2 µg/g) derived for protection of bald eagles (U.S. Fish and Wildlife Service 1999a and this study).
[q] TFC of 0.9 pg/g for TCDD and 7.5 pg/g for TCDF derived from site specific data for the protection of bald eagles (U.S. Fish and Wildlife Service 1999a and this study), and dietary NOAEL (0.6 pg/g) for TCDD-equivalents (TCDD-EQs) derived from Lake Huron fish fed to chickens and considered protective of bald eagles in the Great Lakes (Giesy et al 1994).
[r] Egg NOAELs of TCDD-EQs to protect herring gulls (10 pg/g), Caspian terns (7.5 pg/g), or double-crested cormorants (4.6 pg/g) in the Great Lakes (Giesy et al. 1994).
[s] TCDD and TCDF concentrations estimated in these three cormorant eggs due to differences in analytical methods as explained in the text.
[t] E=TCDF results are estimated maximum possible concentrations in one or more samples due to interference during quantification of analyte. Number of samples above guidance and HQs could be overestimated.

Table 12. Concentrations (pg/g wet weight) of dioxins and furans in composite invertebrate samples collected from the Columbia River in 1991. See Table 4 for detailed information on compositing and sample numbers.

	Baker Bay	Cathlamet Bay	Lewis & Clark NWR	Julia Butler Hansen NWR	Longview	Ridgefield	Camas Slough	Umatilla
Bi-State segment[a]	1	1	1	2	2	3	4	NA
River miles	2-6	19-21	21-37	37-47	64-72	87-102	111-121	274-286
No. of samples[b]	0/0/1/0	0/1/0/3	2/2/0/2	0/0/0/3	0/0/0/2	0/2/0/3	0/2/0/3	0/2/0/0
Dibenzo-*p*-dioxins								
2,3,7,8-Tetra								
Corophium[c]			<1.0-1.4[d]					
Corbicula clam		<2.0	<1.0			<1.0	<1.0	<1.0
Macoma clam	<0.5							
Crayfish		<1.0-1.2	<1.0	<1.0	<1.0-0.3	<1.0	<1.0	
1,2,3,7,8-Penta								
Corbicula clam			<0.7			<0.2	<0.2	<0.1
Macoma clam	<0.9							
Crayfish		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
1,2,3,4,7,8-Hexa								
Corbicula clam			<0.4			<0.1	<0.2	<0.1
Macoma clam	<0.4							
Crayfish		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
1,2,3,6,7,8-Hexa								
Corbicula clam			<0.3			0.1	<0.1	<0.1
Macoma clam	0.3							
Crayfish		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
1,2,3,7,8,9-Hexa								
Corbicula clam			<0.3			<0.1	<0.1	<0.1
Macoma clam	<0.4							
Crayfish		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	

Table 12. Continued.

	Baker Bay	Cathlamet Bay	Lewis & Clark NWR	Julia Butler Hansen NWR	Longview	Ridgefield	Camas Slough	Umatilla
Bi-State segment[a]	1	1	1	2	2	3	4	NA
River miles	2-6	19-21	21-37	37-47	64-72	87-102	111-121	274-286
No. of samples[b]	0/0/1/0	0/1/0/3	2/2/0/2	0/0/0/3	0/0/0/2	0/2/0/3	0/2/0/3	0/2/0/0
1,2,3,4,6,7,8-Hepta								
Corbicula clam			<4.3			1.3	1.4	0.8
Macoma clam	5.4							
Crayfish		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
Octa								
Corbicula clam			70			17	22	15Q[e]
Macoma clam	52							
Crayfish		<2.0	4.1	<2.0	3.3	<2.0	2.7	
Dibenzofurans								
2,3,7,8-Tetra								
Corophium[c]			2.6E[f] 2.0-3.5E					
Corbicula clam		10E	<1.3-2.5E			1.7E 1.3-2.3E	2.6E 1.5-4.5E	3.3E 2.5-4.4E
Macoma clam	0.6							
Crayfish		2.8 1.3-4.0	2.3 1.4-3.9	4.4 1.6-4.9	3.6 3.0-5.0	2.1 1.4-3.0	1.9 0.8-4.6	
1,2,3,7,8-Penta								
Corbicula clam			<0.4			<0.2	<0.1	<0.1
Macoma clam	<0.6							
Crayfish		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
2,3,4,7,8-Penta								
Corbicula clam			<0.4			<0.1	<0.1	<0.1
Macoma clam	<0.5							
Crayfish		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	

Table 12. Continued.

	Baker Bay	Cathlamet Bay	Lewis & Clark NWR	Julia Butler Hansen NWR	Longview	Ridgefield	Camas Slough	Umatilla
Bi-State segment[a]	1	1	1	2	2	3	4	NA
River miles	2-6	19-21	21-37	37-47	64-72	87-102	111-121	274-286
No. of samples[b]	0/0/1/0	0/1/0/3	2/2/0/2	0/0/0/3	0/0/0/2	0/2/0/3	0/2/0/3	0/2/0/0
1,2,3,4,7,8-Hexa								
Corbicula clam			<0.3			<0.1	<0.1	<0.1
Macoma clam	<0.3							
Crayfish		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
1,2,3,6,7,8-Hexa								
Corbicula clam			<0.2			<0.1	<0.1	<0.1
Macoma clam	<0.2							
Crayfish		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
1,2,3,7,8,9-Hexa								
Corbicula clam			<0.3			<0.1	<0.1	<0.1
Macoma clam	<0.3							
Crayfish		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
2,3,4,6,7,8-Hexa								
Corbicula clam			0.6			0.1	0.1	<0.1
Macoma clam	0.3							
Crayfish		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
1,2,3,4,6,7,8-Hepta								
Corbicula clam			<0.2			0.1	0.1	<0.1
Macoma clam	<0.6							
Crayfish		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
1,2,3,4,7,8,9-Hepta								
Corbicula clam			<0.3			<0.1	<0.1	<0.1
Macoma clam	<0.3							
Crayfish		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	

Table 12. Continued.

	Baker Bay	Cathlamet Bay	Lewis & Clark NWR	Julia Butler Hansen NWR	Longview	Ridgefield	Camas Slough	Umatilla
Bi-State segment[a]	1	1	1	2	2	3	4	NA
River miles	2-6	19-21	21-37	37-47	64-72	87-102	111-121	274-286
No. of samples[b]	0/0/1/0	0/1/0/3	2/2/0/2	0/0/0/3	0/0/0/2	0/2/0/3	0/2/0/3	0/2/0/0
Octa								
Corbicula clam			<0.5			<0.2	0.3	0.2Q
Macoma clam	1.6							
Crayfish		<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	

[a] Segments correspond to those derived by the Bi-State Water Quality Program (Tetra Tech 1992b). NA=segment designation not available.
[b] For the 2,3,7,8-tetra substituted dioxin and furan congeners, the number of composite samples analyzed are presented in the order *Corophium*/corbicula clam/macoma clam/crayfish. For all other congeners, only one composite sample per species was analyzed.
[c] Due to insufficient quantity of sample material, *Corophium* were analyzed for the 2,3,7,8-tetra substituted congeners only.
[d] Geometric mean and range. Only the range or a single value was reported when sample size was insufficient to calculate a geometric mean, or the majority of samples was below detection. A "< " sign indicates the sample was below the detection limit, which is the number listed following the sign. All numbers reported as the maximum value within a range are the actual concentrations found in a sample. Detection limits were 1 pg/g unless otherwise noted.
[e] Q=Ion instabilities caused by quantitative interferences for this analyte. Result is estimated.
[f] E=Result is the estimated maximum possible concentration due to unresolved interfering compounds (confirmation column not performed or not effective for analyte).

Table 13. Concentrations (µg/g wet weight) of total polychlorinated biphenyls (PCBs), selected organochlorine pesticides[a], and total mercury in single composite samples of whole body fish collected from the lower Columbia River and Willamette River at Portland in 1990. Each composite sample consisted of three individual fish unless otherwise noted in parenthesis.

	Cathlamet Bay	Longview	St. Helens	Portland	Camas Slough
Bi-State segment[b]	1	2	3	NA	4
River miles	19-21	64-72	79-87	3-6	111-121
Total PCBs [c]					
Sucker	1.03[d] (1)	0.64[d]	0.26[d]		
Common carp		0.43[d] (1)	0.23[d] (2)	0.23 (2)	<0.05[e]
Peamouth chub	0.74				
Northern pikeminnow	<0.05	0.76[d]	0.81[d]		0.13 (2)
Largemouth bass		0.80[d] (1)	0.18[d]		
Smallmouth bass				0.74[d] (2)	
p,p'-DDT					
Sucker	0.04 (1)	0.02	0.01		
Common carp		<0.01 (1)	<0.01 (2)	<0.05 (2)[f]	<0.05[f]
Peamouth chub	<0.05[f]				
Northern pikeminnow	<0.05[f]	<0.01	<0.01		<0.05 (2)[f]
Largemouth bass		0.02 (1)	<0.01		
Smallmouth bass				0.02 (2)	
p,p'-DDE					
Sucker	0.34 (1)	0.24	0.10		
Common carp		0.20 (1)	0.10 (2)	0.27 (2)	0.11
Peamouth chub	0.65				
Northern pikeminnow	0.09	0.16	0.37		0.24 (2)
Largemouth bass		0.29 (1)	0.07		
Smallmouth bass				0.18 (2)	
p,p'-DDD					
Sucker	0.07 (1)	0.06	0.04		
Common carp		0.03 (1)	0.04 (2)	0.05 (2)	<0.02
Peamouth chub	0.07				
Northern pikeminnow	0.02	0.04	0.08		0.02 (2)
Largemouth bass		0.05 (1)	0.02		
Smallmouth bass				0.08 (2)	
Total Chlordane					
Sucker	0.03 (1)	0.01	0.02		
Common carp		0.01 (1)	0.03 (2)		
Peamouth chub					
Northern pikeminnow		0.03	0.04		
Largemouth bass		0.04 (1)	0.03		
Smallmouth bass				0.10 (2)	

Table 13. Continued.

	Cathlamet Bay	Longview	St. Helens	Portland	Camas Slough
Bi-State segment[b]	1	2	3	NA	4
River miles	19-21	64-72	79-87	3-6	111-121
Chlordane					
Sucker					
Common carp				0.04 (2)	<0.02
Peamouth chub	0.07				
Northern pikeminnow	<0.02				<0.02 (2)
Trans-nonachlor					
Sucker	0.01	0.01	0.01		
Common carp		0.01 (1)	0.01 (2)		
Peamouth chub					
Northern pikeminnow		0.01	0.02		
Largemouth bass		0.02 (1)	0.01		
Smallmouth bass				0.03 (2)	
Total mercury					
Common carp				<0.07 (2)	<0.07
Peamouth chub	0.21 (2)				
Northern pikeminnow	<0.07	0.39 (4)	1.1		0.32 (2)

[a] Other organochlorine pesticides analyzed were at or below detection limits and included dieldrin, aldrin, endrin, lindane, HCB, total-BHC, alpha-BHC, beta-BHC, delta-BHC, gamma-BHC, heptachlor, heptachlor-epoxide, oxychlordane, alpha-chlordane, gamma-chlordane, cis-nonachlor, mirex, toxaphene, endosulfan-I, endosulfan-II, and o,p'-isomers of DDT and transformation products.

[b] Segments correspond to those derived by the Bi-State Water Quality Program (Tetra Tech 1992b). NA=segment designation not available.

[c] Measured as total Aroclor PCBs unless otherwise noted.

[d] Total PCBs calculated by summation of individual PCB congener concentrations.

[e] A "< " sign indicates the value was below the specified detection limit. Detection limits were 0.05 µg/g for total PCBs, and 0.08 µg/g for total mercury, and ranged from 0.01 to 0.05 µg/g for organochlorine pesticides.

[f] Spike recovery results were low (54%) for p,p'-DDT and actual result could be biased low in this sample.

Table 14. Concentrations (µg/g wet weight) of total polychlorinated biphenyls (PCBs), selected organochlorine pesticides[a], and total mercury in whole-body fish composite samples collected from the Columbia River in 1991. Three composites samples were analyzed for each species at a site unless otherwise noted in parenthesis.

	Cathlamet Bay	Lewis & Clark NWR	Julia Butler NWR	Longview	Ridgefield	Camas Slough	Umatilla
Bi-State segment[b]	1	1	2	2	3	4	NA
River miles	19-21	21-37	37-47	64-72	87-102	111-121	274-286
Total PCBs [c]							
Sucker	<0.05[d]	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Carp				0.11 <0.05-0.18	0.06[e] 0.03-0.14	0.07 <0.05 -0.15	<0.05-0.32
Peamouth chub	0.29[e] 0.20-0.54	<0.05	0.12[e] 0.08-0.20	<0.05-0.17[e]	<0.05		<0.05 (1)
Whitefish							<0.05 (2)
p,p'-DDT							
Sucker	0.02 0.01-0.04	0.01 0.01-0.01	0.01 0.01-0.01	0.01 0.01-0.03	0.02 0.02-0.02	0.01 <0.01-0.01	0.02 0.01-0.02
Carp				<0.01-0.01	<0.01	<0.01	<0.01-0.02
Peamouth chub	<0.01	0.02 0.02-0.03	<0.01	0.02 <0.01-0.03	0.01 0.01-0.02		0.01 (1)
Whitefish							0.03 0.03-0.04 (2)
p,p'-DDE							
Sucker	0.07 0.03-0.11	0.05 0.05-0.06	0.02 0.01-0.04	0.06 0.02-0.13	0.10 0.09-0.12	0.04 0.03-0.05	0.08 0.06-0.11
Carp				0.03 0.01-0.11	0.10 0.06-0.14	0.07 0.05-0.08	0.17 0.07-0.47
Peamouth chub	0.24 0.22-0.25	0.09 0.07-0.12	0.17 0.13-0.24	0.08 0.05-0.11	0.07 0.04-0.10		0.14 (1)
Whitefish							0.16 0.15-0.17 (2)

Table 14. Continued.

	Cathlamet Bay	Lewis & Clark NWR	Julia Butler NWR	Longview	Ridgefield	Camas Slough	Umatilla
Bi-State segment[b]	1	1	2	2	3	4	NA
River miles	19-21	21-37	37-47	64-72	87-102	111-121	274-286
p,p'-DDD							
Sucker	0.01 <0.01-0.03	0.01 <0.01-0.02	<0.01	0.02 <0.01-0.04	0.02 0.02-0.02	<0.01	0.02 0.02-0.03
Carp				0.01 <0.01-0.02	0.02 0.01-0.03	0.02 0.01-0.03	0.03 <0.01-0.09
Peamouth chub	0.06 0.05-0.08	0.01 0.01-0.02	0.04 0.04-0.05	0.01 0.01-0.02	0.01 <0.01-0.01		0.02 (1)
Whitefish							0.05 0.03-0.07 (2)
Dieldrin							
Sucker	0.01 <0.01-0.02	<0.01	<0.01	0.01 <0.01-0.02	0.01 <0.01-0.02	<0.01	<0.01
Carp				<0.01	<0.01	<0.01	<0.01
Peamouth chub	<0.01-0.01	0.01 <0.01-0.02	<0.01	<0.01-0.02	0.01 <0.01-0.01		<0.01 (1)
Whitefish							<0.01-0.01 (2)
Cis-nonachlor							
Sucker	0.01 <0.01-0.02	<0.01	<0.01	0.01 <0.01-0.02	<0.01-0.01	<0.01	<0.01
Carp				<0.01	<0.01	<0.01	<0.01
Peamouth chub	<0.01-0.01	0.01 <0.01-0.02	<0.01	<0.01-0.02	0.01 <0.01-0.01		<0.01 (1)
Whitefish							<0.01-0.01 (2)

Table 14. Continued.

	Cathlamet Bay	Lewis & Clark NWR	Julia Butler NWR	Longview	Ridgefield	Camas Slough	Umatilla
Bi-State segment[b]	1	1	2	2	3	4	NA
River miles	19-21	21-37	37-47	64-72	87-102	111-121	274-286
Trans-nonachlor							
Sucker	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Carp							0.01
				<0.01	<0.01	<0.01-0.01	<0.01-0.02
Peamouth chub	0.02						
	0.01-0.03	<0.01	<0.01-0.01	<0.01	<0.01		<0.01 (1)
Whitefish							<0.01 (2)
Total Mercury							
Sucker	0.07	0.09	0.07	0.12	0.11	0.11	
	0.06-0.08	0.06-0.12	0.06-0.09	0.12-0.13	0.06-0.23	0.08-0.12	<0.05-0.09
Carp				0.12	0.08	0.09	0.11
				0.07-0.16	0.07-0.11	0.08-0.11	0.06-0.18
Peamouth chub	0.05	0.10	0.10	0.04	0.08		
	0.04-0.08	0.09-0.11	0.09-0.13	<0.04-0.09	0.05-0.14		0.09 (1)
Whitefish							0.10
							0.09-0.11 (2)

[a] Other organochlorines analyzed were at or below detection limits and included aldrin, endrin, lindane, HCB, total-BHC, alpha-, beta, delta-, and gamma-BHC, heptachlor, total chlordanes, chlordane, oxychlordane, alpha-chlordane, gamma-chlordane, heptachlor, heptachlor-epoxide, mirex, toxaphene, and o,p'N isomers of DDT and transformation products.

[b] Segments correspond to those derived by the Bi-State Water Quality Program (Tetra Tech 1992b). NA=segment designation not available.

[c] Measured as total Aroclor PCBs unless otherwise noted.

[d] Geometric mean and range. Only the range or a single value was reported when sample size was insufficient to calculate a geometric mean or the majority of samples was below detection. A "< " sign indicates the sample was below the detection limit, which is the number listed following the sign. All numbers reported as the maximum within a range are actual concentrations found in a sample. .

[e] Total PCBs calculated by summation of individual PCB congener concentrations.

Table 15. Concentrations (pg/g wet weight) of dioxins and furans in single composite samples of whole body fish from the lower Columbia River and Willamette River at Portland in 1990. Each composite sample consisted of three fish unless otherwise noted in parenthesis.

	Cathlamet	Longview	St. Helens	Portland	Camas
Bi-state segment [a]	1	2	3	NA	4
River miles	19-21	64-72	79-87	3-6	111-121
Dibenzo-*p*-dioxins					
2,3,7,8-Tetra					
Common carp		5.0 (1)	3.0 (2)	<1.0[b] (2)	1.0
Northern pikeminnow	2.0	4.0	9.0	<1.0 (4)	4.0 (2)
1,2,3,7,8-Penta					
Common carp		9.0 (1)	1.0 (2)	<1.0 (2)	<1.0
Northern pikeminnow	<1.0	2.0	3.0	<1.0 (4)	<1.0 (2)
1,2,3,4,7,8-Hexa					
Common carp		14 (1)	<1.0 (2)	<1.0 (2)	<1.0
Northern pikeminnow	<1.0	<1.0	<1.0	<1.0 (4)	<1.0 (2)
1,2,3,6,7,8-Hexa					
Common carp		49 (1)	3.0 (2)	<3.0 (2)	2.0
Northern Pikeminnow	<1.0	3.0	4.0	<2.0 (4)	<1.0 (2)
1,2,3,7,8,9-Hexa					
Common carp		<4.0 (1)	<1.0 (2)	<1.0 (2)	<1.0
Northern Pikeminnow	<1.0	<1.0	<1.0	<2.0 (4)	<1.0 (2)
1,2,3,4,6,7,8-Hepta					
Common carp		57 (1)	5.0 (2)	7.0 (2)	4.0
Northern Pikeminnow	<1.0	4.0	2.0	5.0 (4)	<1.0 (2)
Octa					
Common carp		117 (1)	4.0 (2)	13 (2)	7.0
Northern Pikeminnow	4.0	16	4.0	12 (4)	3.0 (2)
Dibenzofurans					
2,3,7,8-Tetra					
Common carp		17 (1)	15 (2)	5.0 (2)	11
Northern Pikeminnow	24	45	83	11 (4)	56 (2)
1,2,3,7,8-Penta					
Common carp		5.0 (1)	<1.0 (2)	<1.0 (2)	<1.0
Northern Pikeminnow	<1.0	2.0	<1.0	<1.0 (4)	<1.0 (2)
2,3,4,7,8-Penta					
Common carp		9.0 (1)	<1.0 (2)	<1.0 (2)	<1.0
Northern Pikeminnow	<1.0	2.0	2.0	<1.0 (4)	<1.0 (2)
1,2,3,4,7,8-Hexa					
Common carp		3.0 (1)	<1.0 (2)	<1.0 (2)	<1.0
Northern Pikeminnow	<1.0	<1.0	<1.0	<1.0 (4)	<1.0 (2)
1,2,3,6,7,8-Hexa					
Common carp		2.0 (1)	<1.0 (2)	<1.0 (2)	<1.0
Northern Pikeminnow	<1.0	<1.0	<1.0	<1.0 (4)	<1.0 (2)

Table 15. Continued.

	Cathlamet	Longview	St. Helens	Portland	Camas
Bi-state segment[a]	1	2	3	NA	4
River miles	19-21	64-72	79-87	3-6	111-121
1,2,3,7,8,9-Hexa					
Common carp		<1.0 (1)	<1.0 (2)	<1.0 (2)	<1.0
Northern Pikeminnow	<1.0	<1.0	<1.0	<1.0 (4)	<1.0 (2)
2,3,4,6,7,8-Hexa					
Common carp		1.0 (1)	<1.0 (2)	<1.0 (2)	<1.0
Northern Pikeminnow	<1.0	<1.0	<1.0	<1.0 (4)	<1.0 (2)
1,2,3,4,6,7,8-Hepta					
Common carp		5.0 (1)	<1.0 (2)	<2.0 (2)	<1.0
Northern Pikeminnow	<1.0	<1.0	0.5	<1.0 (4)	<1.0 (2)
1,2,3,4,7,8,9-Hepta					
Common carp		<1.0 (1)	<1.0 (2)	<1.0 (2)	<1.0
Northern Pikeminnow	<1.0	<1.0	0.5	<1.0 (4)	<1.0 (2)
Octa					
Common carp		<1.0 (1)	<1.0 (2)	0.5 (2)	<1.0
Northern Pikeminnow	<1.0	<1.0	0.5	<2.0 (4)	<1.0 (2)

[a] Segments correspond to those derived by the Bi-State Water Quality Program (Tetra Tech 1992b). NA=segment designation not available.

[b] A "< " sign indicates the sample was below the detection limit, which is the number listed following the sign.

Table 16. Concentrations (pg/g wet weight) of dioxins and furans in whole-body sucker, carp, and peamouth chub from the Columbia River in 1991. Unless otherwise noted, three composite samples were analyzed per species per site for the 2,3,7,8-tetra substituted congeners, and one composite sample was analyzed for the other congeners.

	Cathlamet	Lewis & Clark NWR	Julia Butler Hansen NWR	Longview	Ridgefield	Camas Slough	Umatilla
Bi-State segment[a]	1	1	2	2	3	4	NA
River miles	19-21	21-37	37-47	64-72	87-102	111-121	274-286
Dibenzo-*p*-dioxins							
2,3,7,8-Tetra							
Sucker	1.1[b] <1.0-1.9	0.9[c] 0.7-1.1	0.7 <1.0-1.1	1.5 1.1-2.6	1.2 0.88-1.6	<1.0-0.8	0.6[c] <1.0-0.63
Carp				2.1 <2.0-4.3	0.9 <1.0-1.4	1.4 <1.0-3.5	11 3.5-33
Peamouth chub	2.4[d] 1.5-3.4	1.8 <2.0-2.5	1.5 1.2-2.2	1.4 1.1-1.7	1.1 <1.0-1.9		2.0[e]
1,2,3,7,8-Penta							
Sucker	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Peamouth chub	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0
1,2,3,4,7,8-Hexa							
Sucker	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Peamouth chub	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0
1,2,3,6,7,8-Hexa							
Sucker	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Peamouth chub	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0
1,2,3,7,8,9-Hexa							
Sucker	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Peamouth chub	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0
1,2,3,4,6,7,8-Hepta							
Sucker	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Peamouth chub	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0
Octa							
Sucker	2.6	<2.0	2.7	<2.0	1.3	2.5	<2.0
Peamouth chub	3.0	<2.0	<2.0	<2.0	1.2		2.2
Dibenzofurans							
2,3,7,8-Tetra							
Sucker	9.5 6.3-14	5.5[c] 4.6-6.6	3.6 2.8-4.3	8.7 5.9-13	5.9 3.3-8.7	1.7 <1.0-5.5	11[c]E[f] 8.1-14E
Carp				9.7E 4.5-34E	3.2 2.1-5.0	3.1 <1.0-7.8	35 16-110
Peamouth chub	34[d] E 20-48E	12E <4.0-29E	24E 18-35E	17E 11-25E	40E 19-64E		17[e]

Table 16. Continued.

	Cathlamet	Lewis & Clark NWR	Julia Butler Hansen NWR	Longview	Ridgefield	Camas Slough	Umatilla
Bi-State segment[a]	1	1	2	2	3	4	NA
River miles	19-21	21-37	37-47	64-72	87-102	111-121	274-286
1,2,3,7,8-Penta							
Sucker	<1.0	<1.0	<1.0	<1.0	5.7	<1.0	<1.0
Peamouth chub	<1.0	<1.0	<1.0	<1.0	5.7		<1.0
2,3,4,7,8-Penta							
Sucker	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Peamouth chub	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0
1,2,3,4,7,8-Hexa							
Sucker	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Peamouth chub	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0
1,2,3,6,7,8-Hexa							
Sucker	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Peamouth chub	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0
1,2,3,7,8,9-Hexa							
Sucker	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Peamouth chub	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0
2,3,4,6,7,8-Hexa							
Sucker	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Peamouth chub	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0
1,2,3,4,6,7,8-Hepta							
Sucker	1.07	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Peamouth chub	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0
1,2,3,4,7,8,9-Hepta							
Sucker	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Peamouth chub	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0
Octa							
Sucker	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Peamouth chub	<2.0	<2.0	<2.0	<2.0	<2.0		<2.0

[a] Segments correspond to those derived by the Bi-State Water Quality Program (Tetra Tech 1992b). NA=segment designation not available.

[b] Geometric mean and range. Only the range or a single value was reported when sample size was insufficient to calculate a geometric mean or the majority of samples was below detection. A "< " sign indicates the sample was below the detection limit, which is the number listed following the sign. All numbers reported as the maximum within a range are actual concentrations found in a sample.

[c] Two composite samples.

[d] Four composite samples.

[e] One composite sample of two fish.

[f] E=Interference from co-eluting diphenyl ethers occurred during analysis of one or more samples used to calculate the geometric mean (confirmation column was not effective for positive identification). Result is the estimated maximum possible concentration.

Table 17. Concentrations of total polychlorinated biphenyls (PCBs) and selected organochlorine pesticides[a] (µg/g fresh weight) in eggs of piscivorous birds from the Columbia River in 1990.

	Lewis and Clark NWR (Rice Island)			Umatilla (Crescent Island)		
	Double-crested corm.	Caspian tern	Gull (*Larus* spp.)[b]	Caspian tern	Forster's tern	Ring-billed gull
No. of samples[c]	7	4	7	3	3	3
Total PCBs	3.35[d] 1.57-6.53	1.51 1.07-2.02	1.20 0.53-1.98	1.88 1.22-3.32	1.11 0.97-1.40	<0.05-0.31
p,p'-DDT	<0.05	<0.05	<0.05	<0.01	<0.01	<0.01
p,p'-DDE	0.50 <0.01-2.85	0.40 <0.02-2.11	0.62 0.29-1.27	2.31 1.57-4.12	0.66 0.63-0.68	1.07 0.46-2.28
p,p'-DDD	<0.01-0.01[e]	<0.02[e]	<0.02-0.01[e]	<0.01-0.02	<0.01	<0.01
Dieldrin	0.02 <0.02-0.03	0.01 <0.02-0.01	<0.02-0.03	0.01 0.01-0.03	0.01 0.01-0.02	0.03 0.02-0.08
HCB	0.01 0.01-0.02 (3)	0.01 0.01-0.01 (3)	0.1 0.01-0.01 (3)	0.01 0.01-0.01	0.01 0.01-0.02	0.01 0.01-0.02
Beta-BHC	<0.01-0.01	<0.01-0.02	<0.01	0.01 <0.01-0.07	<0.01	
Heptachlor epoxide	<0.01-0.04	<0.01-0.02	<0.01-0.01	0.02 0.02-0.03	0.01 0.01-0.01	0.05 0.02-0.07
Chlordane	<0.02 (4)	<0.02 (1)	0.03 0.02-0.05 (4)			
Oxychlordane	0.02 0.02-0.02 (3)	0.01 0.01-0.02 (3)	0.01 0.01-0.02 (3)	0.01 0.01-0.03	0.01 0.01-0.01	0.03 0.02-0.07
Alpha-chlordane	<0.01 (3)	<0.01-0.01 (3)	<0.01-0.03 (3)	<0.01	<0.01	<0.01
Trans-nonachlor	<0.01-0.01 (3)	0.03 0.02-0.03 (3)	0.01 0.01-0.02 (3)	0.02 0.02-0.04	0.03 0.03-0.03	0.03 0.02-0.08
Endosulfan-I	<0.02-0.60 (4)	0.71 (1)	<0.02 (4)			

[a] Other organochlorines analyzed were at or below detection limits and included aldrin, endrin, lindane, total-BHC, alpha-BHC, delta-BHC, gamma-BHC, heptachlor, gamma-chlordane, cis-nonachlor, mirex, toxaphene, endosulfan-II, and o,p'-isomers of DDT and transformation products. Detection limits for all organochlorine pesticides and total PCBs ranged from 0.01 to 0.05 µg/g wet weight.

[b] Western gull, glaucous-winged gull, or hybrid.

[c] Unless otherwise reported in parentheses.

[d] Geometric mean and range. Only the range or a single value was reported when sample size was insufficient to calculate a geometric mean or the majority of samples was below detection. A "< " sign indicates the sample was below the detection limit, which is the number listed following the sign. All numbers reported as the maximum within a range are actual concentrations found in a sample.

[e] Co-eluting PCB peaks interfered with p,p'-DDD separation in four cormorant eggs, four gull eggs, and one Caspian tern eggs, and results are considered estimated.

Table 18. Concentrations of total polychlorinated biphenyls (PCBs) and selected organochlorine pesticides[a] (µg/g fresh weight) in eggs of non-piscivorous birds from the Columbia River in 1991.

	Baker Bay		Lewis & Clark NWR		Longview
	Canada goose	Mallard	Canada goose	Mallard	Canada goose
No. of Samples	1	1	3	3	3
Total PCBs	0.10	0.24	0.14[b] 0.06-0.42	0.22 0.08-0.50	<0.01-0.14
p,p'-DDT	<0.01	0.01	<0.01-0.01	0.01 <0.01-0.02	<0.01
p,p'-DDE	0.04	0.41	0.01 0.01-0.01	0.16 0.05-0.45	0.01 <0.01-0.03
p,p'-DDD	<0.01	<0.01	<0.01-0.01	<0.01-0.01	<0.01-0.01
Total-BHC	<0.01	<0.01	<0.01-0.01	<0.01-0.02	<0.01
Total Chlordane	<0.01	0.01	<0.01-0.02	<0.01-0.03	<0.01-0.01

[a] Other organochlorines analyzed were at or below detection limits and included aldrin, dieldrin, endrin, HCB, alpha-, beta-, delta-, and gamma-BHC, heptachlor, heptachlor epoxide, alpha- and gamma-chlordane, mirex, toxaphene, cis and trans nonachlor, and o,p'- isomers of DDT and transformation products. Detection limits were 0.05 µg/g wet weight for total PCBs and 0.005 to 0.01 µg/g wet weight for organochlorine pesticides.

[b] Geometric mean and range. Only the range or a single value was reported when sample size was insufficient to calculate a geometric mean or the majority of samples was below detection. A "< " sign indicates the sample was below the detection limit, which is the number listed following the sign. All numbers reported as the maximum within a range are actual concentrations found in a sample.

Table 19. Concentrations of total polychlorinated biphenyls (PCBs) and selected organochlorine pesticides[a] (µg/g fresh weight) in eggs of piscivorous birds from the Columbia River in 1991.

	Baker Bay (East Sand Island)		Lewis and Clark NWR (Rice Island)			Umatilla (Crescent Island)	
	Double-crested corm.	Gull (*Larus* spp.)[b]	Double-crested corm.	Caspian tern	Gull (*Larus* spp.)	Caspian tern	Ring-billed gull
No. of samples	3	3	3	3	3	5	3
Total PCBs	1.66[c] 1.26-2.25	0.89 0.67-1.12	6.07 4.34-10.8	1.37 1.02-1.69	1.15 0.53-3.58	0.59[d] 0.28-1.47	0.78 0.42-1.91
p,p'-DDT	<0.01-0.01	0.02 0.02-0.03	0.01 0.01-0.02	<0.01-0.01	0.01 0.01-0.02	<0.01	0.02 <0.01-0.05
p,p'-DDE	2.15 1.47-3.04	0.87 0.37-1.35	5.31 3.66-9.88	1.61 0.84-2.85	0.93 0.39-2.28	3.40 1.82-6.90	1.31 1.03-1.65
p,p'-DDD	<0.01	0.01 0.01-0.02	0.01 0.01-0.02	0.01 <.01-0.02	0.01 0.01-0.02	<0.01-0.01	<0.01-0.01
Dieldrin	0.03 0.02-0.06	0.02 0.02-0.03	0.04 0.02-0.18	0.01 0.01-0.03	0.02 0.02-0.04	0.01 0.01-0.02	0.04 <0.01-0.13
Endrin	<0.01	<0.01	<0.01-0.13	<0.01	<0.01	<0.01-0.01	<0.01
Total-BHC	<0.01	0.01 0.01-0.03	0.01 <0.01-0.01	0.03 0.03-0.05	<0.01-0.01	0.03 <0.01-0.17	<0.01
Heptachlor epoxide	0.01 <0.01-0.01	0.01 0.01-0.01	0.01 <0.01-0.02	0.01 <0.01-0.01	0.01 0.01-0.01	0.01 <0.01-0.01	0.13 0.04-0.27
Total Chlordanes	0.02 <0.01-0.05	0.05 0.05-0.05	0.06 0.03-0.14	0.04 0.02-0.07	0.03 0.02-0.08	0.02 0.02-0.03	0.10 <0.01-0.50
Oxychlordane	0.02 <0.01-0.03	0.02 0.01-0.03	0.04 0.02-0.08	0.01 <0.01-0.01	0.01 <0.01-0.04	<0.01-0.01	0.05 0.02-0.09
Alpha-chlordane	<0.01	<0.01-0.01	<0.01	<0.01-0.01	<0.01	<0.01-0.01	0.01 <0.01-0.02
Cis-nonachlor	0.01 <0.01-0.02	<0.01-0.01	0.01 <0.01-0.05	<0.01-0.01	<0.01-0.01	<0.01-0.01	0.01 <0.01-0.01
Trans-nonachlor	<0.01	0.01 0.01-0.01	<0.01	0.02 0.01-0.03	0.01 <0.01-0.03	0.01 0.01-0.02	0.06 0.02-0.13

[a] Other organochlorines analyzed were at or below detection limits and included aldrin, HCB, alpha-, beta-, delta-, and gamma-BHC, heptachlor, alpha- and gamma-chlordane, mirex, toxaphene, and o,p'-isomers of DDT and transformation products. Detection limits were 0.05 µg/g wet weight for total PCBs and were 0.005 to 0.01 µg/g wet weight for organochlorine pesticides.

[b] Western gull, glaucous-winged gull, or hybrid.

[c] Geometric mean and range. Only the range or a single value was reported when sample size was insufficient to calculate a geometric mean or the majority of samples was below detection. A "< " sign indicates the sample was below the detection limit, which is the number listed following the sign. All numbers reported as the maximum within a range are actual concentrations found in a sample.

[d] Total PCBs for this species at Umatilla are reported as sum of congeners. All other PCB concentrations values reported as Aroclor PCBs.

Table 20. Geometric means (µg/g fresh weight), range (parenthesis), and number of samples analyzed for total mercury concentrations in eggs of piscivorous and non-piscivorous birds from the Columbia River in 1990 and 1991.

	Baker Bay	Lewis & Clark NWR		Longview	Umatilla	
	1991	1990	1991	1991	1990	1991
Piscivorous						
Double-crested cormorant	2.0 (1.2-3.2) 3	0.40 (0.29-0.63) 4	1.6 (1.4-2.0) 3			
Caspian tern		0.51[a] (0.31-0.84) 4	1.6 (1.1-2.7) 3		0.72[a] (0.53-0.89) 3	0.91 (0.60-2.02) 5
Gull (*Larus* spp.)[b]	0.41 (0.23-0.70) 3	0.20 (0.12-0.29) 4	0.58 (0.42-0.79) 3			
Ring-billed gull						0.09 (0.06-0.16) 3
Non-Piscivorous						
Canada goose	NC[c] 0.002 1		0.003 (0.003-0.004) 3	0.002 (0.002-0.003) 3		
Mallard	NC 0.08 1		0.06 (0.05-0.06) 3			

[a] In 1990, three of four tern samples at Lewis and Clark NWR and all tern samples at Umatilla were analyzed by inductively coupled plasma (ICP) as part of a metals scan. All other samples analyzed by cold vapor atomic adsorbtion.
[b] Western gull, glaucous-winged gull, or hybrid.
[c] Not calculated due to insufficient number of samples to calculate geometric mean. Value of single sample reported.

Table 21. Concentrations (pg/g fresh weight) of dioxins and furans in eggs of piscivorous birds from the Columbia River in 1990.

	Lewis and Clark NWR (Rice Island)			Umatilla (Crescent Island)		
	Double-crested corm.	Caspian tern	Gull (*Larus* spp.)[a]	Caspian tern	Forster's tern	Ring-billed gull
No. of samples	3	2	2	2	3	2
Dibenzo-*p*-dioxins						
2,3,7,8-Tetra	34[b,c] (28-44)	3.8 (2.6-5.4)	4.9 (3.7-6.4)	6.4 (2.6-16)	<22[c]	<1.0
1,2,3,7,8-Penta		<1.0 -1.8	2.2 (1.8-2.7)	<1.0-1.9		<1.0
1,2,3,4,7,8-Hexa		<1.0	<2.0	<1.0		<1.0-1.8
1,2,3,6,7,8-Hexa		<5.0-2.7	7.8 (7.4-8.2)	3.5 (1.8-6.8)		<1.0-5.3
1,2,3,7,8,9-Hexa		<2.0	<2.0	<2.0		<4.0
1,2,3,4,6,7,8-Hepta		<2.0	3.9 (2.7-5.5)	<3.0		<1.0-8.0
Octa		8.3 (7.0-9.9)	4.6	6.2 (4.4-8.8)	96[c,d]	12.6 (6.6-24)
Dibenzofurans						
2,3,7,8-Tetra	<3.8-4.0[c,e]	2.5 (1.8-3.5)	<1.0	2.8 (2.6-2.9)	7.7[c] (<2.0-50[e])	<1.0-1.8
1,2,3,7,8-Penta		<1.0	<1.0	<1.0		<1.0
2,3,4,7,8-Penta		<1.0	<1.0	<1.0		<1.0
1,2,3,4,7,8-Hexa		<1.0	<1.0	<1.0		<1.0
1,2,3,6,7,8-Hexa		<1.0	<1.0	<1.0		<1.0
1,2,3,7,8,9-Hexa		<1.0	<1.0	<2.0		<1.0
2,3,4,6,7,8-Hexa		<1.0-1.8	<1.0	<1.0		<1.0
1,2,3,4,6,7,8-Hepta		<1.0	<1.0	<2.0		<1.0-1.8
1,2,3,4,7,8,9-Hepta		<1.0	<1.0	<1.0		<1.0
Octa		<1.0	<1.0	<2.0	96[c,d]	<1.0-6.2

[a] Western gull, glaucous-winged gull, or hybrid.
[b] Geometric mean with range in parenthesis. Geometric mean was not calculated, and only a single number or the range reported, when insufficient sample size was available or the majority of samples was less than detection limits. A "< " sign indicates concentration was below the detection limit, which is the number listed after the sign. All numbers reported as the maximum within a range are actual concentrations found in a sample.
[c] Results considered estimates due to differences in the method used to analyze these samples. Results could be influenced by presence of diphenyl ethers as co-contaminants.
[d] Only one sample analyzed for this congener.
[e] The maximum value represents one sample analyzed for total tetrachlorodibenzofuran, which represents a high estimate of the 2,3,7,8-tetrachlorodibenzofuran component. Result is an estimate.

Table 22. Geometric mean (pg/g fresh weight) and range (parentheses) of dioxins and furans in eggs of piscivorous birds from the Columbia River in 1991.

	Baker Bay (E.Sand Island)		Lewis and Clark NWR (Rice Island)			Umatilla (Crescent Island)		
	Double-crested cormorant	Gull (*Larus* spp.)[a]	Double-crested cormorant	Caspian tern	Gull (*Larus* spp.)[a]	Caspian tern	Forster's tern	Ring-Billed gull
No. of samples	5	3	5	3	3	3	5	3
Dibenzo-*p*-dioxins								
2,3,7,8-Tetra	4.6 (<1.0-24)[b]	1.6 (0.65-2.7)	6.3 (<1.0-15)	2.9 (2.7-3.1)	8.6 (5.0-22)	1.8 (1.4-3.0)	NC[c] (<2.0-1.2)	0.50 (<0.82-0.84)
Dibenzofurans								
2,3,7,8-Tetra	0.29 (<1.0-1.8)	0.37E[d] (0.28-0.46)	0.69 (<2.0-1.1)	3.2 (0.86-14)	0.59[e] (0.31-0.85)	2.6 (1.4-4.8)	NC (<2.0-1.9E)	NC (<0.30)

[a] Western gull, glaucous-winged gull, or hybrid.
[b] A "< " sign indicates the value was below the specified detection limit (number listed after the sign). All numbers reported as the maximum within a range are actual concentrations found in a sample.
[c] NC=not calculated because insufficient sample size or the majority of samples was less than detection limits.
[d] E=Result from one egg in this group is the estimated maximum possible concentration due to unresolved interfering compounds (confirmation column did not improve results).
[e] Mean includes one sample analyzed for total tetrachlorodibenzofuran, which represents a high estimate of the 2,3,7,8-tetrachlorodibenzofuran component. Result is an estimate.

Table 23. Mean apparent biomagnification factors (BMFs) for selected contaminants from prey fish to bald eagle egg, and geometric means (GMs) in eagle eggs and prey fish tissue collected from various segments of the lower Columbia River. Eagle eggs were collected from 1994 to 1995 (U.S. Fish and Wildlife Service 1999a), and prey fish were collected in 1991[a].

	Segment 1[b]		Segment 2		Segment 3		Segments 1-3	
	Present Study	Bi-State Data[c]	Present Study	Bi-State Data	Present Study	Bi-State Data	Present Study	Bi-State Data
No. egg samples[d]	12 (7)	12 (7)	5 (3)	5 (3)	2 (1)	2 (1)	19 (11)	19 (11)
No. fish samples	12	11-12[e]	15	8-12[f]	9	12-18[g]	36	31-42[h]
Total PCBs								
BMF	104	52	90	45	155	38	113	50
GM Egg (µg/g)	5.2	5.2	4.5	4.5	5.3	5.3	5.0	5.0
GM Prey Fish (µg/g)	0.05	0.10	0.05	0.11	0.034	0.14	0.044	0.1
DDE								
BMF	61	122	78	157	62	138	75	141
GM Egg (µg/g)	6.1	6.1	4.7	4.7	5.5	5.5	5.6	5.6
GM Prey Fish (µg/g)	0.10	0.05	0.06	0.03	0.089	0.04	0.075	0.04
Total mercury								
BMF	2.8	1.6	2.9	2.6	1.9	1.7	2.8	2.2
GM Egg (µg/g)	0.22	0.22	0.23	0.23	0.17	0.17	0.22	0.22
GM Prey Fish (µg/g)	0.08	0.14	0.08	0.09	0.09	0.10	0.08	0.10
2,3,7,8-TCDD								
BMF	15	30	14	15	17	16	16	20
GM Egg (pg/g)	24	24	20	20	19	19	22	22
GM Prey Fish (pg/g)	1.6	0.80	1.4	1.3	1.1	1.2	1.4	1.1
2,3,7,8-TCDF								
BMF	2	4.6	2	1.8	1.7	1.8	2	3
GM Egg (pg/g)	26	26	17	17	14	14	22	22
GM Prey Fish (pg/g)	12	5.7	8.3	9.5	8.4	7.7	9.5	7.3

[a] All fish collected and analyzed were within the size range (<60 cm) that included 94% of the fish captured by bald eagles along the lower Columbia River (Watson et al. 1991).
[b] Segments correspond to those derived by the Bi-State Water Quality Program (Tetra Tech 1992b).
[c] Biomagnification factors based on whole-body peamouth, largescale sucker, and carp data derived from the Bi-State Program (Tetra Tech 1993b,c)
[d] Value represents number of eagle egg samples analyzed for all compounds excluding mercury. The number of mercury samples (analyzed in 1994 only) is shown in parenthesis (U.S. Fish and Wildlife Service 1999a).
[e] 12 fish samples were analyzed for PCBs, DDE, and mercury and 11 for TCDD and TCDF.
[f] 12 fish samples were analyzed for PCBs, DDE, and mercury and eight for TCDD and TCDF.
[g] 18 fish samples were analyzed for PCBs and DDE, 17 for mercury, and 12 for TCDD and TCDF.
[h] 42 samples were analyzed for PCBs and DDE, 41 for mercury, and 31 for TCDD and TCDF.

Table 24. Estimated target fish concentrations (TFCs), hazard quotients (HQs), and no-observable adverse effect levels (NOAELs) for bald eagles nesting along the lower Columbia River. TFCs and HQs derived from eagles nesting in Segments one to three. Eagle eggs were collected from the lower Columbia River from 1994 to 1995 (U.S. Fish and Wildlife Service 1999a).

	No. eagle egg samples, Segments 1-3[a]	No. fish samples[b], Segments 1-3	Geometric mean in bald eagle eggs	Estimated NOAEL	HQ[c]	BMF[d] Segments 1-3	TFC[e]
Total PCBs							
Present Study	19	36	5.0 µg/g	4.0 µg/g	1.3	113	0.04[f] µg/g
Bi-State Data	NA[g]	42	NA	4.0 µg/g	NA	50	0.08[f] µg/g
DDE							
Present Study	19	36	5.6 µg/g	3.6 µg/g	1.6	75	0.05[f] µg/g
Bi-State Data	NA	42	NA	3.6 µg/g	NA	141	0.03[f] µg/g
Total mercury							
Present Study	11	36	0.22 µg/g	0.5 µg/g	0.6	2.8	0.2 µg/g
Bi-State Data	NA	41	NA	0.5 µg/g	NA	2.2	0.2 µg/g
2,3,7,8-TCDD							
Present Study	19	36	22 pg/g	15 pg/g	1.5	16	0.9 pg/g
Bi-State Data	NA	31	NA	15 pg/g	NA	20	0.8 pg/g
2,3,7,8-TCDF							
Present Study	19	36	22 pg/g	15 pg/g	1.5	2	7.5 pg/g
Bi-State Data	NA	31	NA	15 pg/g	NA	3	5 pg/g

[a] Segments correspond to those derived by the Bi-State Water Quality Program (Tetra Tech 1992b).
[b] All fish collected and analyzed were within the size range (<60 cm) that included 94% of the fish captured by bald eagles along the lower Columbia River (Watson et al. 1991).
[c] Hazard quotient calculated as the ratio of geometric mean of contaminant in bald eagle eggs over the NOAEL for the egg.
[d] Biomagnification factors based on whole-body peamouth, largescale sucker, and carp data derived from the Bi-State Program (Tetra Tech 1993b,c) and the present study (as listed in Table 23).
[e] Target fish concentrations (TFC) calculated as the ratio fo the no-observable adverse affect level over the BMF from Segments 1 to 3 using data collected on fish from the Bi-State Program (Tetra Tech 1993b,c) and the present study. Estimated NOAELs were 4.0 (Wiemeyer et al. 1984), 3.6 (Wiemeyer et al. 1993) and 0.5 Wiemeyer et al. (1984) µg/g for total PCBs, DDE, and mercury, respectively, and 15 pg/g for TCDD and TCDF based on eagles reproducing successfully along the coast of British Columbia (Elliott et al. 1996b).
[f] The average of the two TFC values from the two studies was used to represent DDE and PCB due to detection limit problems as explained in the text. Thus, the TFC values used as guidance for comparison in this report were 0.06 and 0.04 µg/g for total PCBs and DDE, respectively.
[g] Not analyzed.

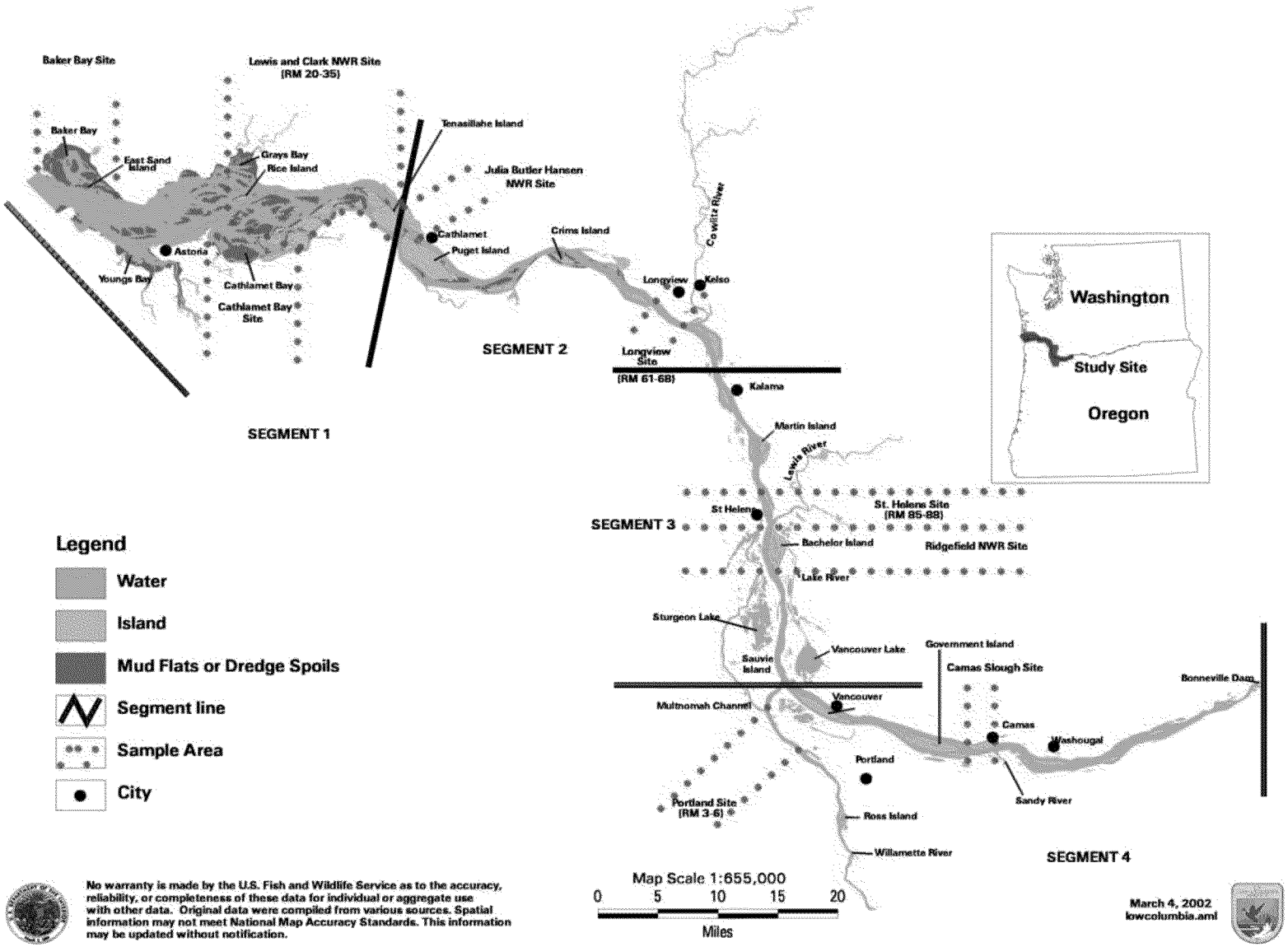

Figure 1. Study sites along the lower Columbia River, 1990 to 1991: Segments 1 to 4 and the Portland Site.

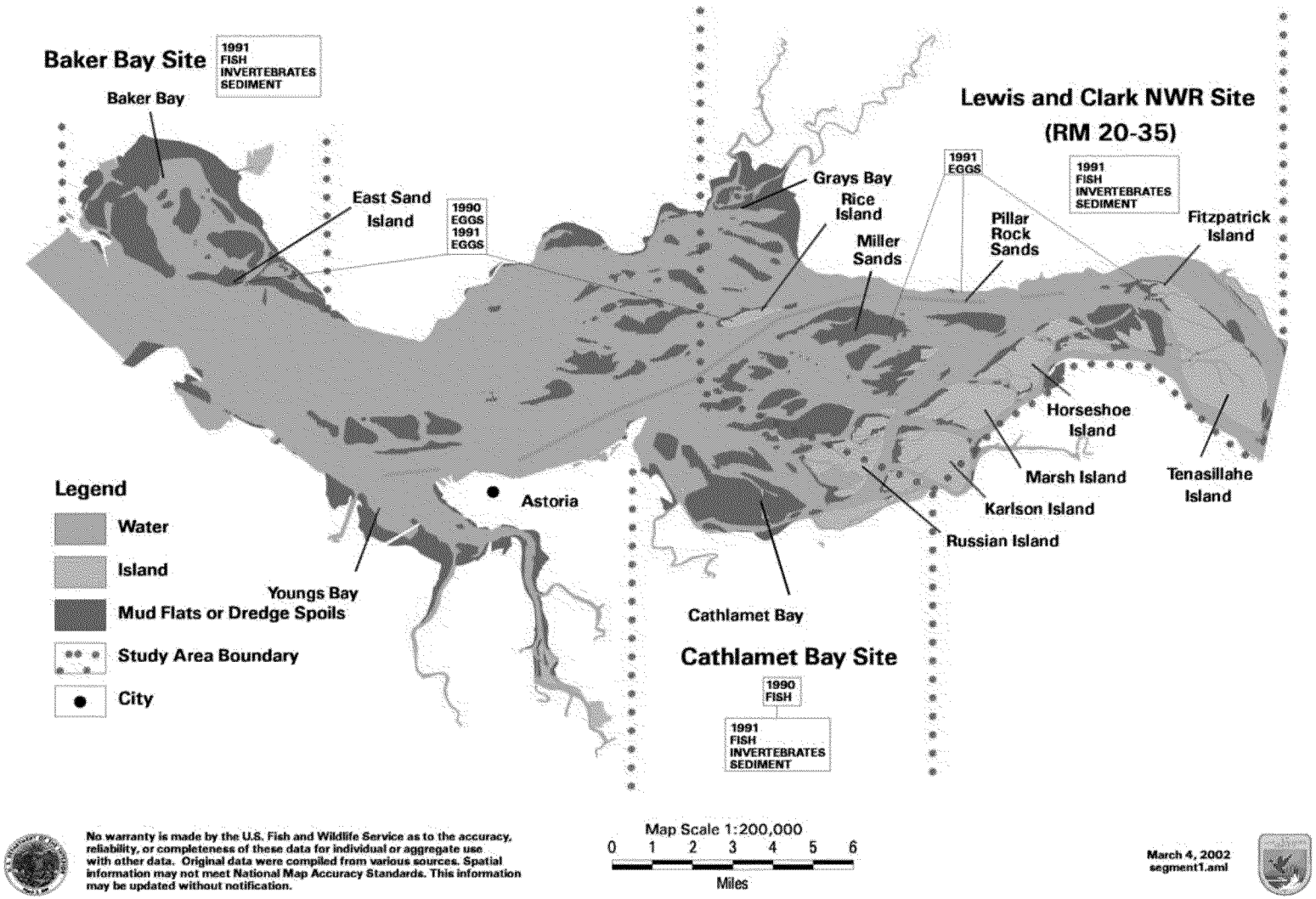

Figure 2. Study sites along the lower Columbia River, 1990 to 1991: Segment 1.

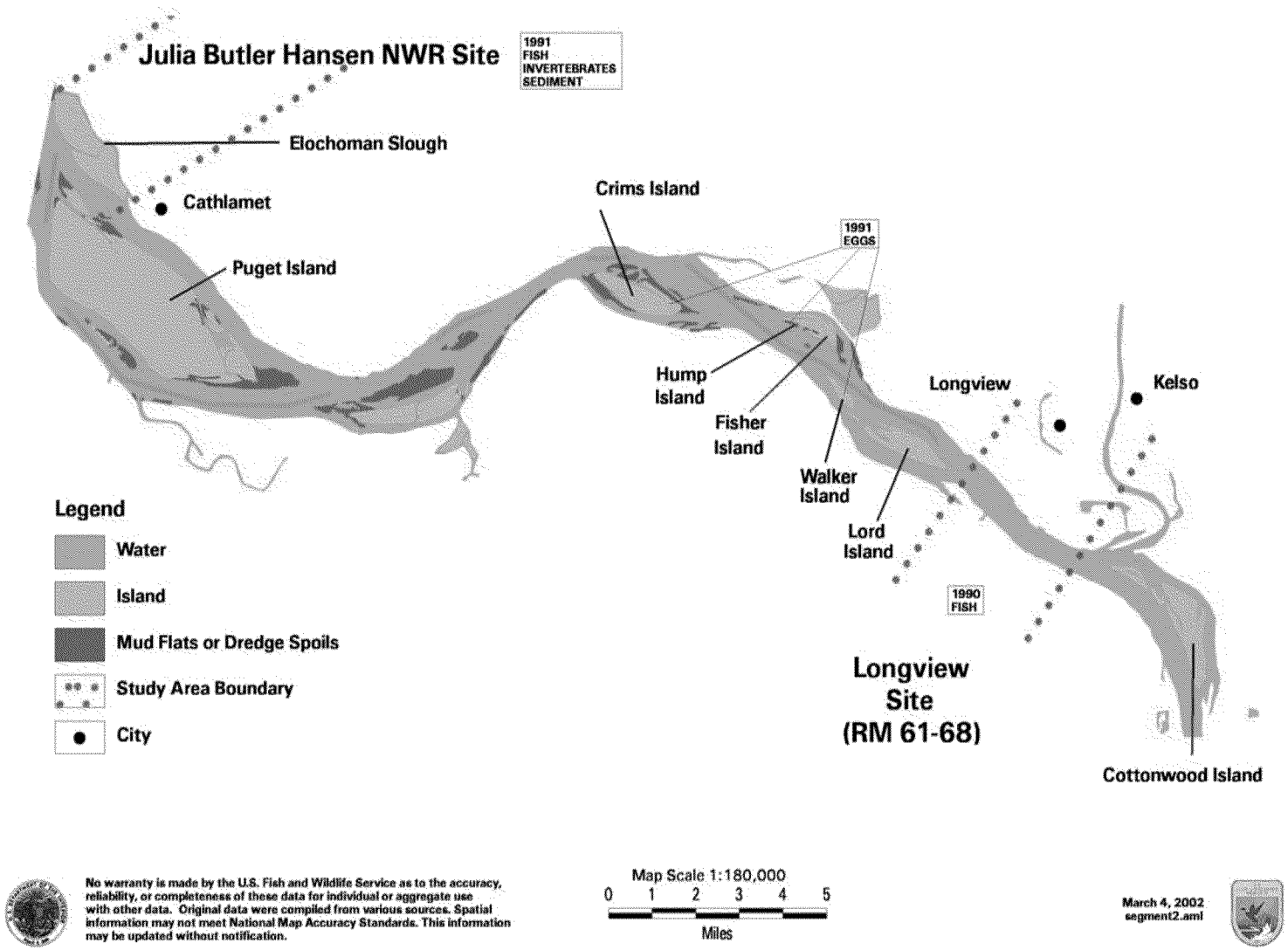

Figure 3. Study sites along the lower Columbia River, 1990 to 1991: Segment 2.

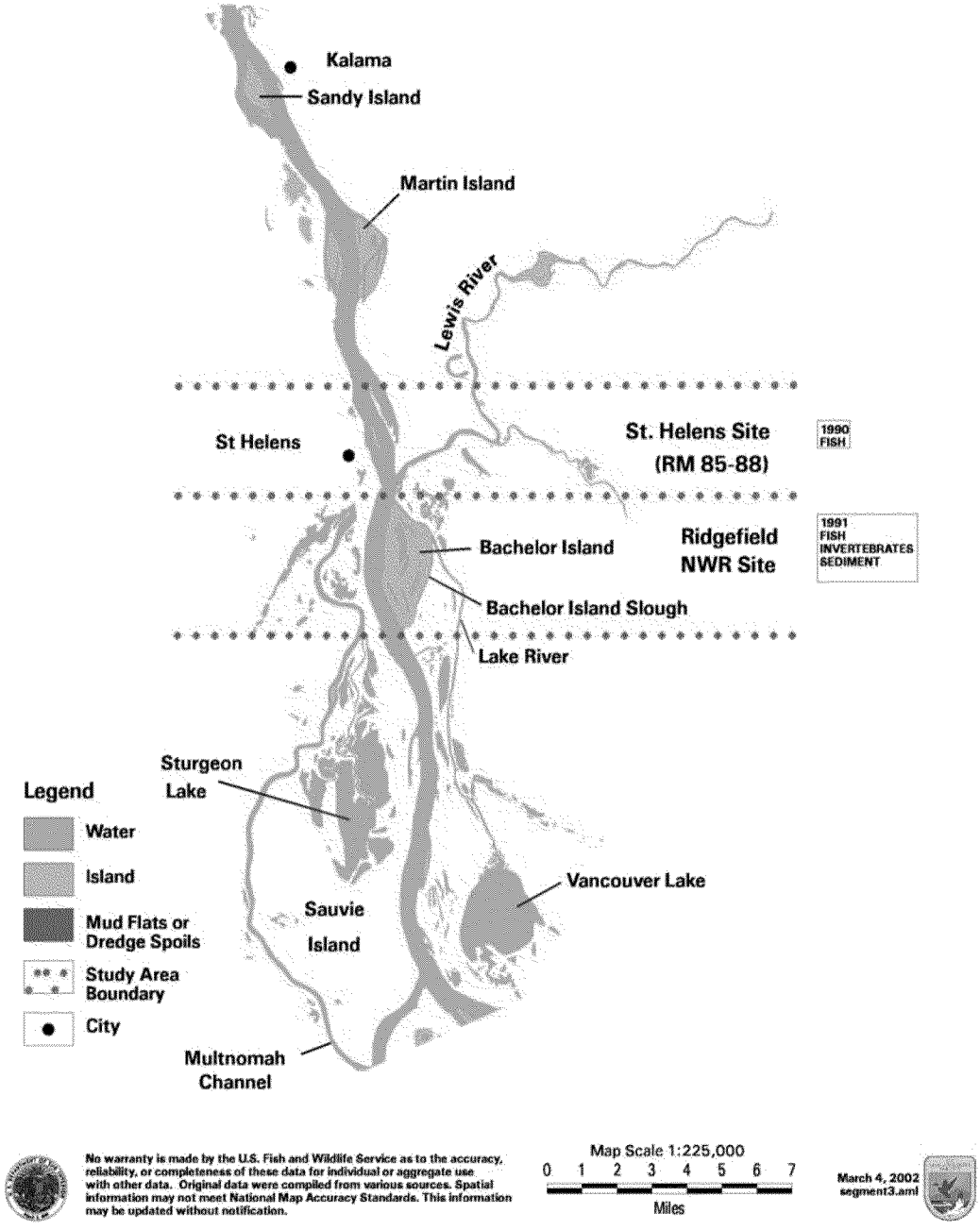

Figure 4. Study sites along the lower Columbia River, 1990 to 1991: Segment 3.

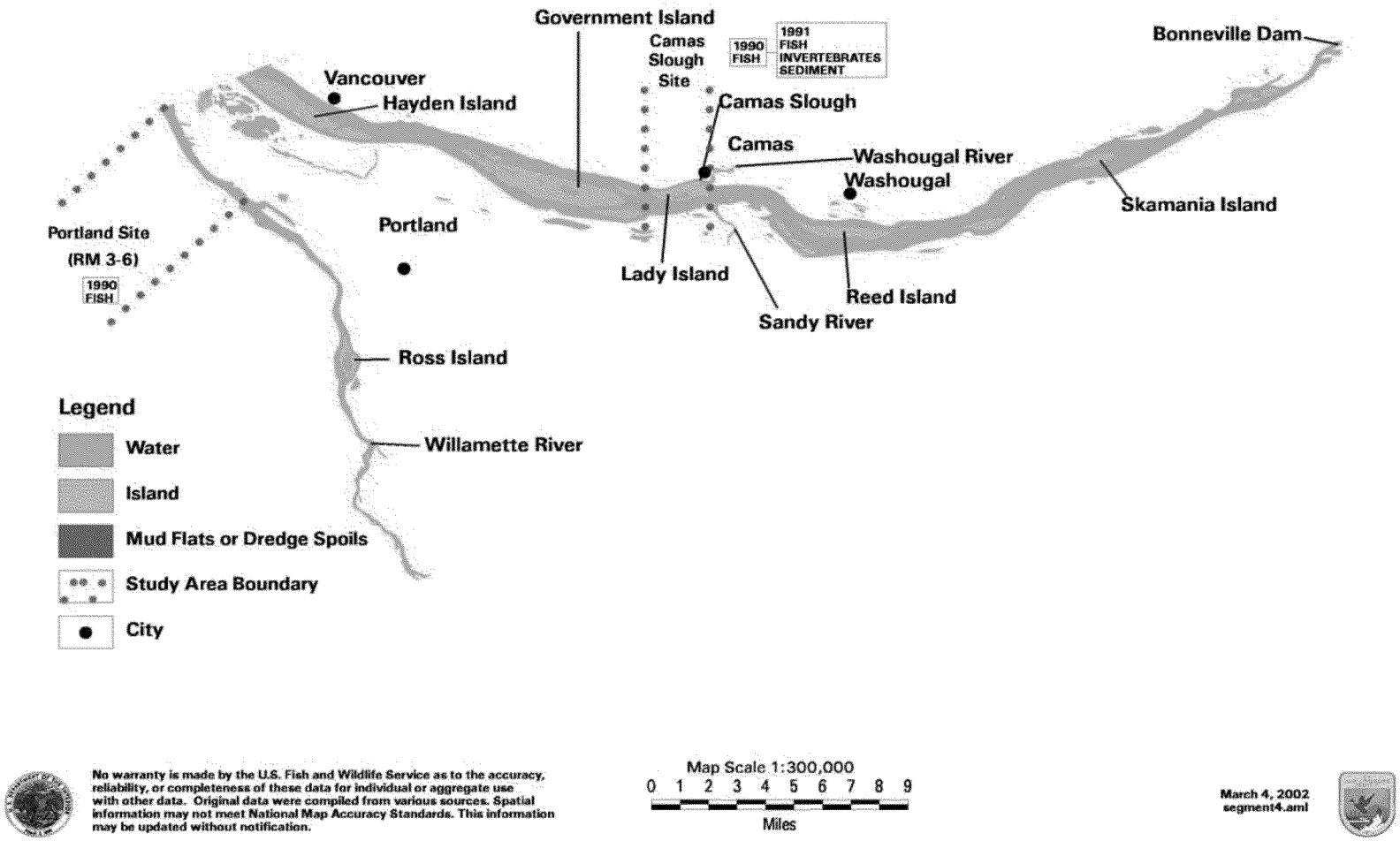

Figure 5. Study sites along the lower Columbia River, 1990 to 1991: Segment 4 and the Portland Site.

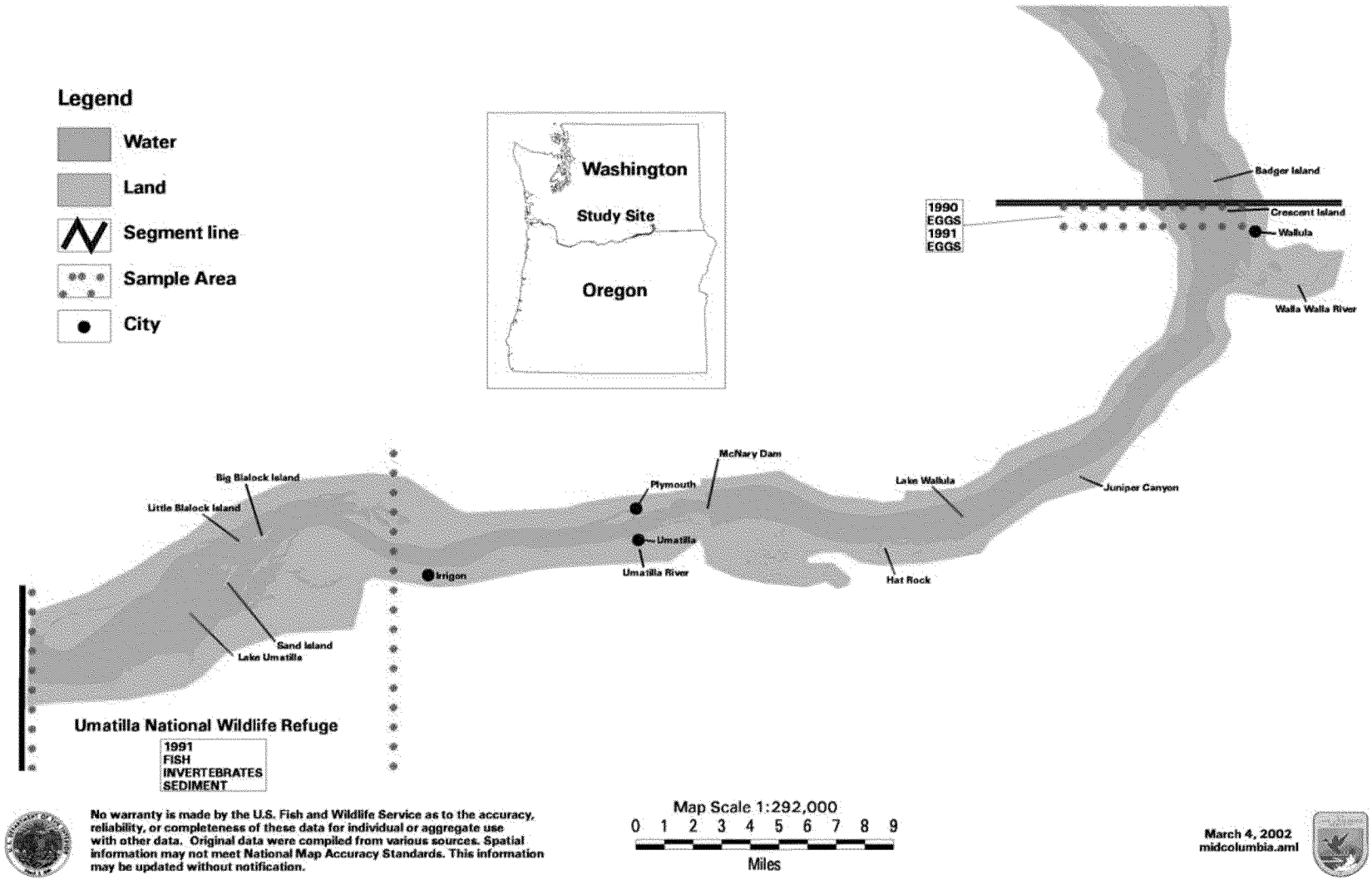

Figure 6. Study sites along the middle Columbia River, 1990 to 1991: Umatilla Segment.

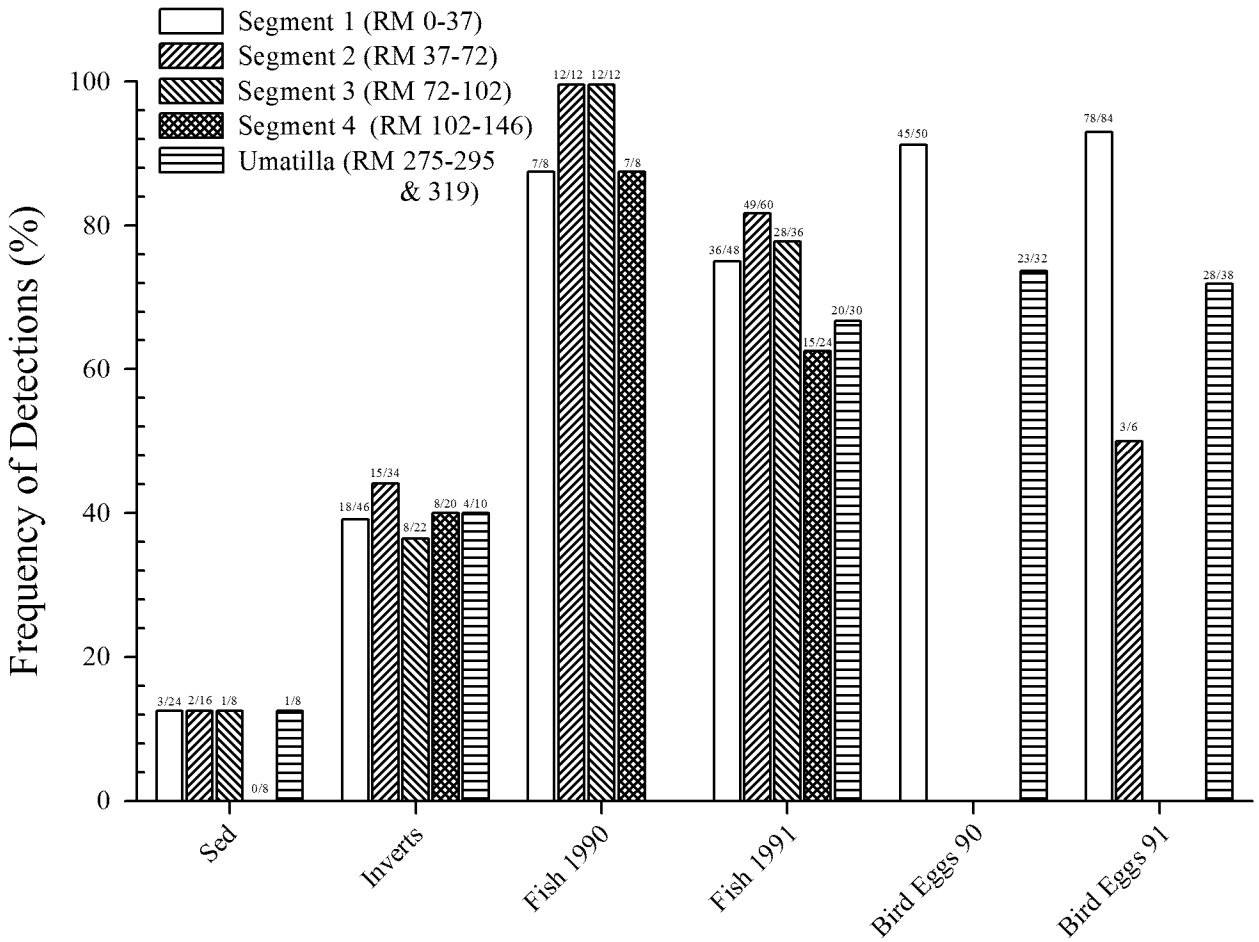

Figure 7. Frequency of detection (number of detections/number of samples) for all selected organochlorine contaminants (DDE, total polychlorinated biphenyls, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin, and 2,3,7,8-tetrachlorodibenzofuran) combined within a sample matrix (sediment [sed], invertebrates, fish, and bird eggs) collected from various segments of the Columbia River in 1990 and 1991. Numbers above bars represent the total number of samples within a segment for each matrix with concentrations above detection/total number of samples collected within the segment.

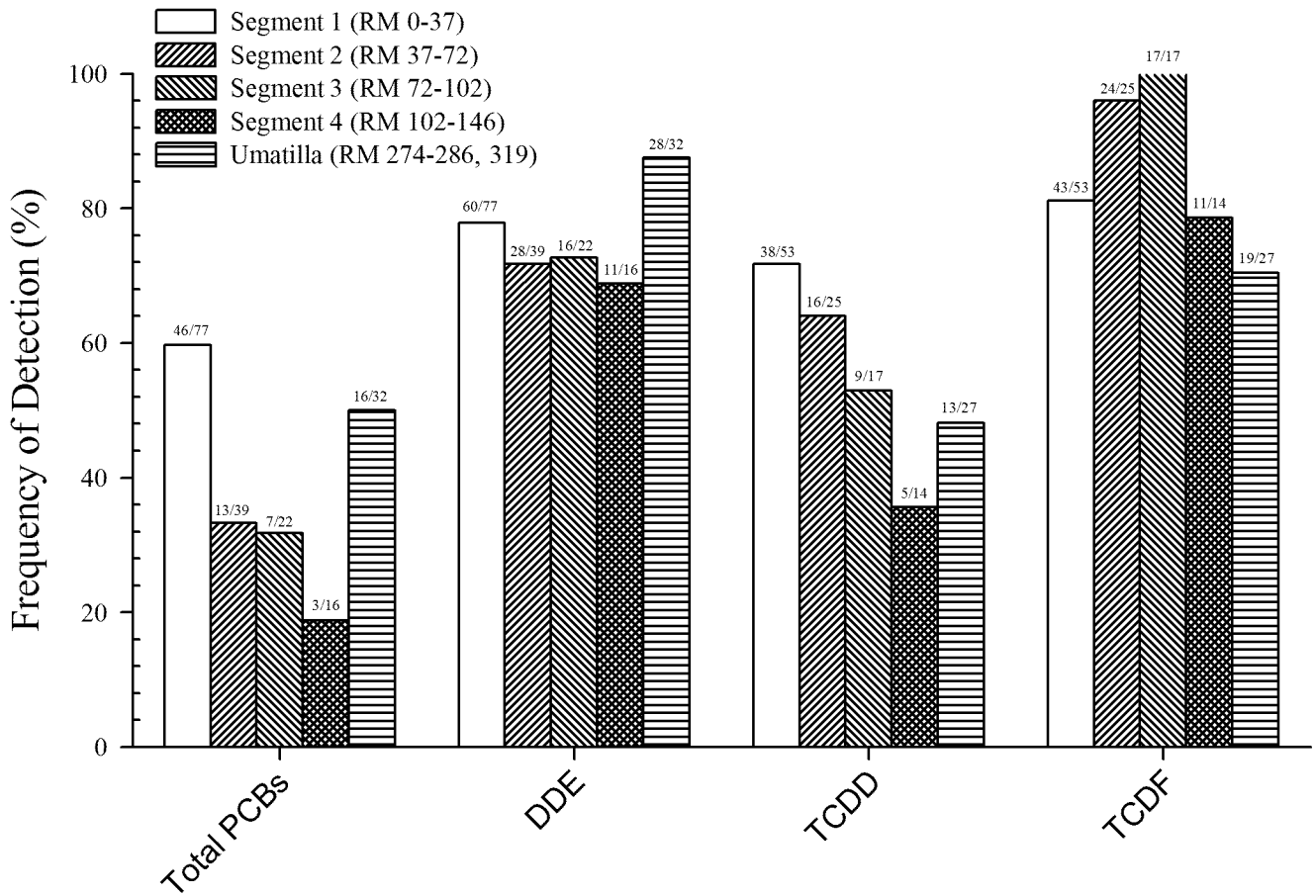

Figure 8. Frequency of detection of selected organochlorine compounds (DDE, total polychlorinated biphenyls [PCBs], 2,3,7,8-tetrachlorodibenzo-*p*-dioxin, and 2,3,7,8-tetrachlorodibenzofuran) with all matrix types (sediment, invertebrates, fish, and bird eggs) collected in 1990 and 1991 from each segment of the lower Columbia River combined. Numbers above bars represent the total number of samples of all matrix types within a segment with concentrations above detection/total number of samples collected within the segment. Bird eggs were only collected from Segments 1, 2 (1991 only), and the Umatilla site, and no fish were collected from the Umatilla site in 1990.

APPENDICES

Appendix A. Mass, pool (number of samples within a composite), moisture, lipid, type of chemical analysis, and laboratory conducting analysis for 274 individual samples collected at various locations (reported from the mouth of the river to Umatilla) along the Columbia River in 1990 and 1991. Blank cells in the table indicate data was not available. Bold indicates sample results for dioxin and furan failed quality control limits and were re-analyzed as indicated in Appendix B.

Sample number	Species or Sample Type	Sample location	Year	Pool	Sample mass (g)	% Moisture	% Lipid	Analyses[a]	Laboratory[b]
CRBSD174	Sediment	Baker Bay	1991	3	386	45.1		OC,TCDD/F	PACF,PA
CRBSD175	Sediment	Baker Bay	1991	3	382	73.0		OC	PACF
CRBSD176	Sediment	Baker Bay	1991	3	453	70.4		OC	PACF
CRASD200	Sediment	Cathlamet Bay	1991	3	468	43.0		OC,PCDD/F	PACF,TLI
CRASD201	Sediment	Cathlamet Bay	1991	3	499	36.5		OC	PACF
CRASD202	Sediment	Cathlamet Bay	1991	3	499	43.0		OC	PACF
CRMSD214	Sediment	Lewis & Clark NWR	1991	3	446	62.4		OC,PCDD/F	PACF,TLI
CRMSD215	Sediment	Lewis & Clark NWR	1991	3	512	41.9		OC	PACF
CRMSD216	Sediment	Lewis & Clark NWR	1991	3	543	53.9		OC	PACF
CRJSD120	Sediment	Julia Butler Hansen NWR	1991	3	479	34.0		OC,PCDD/F	PACF,TLI
CRJSD121	Sediment	Julia Butler Hansen NWR	1991	3	485	51.2		OC	PACF
CRJSD122	Sediment	Julia Butler Hansen NWR	1991	3	460	55.2		OC	PACF
CRLSD171	Sediment	Longview	1991	3	523	26.9		OC,PCDD/F	PACF,TLI
CRLSD172	Sediment	Longview	1991	3	461	38.2		OC	PACF
CRLSD173	Sediment	Longview	1991	3	429	42.9		OC	PACF
CRRSD117	Sediment	Ridgefield	1991	3	369	31.9		OC,PCDD/F	PACF,TLI
CRRSD118	Sediment	Ridgefield	1991	3	416	35.0		OC	PACF
CRRSD119	Sediment	Ridgefiled	1991	3	356	34.6		OC	PACF
CRCSD151	Sediment	Camas Slough	1991	3	551	39.1		OC,PCDD/F	PACF,TLI
CRCSD152	Sediment	Camas Slough	1991	3	540	46.2		OC	PACF
CRCSD153	Sediment	Camas Slough	1991	3	531	31.5		OC	PACF
CRUSD128	Sediment	Umatilla	1991	3	570	46.8		OC,PCDD/F	PACF,TLI
CRUSD129	Sediment	Umatilla	1991	3	667	29.0		OC	PACF
CRUSD130	Sediment	Umatilla	1991	3	485	33.5		OC	PACF
CRBMC139	Macoma clam	Baker Bay	1991	12	24.7	81.4	0.1	OC,PCDD/F	PACF,TLI
CRBMC143	Macoma clam	Baker Bay	1991	12	14.1	81.6	9.3	OC	PACF
CRBMC163	Macoma clam	Baker Bay	1991	16	16.4	84.5	0.4	OC	PACF
CRACC206	Corbicula clam	Cathlamet Bay	1991	16	15.9	83.7		OC,TCDD/F	PACF,PA
CRACC207	Corbicula clam	Cathlamet Bay	1991	15	12.6	85.1		OC	PACF
CRACF098	Crayfish	Cathlamet Bay	1991	2	110	64.3	0.7	OC,PCDD/F	PACF,MRI
CRACF220	Crayfish	Cathlamet Bay	1991	1	39.0	46.0		TCDD/F	PA

Sample number	Species or Sample Type	Sample location	Year	Pool	Sample mass (g)	% Moisture	% Lipid	Analyses[a]	Laboratory[b]
CRACF223	Crayfish	Cathlamet Bay	1991	1	42.0	53.0		TCDD/F	PA
CRACO204	Corophium	Cathlamet Bay	1991	100s	14.6		2.3	OC	PACF
CRMCC142	Corbicula clam	Lewis & Clark NWR	1991	12	31.3	81.2	0.1	OC,PCDD/F	PACF,TLI
CRMCC146	Corbicula clam	Lewis & Clark NWR	1991	12	31.6	82.1	0.9	OC,TCDD/F	PACF,PA
CRMCC147	Corbicula clam	Lewis & Clark NWR	1991	12	32.9	83.7		OC	PACF
CRMCF208	Crayfish	Lewis & Clark NWR	1991	3	102	64.5	1.7	OC	PACF
CRMCF209	Crayfish	Lewis & Clark NWR	1991	3	145	55.0		TCDD/F	PA
CRMCF217	Crayfish	Lewis & Clark NWR	1991	4	216	69.1	0.9	OC,PCDD/F	PACF,MRI
CRMCO140	Corophium	Lewis & Clark NWR	1991	100s	23.0			TCDD/F	PA
CRMCO141	Corophium	Lewis & Clark NWR	1991	100s	22.0			TCDD/F	PA
CRJCC103	Corbicula clam	Julia Butler Hansen NWR	1991	12	62.0	72.3	3.9	OC-PCB,Hg	GERG
CRJCC110	Corbicula clam	Julia Butler Hansen NWR	1991	12	39.0	76.4	3.2	OC-PCB,Hg	GERG
CRJCC111	Corbicula clam	Julia Butler Hansen NWR	1991	12	35.0	76.5	3.7	OC-PCB,Hg	GERG
CRJCF099	Crayfish	Julia Butler Hansen NWR	1991	3	97.0	75.7	0.9	PCDD/F	MRI
CRJCF100	Crayfish	Julia Butler Hansen NWR	1991	3	63.0			TCDD/F	PA
CRJCF107	Crayfish	Julia Butler Hansen NWR	1991	3	121	72.1	1.2	OC-PCB,Hg	GERG
CRJCF108	Crayfish	Julia Butler Hansen NWR	1991	3	166	70.2	1.2	OC-PCB,Hg	GERG
CRJCF109	Crayfish	Julia Butler Hansen NWR	1991	5	130	67.8	1.5	OC,TCDD/F, Hg	GERG,PA,GERG
CRLCC124	Corbicula clam	Longview	1991	16	49.0	90.1	1.1	OC-PCB,Hg	GERG
CRLCC125	Corbicula clam	Longview	1991	16	38.0	89.9	1.0	OC-PCB,Hg	GERG
CRLCC126	Corbicula clam	Longview	1991	16	38.0	89.0	1.2	OC-PCB,Hg	GERG
CRLCF170	Crayfish	Longview	1991	2	109	62.0		TCDD/F	PA
CRLCF218	Crayfish	Longview	1991	3	157	73.1	0.9	OC PCDD/F	PACF,MRI
CRLCF219	Crayfish	Longview	1991	3	130	68.0		OC,TCDD/F	PACF,PA
CRCCC210	Corbicula clam	Camas Slough	1991	15	31.0	88.8		OC	PACF
CRCCC211	Corbicula clam	Camas Slough	1991	15	47.3	86.4	0.1	OC,TCDD/F	PACF,TLI
CRCCC212	Corbicula clam	Camas Slough	1991	15	33.1	94.5		OC,TCDD/F	PACF,TLI
CRCCF156	Crayfish	Camas Slough	1991	4	121	50.0		TCDD/F	PA
CRCCF157	Crayfish	Camas Slough	1991	4	177	69.5	1.0	OC,TCDD/F	PACF,PA
CRCCF165	Crayfish	Camas Slough	1991	4	194	71.5	0.6	OC,PCDD/F	PACF,MRI
CRRCC160	Corbicula clam	Ridgefield	1991	16	65.1	86.1		OC,PCDD/F	PACF,TLI
CRRCC161	Corbicula clam	Ridgefield	1991	16	42.7	82.9		OC,TCDD/F	PACF,PA
CRRCC162	Corbicula clam	Ridgefield	1991	16	35.0	85.0		OC	PACF
CRRCF134	Crayfish	Ridgefield	1991	4	240	70.0	1.2	OC,TCDD/F	PACF,PA
CRRCF158	Crayfish	Ridgefield	1991	3	186	78.0	0.9	OC,TCDD/F	PACF,PA
CRRCF159	Crayfish	Ridgefield	1991	3	195	81.5	0.4	OC,PCDD/F	PACF,MRI

Sample number	Species or Sample Type	Sample location	Year	Pool	Sample mass (g)	% Moisture	% Lipid	Analyses[a]	Laboratory[b]
CRUCC231	Corbicula clam	Umatilla	1991	18	62.8	78.3		OC	PACF
CRUCC232	Corbicula clam	Umatilla	1991	20	65.0	80.4	0.1	OC,PCDD/F	PACF,TLI
CRUCC233	Corbicula clam	Umatilla	1991	23	62.1	81.8	2.4	OC,TCDD/F	PACF,PA
CR1K120	Sucker	Cathlamet Bay	1990	1	893	73.9	6.8	OC-PCB	GERG
CR1P64	Peamouth chub	Cathlamet Bay	1990	3	826			OC,Hg	NCL(Alta)
CR1S58	Northern pikeminnow	Cathlamet Bay	1990	3	902			PCDD/F	CERC
CR1S60	Northern pikeminnow	Cathlamet Bay	1990	3	675			OC,Hg	NCL(Alta)
CR2B114	Largemouth bass	Longview	1990	1	942	68.9	8.1	OC-PCB	GERG
CR2C69	Common carp	Longview	1990	1	2,585			PCDD/F	CERC
CR2C70	Common carp	Longview	1990	1	2,436	80.2	1.3	OC-PCB	GERG
CR2L71	Sucker (largescale)	Longview	1990	3	2,356	71.3	5.8	OC-PCB	GERG
CR2S65	Northern pikeminnow	Longview	1990	3	1,388			PCDD/F	CERC
CR2S67	Northern pikeminnow	Longview	1990	3	982	73.7	5.4	OC-PCB	GERG
CR2S68	Northern pikeminnow	Longview	1990	4	418			Hg	ETSL
CR3B111	Largemouth bass	St. Helens	1990	3	496	72.9	5.7	OC-PCB	GERG
CR3C76	Common carp	St. Helens	1990	2	3,790			PCDD/F	CERC
CR3C77	Common carp	St. Helens	1990	2	3,080	68.3	7.6	OC-PCB	GERG
CR3L78	Sucker (largescale)	St. Helens	1990	3	1,598	69.2	8.8	OC-PCB	GERG
CR3S72	Northern pikeminnow	St. Helens	1990	3	3,461			PCDD/F	CERC
CR3S74	Northern pikeminnow	St. Helens	1990	3	2,543	71.8	6.7	OC-PCB	GERG
CR3S75	Northern pikeminnow	St. Helens	1990	3	1,047			Hg	ETSL
CR4B81	Smallmouth bass	Portland	1990	2	879	68.1	8.6	OC-PCB	GERG
CR4C83	Common carp	Portland	1990	2	2,476			PCDD/F	CERC
CR4C84	Common carp	Portland	1990	2	2,788			OC,Hg	NCL(Alta)
CR4S79	Northern pikeminnow	Portland	1990	4	181			PCDD/F	CERC
CR6C90	Common carp	Camas Slough	1990	3	4,227			PCDD/F	CERC
CR6C91	Common carp	Camas Slough	1990	3	4,799			OC,Hg	NCL(Alta)
CR6S86	Northern pikeminnow	Camas Slough	1990	2	2,951			PCDD/F	CERC
CR6S88	Northern pikeminnow	Camas Slough	1990	2	1,750			OC,Hg	NCL(Alta)
CRAPM091	Peamouth chub	Cathlamet Bay	1991	3	238	73.6	7.2	OC-PCB,TCDD/F,Hg	GERG,TLI,GERG
CRAPM092	Peamouth chub	Cathlamet Bay	1991	3	229	70.2	13.8	OC-PCB,TCDD/F,Hg	GERG,TLI,GERG
CRAPM093	Peamouth chub	Cathlamet Bay	1991	3	241	71.0	12.0	OC-PCB,TCDD/F,Hg	GERG,TLI,GERG
CRAPM097	Peamouth chub	Cathlamet Bay	1991	4	186	71.3	9.4	PCDD/F	MRI
CRASC094	Sucker (bridgelip)	Cathlamet Bay	1991	3	1,334	67.7	7.4	OC,TCDD/F,Hg	PACF,PA,PACF
CRASC095	Sucker (largescale)	Cathlamet Bay	1991	3	556	77.7	6.7	OC,TCDD/F,Hg	PACF,PA,PACF
CRASC096	Sucker (bridgelip)	Cathlamet Bay	1991	3	2,478	70.7	9.2	OC,PCDD/F,Hg	PACF,MRI,PACF

Sample number	Species or Sample Type	Sample location	Year	Pool	Sample mass (g)	% Moisture	% Lipid	Analyses[a]	Laboratory[b]
CRMPM183	Peamouth chub	Lewis & Clark NWR	1991	5	557	73.6	7.0	OC,TCDD/F,Hg	PACF,PA,PACF
CRMPM184	Peamouth chub	Lewis & Clark NWR	1991	5	745	71.1	7.8	OC,PCDD/F,Hg	PACF,MRI,PACF
CRMPM185	Peamouth chub	Lewis & Clark NWR	1991	5	620	76.7	3.2	OC,TCDD/F,Hg	PACF,PA,PACF
CRMSC149	Sucker (largescale)	Lewis & Clark NWR	1991	3	1,880	84.7	3.6	OC,PCDD/F,Hg	PACF,MRI,PACF
CRMSC186	Sucker	Lewis & Clark NWR	1991	3	1,683	69.1	6.2	OC,Hg	PACF
CRMSC187	Sucker	Lewis & Clark NWR	1991	3	1,890	75.4	3.3	OC,TCDD/F,Hg	PACF,PA,PACF
CRJPM104	Peamouth chub	Julia Butler Hansen NWR	1991	5	581	84.3	6.6	OC-PCB,PCDD/F,Hg	GERG,MRI,GERG
CRJPM105	Peamouth chub	Julia Butler Hansen NWR	1991	5	528	71.4	6.1	OC-PCB,TCDD/F,Hg	GERG,TLI,GERG
CRJPM106	Peamouth chub	Julia Butler Hansen NWR	1991	5	544	75.8	5.0	OC-PCB,TCDD/F,Hg	GERG,TLI,GERG
CRJSC101	Sucker	Julia Butler Hansen NWR	1991	3	1,330	84.3	4.2	OC,PCDD/F,Hg	PACF,MRI,PACF
CRJSC102	Sucker	Julia Butler Hansen NWR	1991	2	498	77.2	5.7	OC,TCDD/F,Hg	PACF,PA,PACF
CRJSC113	Sucker (bridgelip)	Julia Butler Hansen NWR	1991	3	1,217	77.3	5.6	OC,TCDD/F,Hg	PACF,PA,PACF
CRLCP182	Common carp	Longview	1991	1	1,644	74.2	6.8	OC,TCDD/F,Hg	PACF,PA,PACF
CRLCP234	Common carp	Longview	1991	1	977	73.8	10.2	OC,TCDD/F,Hg	PACF,PA,PACF
CRLCP235	Common carp	Longview	1991	1	970	71.9	9.2	OC,TCDD/F,Hg	PACF,PA,PACF
CRLPM123	Peamouth chub	Longview	1991	3	117	71.8	7.4	OC-PCB,TCDD/F,Hg	GERG,PA,GERG
CRLPM180	Peamouth chub	Longview	1991	6	648	72.9	6.3	OC,PCDD/F,Hg	PACF,MRI,PACF
CRLPM181	Peamouth chub	Longview	1991	6	724	72.3	6.3	OC,TCDD/F,Hg	PACF,PA,PACF
CRLSC177	Sucker	Longview	1991	3	2,656	69.2	6.6	OC,PCDD/F,Hg	PACF,MRI,PACF
CRLSC178	Sucker	Longview	1991	3	2,404	75.2	5.8	OC,TCDD/F,Hg	PACF,PA,PACF
CRLSC179	Sucker	Longview	1991	3	2,133	77.4	6.7	OC,TCDD/F,Hg	PACF,PA,PACF
CRRCP114	Common carp	Ridgefield	1991	3	2,012	73.3	5.6	OC-PCB,TCDD/F,Hg	GERG,PA,GERG
CRRCP115	Common carp	Ridgefield	1991	3	2,286	70.6	4.9	OC-PCB,TCDD/F,Hg	GERG,PA,GERG
CRRCP116	Common carp	Ridgefield	1991	2	1,650	70.7	6.9	OC-PCB,TCDD/F,Hg	GERG,PA,GERG
CRRPM127	Peamouth chub	Ridgefield	1991	3	212	75.6	7.3	OC,TCDD/F,Hg	PACF,PA,PACF
CRRPM166	Peamouth chub	Ridgefield	1991	6	695	75.6	6.1	OC,TCDD/F,Hg	PACF,PA,PACF
CRRPM167	Peamouth chub	Ridgefield	1991	6	810	72.9	7.8	OC,PCDD/F,Hg	PACF,MRI,PACF
CRRSC164	Sucker	Ridgefield	1991	2	1,408	85.4	3.8	OC,PCDD/F,Hg	PACF,MRI,PACF
CRRSC168	Sucker	Ridgefield	1991	3	1,564	75.9	7.4	OC,TCDD/F,Hg	PACF,PA,PACF
CRRSC169	Sucker	Ridgefield	1991	3	1,648	75.9	5.9	OC,TCDD/F,Hg	PACF,PA,PACF
CRCCP150	Common carp	Camas Slough	1991	2	2,664	72.1	8.2	OC,TCDD/F,Hg	PACF,PA,PACF
CRCCP154	Common carp	Camas Slough	1991	2	2,516	75.3	5.0	OC,TCDD/F,Hg	PACF,PA,PACF
CRCCP230	Common carp	Camas Slough	1991	2	2,561	70.1	9.0	OC,TCDD/F,Hg	PACF,PA,PACF
CRCSC155	Sucker	Camas Slough	1991	2	694	72.0	7.2	OC,PCDD/F,Hg	PACF,MRI,PACF
CRCSC213	Sucker	Camas Slough	1991	1	578	87.2	0.8	OC,TCDD/F,Hg	PACF,PA,PACF
CRCSC222	Sucker	Camas Slough	1991	1	541	87.8	0.9	OC,TCDD/F,Hg	PACF,PA,PACF

Sample number	Species or Sample Type	Sample location	Year	Pool	Sample mass (g)	% Moisture	% Lipid	Analyses[a]	Laboratory[b]
CRUCP131	Common carp	Umatilla	1991	3	4,788	72.6	13.3	OC,TCDD/F,Hg	PACF,PA,PACF
CRUCP132	Common carp	Umatilla	1991	3	3,526	69.8	6.5	OC,TCDD/F,Hg	PACF,PA,PACF
CRUCP221	Common carp	Umatilla	1991	1	5,000	63.1	14.5	OC,TCDD/F,Hg	PACF,PA,PACF
CRUPM229	Peamouth chub	Umatilla	1991	2	298	69.8	5.1	OC,PCDD/F,Hg	PACF,MRI,PACF
CRUSC133	Sucker	Umatilla	1991	3	1,781	69.2	11.0	OC,PCDD/F,Hg	PACF,MRI,PACF
CRUSC224	Sucker	Umatilla	1991	3	2,377	64.1	8.8	OC,TCDD/F,Hg	PACF,PA,PACF
CRUSC225	Sucker	Umatilla	1991	3	2,666	68.4	8.1	OC,Hg	PACF
CRUWF227	Whitefish	Umatilla	1991	3	776	74.1	5.3	OC,Hg	PACF
CRUWF228	Whitefish	Umatilla	1991	4	922	75.0	4.7	OC,Hg	PACF
CR1D48	Double-crested cormorant	Lewis & Clark NWR	1990	1	42.0			TCDD/F, Tot. CDD/F	RADIAN
CR1D49	Double-crested cormorant	Lewis & Clark NWR	1990	1	41.0			TCDD/F	RADIAN
CR1D50	Double-crested cormorant	Lewis & Clark NWR	1990	1	44.0			TCDD/F	RADIAN
CR1D51	Double-crested cormorant	Lewis & Clark NWR	1990	1	42.5	82.0	4.6	OC	MCSL
CR1D52	Double-crested cormorant	Lewis & Clark NWR	1990	1	46.0	83.5	3.8	OC	MSCL
CR1D53	Double-crested cormorant	Lewis & Clark NWR	1990	1	44.0	82.0	3.5	OC	MSCL
CR1D54	Double-crested cormorant	Lewis & Clark NWR	1990	1	48.0			OC,Hg	NCL(Alta)
CR1D55	Double-crested cormorant	Lewis & Clark NWR	1990	1	47.0			OC,Hg	NCL(Alta)
CR1D56	Double-crested cormorant	Lewis & Clark NWR	1990	1	41.0			OC,Hg	NCL(Alta)
CR1D57	Double-crested cormorant	Lewis & Clark NWR	1990	1	50.0			OC,Hg	NCL(Alta)
CR1T39	Caspian tern	Lewis & Clark NWR	1990	1	58.0			TCDD/F	CERC
CR1T40	Caspian tern	Lewis & Clark NWR	1990	1	66.0			PCDD/F	CERC
CR1T41	Caspian tern	Lewis & Clark NWR	1990	1	56.1	76.0	9.5	OC	MSCL
CR1T42	Caspian tern	Lewis & Clark NWR	1990	1	52.3	74.5	10.8	OC	MSCL
CR1T43	Caspian tern	Lewis & Clark NWR	1990	1	59.5	76.5	8.2	OC	MSCL
CR1T44	Caspian tern	Lewis & Clark NWR	1990	1	61.0	76.3		Hg by ICP	HAZL
CR1T45	Caspian tern	Lewis & Clark NWR	1990	1	64.0	78.9		Hg by ICP	HAZL
CR1T46	Caspian tern	Lewis & Clark NWR	1990	1	61.0	75.8		Hg by ICP	HAZL
CR1T47	Caspian tern	Lewis & Clark NWR	1990	1	59.0			OC,Hg	NCL(Alta)
CR1W29	West./Glaucous-winged gull	Lewis & Clark NWR	1990	1	85.0			PCDD/F	CERC
CR1W30	West./Glaucous-winged gull	Lewis & Clark NWR	1990	1	89.0			PCDD/F	CERC
CR1W31	West./Glaucous-winged gull	Lewis & Clark NWR	1990	1	77.2	75.0	9.4	OC	MSCL
CR1W32	West./Glaucous-winged gull	Lewis & Clark NWR	1990	1	83.1	76.5	8.1	OC	MSCL
CR1W33	West./Glaucous-winged gull	Lewis & Clark NWR	1990	1	75.1	75.5	9.3	OC	MSCL
CR1W34	West./Glaucous-winged gull	Lewis & Clark NWR	1990	1	90.0			OC,Hg	NCL(Alta)
CR1W35	West./Glaucous-winged gull	Lewis & Clark NWR	1990	1	88.0			OC,Hg	NCL(Alta)
CR1W36	West./Glaucous-winged gull	Lewis & Clark NWR	1990	1	82.0			OC,Hg	NCL(Alta)
CR1W37	West./Glaucous-winged gull	Lewis & Clark NWR	1990	1	71.0			OC,Hg	NCL(Alta)

Sample number	Species or Sample Type	Sample location	Year	Pool	Sample mass (g)	% Moisture	% Lipid	Analyses[a]	Laboratory[b]
CR8F19	Forster's tern	Umatilla	1990	1	20.0			TCDD/F, Tot. CDD/F	RADIAN
CR8F20	Forster's tern	Umatilla	1990	1	17.0			TCDD/F	RADIAN
CR8F21	Forster's tern	Umatilla	1990	1	20.0			TCDD/F	RADIAN
CR8F22	Forster's tern	Umatilla	1990	1	20.1	77.5	7.6	OC	MSCL
CR8F23	Forster's tern	Umatilla	1990	1	20.7	79.0	7.1	OC	MSCL
CR8F24	Forster's tern	Umatilla	1990	1	19.0	76.5	10.0	OC	MSCL
CR8R02	Ring-billed gull	Umatilla	1990	1	44.0			PCDD/F	CERC
CR8R03	Ring-billed gull	Umatilla	1990	1	49.0			PCDD/F	CERC
CR8R04	Ring-billed gull	Umatilla	1990	1	44.0	76.5	8.9	OC	MSCL
CR8R05	Ring-billed gull	Umatilla	1990	1	44.3	76.5	8.3	OC	MSCL
CR8R06	Ring-billed gull	Umatilla	1990	1	48.3	74.0	9.4	OC	MSCL
CR8T11	Caspian tern	Umatilla	1990	1	52.0			TCDD/F	CERC
CR8T12	Caspian tern	Umatilla	1990	1	63.0			PCDD/F	CERC
CR8T13	Caspian tern	Umatilla	1990	1	59.0	76.0	9.3	OC	MSCL
CR8T14	Caspian tern	Umatilla	1990	1	59.2	76.0	9.8	OC	MSCL
CR8T15	Caspian tern	Umatilla	1990	1	60.4	76.5	8.6	OC	MSCL
CR8T16	Caspian tern	Umatilla	1990	1	54.0	74.0		Hg by ICP	HAZL
CR8T17	Caspian tern	Umatilla	1990	1	59.0	75.9		Hg by ICP	HAZL
CR8T18	Caspian tern	Umatilla	1990	1	57.0	78.7		Hg by ICP	HAZL
CRBCG013	Canada gull	Baker Bay	1991	1	141	66.9	14.7	OC,Hg	GERG
CRBDC062	Double-crested cormorant	Baker Bay	1991	1	41.0		5.7	TCDD/F	TLI
CRBDC063	Double-crested cormorant	Baker Bay	1991	1	39.0	80.1	5.4	OC	GERG
CRBDC064	Double-crested cormorant	Baker Bay	1991	1	42.0		2.4	TCDD/F	PA
CRBDC065	Double-crested cormorant	Baker Bay	1991	1	40.0			Hg	ETSL
CRBDC066	Double-crested cormorant	Baker Bay	1991	1	43.0		5.1	TCDD/F	TLI
CRBDC067	Double-crested cormorant	Baker Bay	1991	1	39.0			Hg	ETSL
CRBDC068	Double-crested cormorant	Baker Bay	1991	1	44.0	83.0	3.0	OC	GERG
CRBDC069	Double-crested cormorant	Baker Bay	1991	1	40.0		3.2	TCDD/F	PA
CRBDC070	Double-crested cormorant	Baker Bay	1991	1	45.0	85.8	3.1	OC	GERG
CRBDC071	Double-crested cormorant	Baker Bay	1991	1	44.0			Hg	ETSL
CRBDC072	Double-crested cormorant	Baker Bay	1991	1	46.0		2.9	TCDD/F	TLI
CRBM014	Mallard	Baker Bay	1991	1	45.0	71.0	9.6	OC,Hg	GERG
CRBWG073	West./Glaucous-winged gull	Baker Bay	1991	1	81.0			Hg	ETSL
CRBWG074	West./Glaucous-winged gull	Baker Bay	1991	1	84.0			Hg	ETSL
CRBWG075	West./Glaucous-winged gull	Baker Bay	1991	1	78.0	70.1	13.3	OC	GERG
CRBWG076	West./Glaucous-winged gull	Baker Bay	1991	1	81.0			Hg	ETSL
CRBWG077	West./Glaucous-winged gull	Baker Bay	1991	1	76.0		14.6	TCDD/F	TLI

Sample number	Species or Sample Type	Sample location	Year	Pool	Sample mass (g)	% Moisture	% Lipid	Analyses[a]	Laboratory[b]
CRBWG080	West./Glaucous-winged gull	Baker Bay	1991	1	68.0	67.1	40.6	OC	GERG
CRBWG081	West./Glaucous-winged gull	Baker Bay	1991	1	77.0	69.4	11.4	OC	GERG
CRBWG082	West./Glaucous-winged gull	Baker Bay	1991	1	88.0		14.2	TCDD/F	TLI
CRBWG083	West./Glaucous-winged gull	Baker Bay	1991	1	83.0		19.7	TCDD/F	TLI
CRACG003	Canada gull	Lewis & Clark NWR	1991	1	133	65.4	20.3	OC,Hg	GERG
CRACG009	Canada gull	Lewis & Clark NWR	1991	1	137	68.6	24.9	OC,Hg	GERG
CRACG010	Canada gull	Lewis & Clark NWR	1991	1	143	65.6	14.0	OC,Hg	GERG
CRACT030	Caspian tern	Lewis & Clark NWR	1991	1	63.0	71.7	24.0	OC	GERG
CRACT031	Caspian tern	Lewis & Clark NWR	1991	1	54.0			Hg	ETSL
CRACT032	Caspian tern	Lewis & Clark NWR	1991	1	66.0	72.4	28.0	OC	GERG
CRACT034	Caspian tern	Lewis & Clark NWR	1991	1	66.0		8.5	TCDD/F	TLI
CRACT036	Caspian tern	Lewis & Clark NWR	1991	1	55.0	72.4	15.3	OC	GERG
CRACT037	Caspian tern	Lewis & Clark NWR	1991	1	55.0			Hg	ETSL
CRACT038	Caspian tern	Lewis & Clark NWR	1991	1	47.0			Hg	ETSL
CRACT039	Caspian tern	Lewis & Clark NWR	1991	1	56.0		9.2	TCDD/F	TLI
CRACT040	Caspian tern	Lewis & Clark NWR	1991	1	60.0		9.2	TCDD/F	TLI
CRADC052	Double-crested cormorant	Lewis & Clark NWR	1991	1	44.0		2.6	TCDD/F	PA
CRADC053	Double-crested cormorant	Lewis & Clark NWR	1991	1	39.0		2.2	TCDD/F	PA
CRADC054	Double-crested cormorant	Lewis & Clark NWR	1991	1	47.0			Hg	ETSL
CRADC055	Double-crested cormorant	Lewis & Clark NWR	1991	1	45.0	80.7	13.0	OC	GERG
CRADC056	Double-crested cormorant	Lewis & Clark NWR	1991	1	46.0			Hg	ETSL
CRADC057	Double-crested cormorant	Lewis & Clark NWR	1991	1	42.0	84.1	4.1	OC	GERG
CRADC058	Double-crested cormorant	Lewis & Clark NWR	1991	1	42.0		5.1	TCDD/F	TLI
CRADC059	Double-crested cormorant	Lewis & Clark NWR	1991	1	42.0		4.9	TCDD/F	TLI
CRADC060	Double-crested cormorant	Lewis & Clark NWR	1991	1	42.0	83.8	2.9	OC	GERG
CRADC061	Double-crested cormorant	Lewis & Clark NWR	1991	1	44.0			Hg	ETSL
CRADC062	Double-crested cormorant	Lewis & Clark NWR	1991	1	39.0		5.0	TCDD/F	TLI
CRAMD100	Mallard	Lewis & Clark NWR	1991	1	44.0	68.8	14.4	OC,Hg	GERG
CRAMD101	Mallard	Lewis & Clark NWR	1991	1	42.0	67.1	14.7	OC,Hg	GERG
CRAWG041	West./Glaucous-winged gull	Lewis & Clark NWR	1991	1	77.0		8.5	TCDD/F	TLI
CRAWG042	West./Glaucous-winged gull	Lewis & Clark NWR	1991	1	90.0		10.4	TCDD/F	TLI
CRAWG043	West./Glaucous-winged gull	Lewis & Clark NWR	1991	1	74.0	69.5	12.8	OC	GERG
CRAWG044	West./Glaucous-winged gull	Lewis & Clark NWR	1991	1	81.0			Hg	ETSL
CRAWG045	West./Glaucous-winged gull	Lewis & Clark NWR	1991	1	77.0	76.2	7.9	OC	GERG
CRAWG047	West./Glaucous-winged gull	Lewis & Clark NWR	1991	1	79.0		4.1	TCDD/F	TLI
CRAWG048	West./Glaucous-winged gull	Lewis & Clark NWR	1991	1	86.0			Hg	ETSL

Sample number	Species or Sample Type	Sample location	Year	Pool	Sample mass (g)	% Moisture	% Lipid	Analyses[a]	Laboratory[b]
CRAWG050	West./Glaucous-winged gull	Lewis & Clark NWR	1991	1	82.0			Hg	ETSL
CRAWG051	West./Glaucous-winged gull	Lewis & Clark NWR	1991	1	85.0	71.6	11.6	OC	GERG
CRMM016	Mallard	Lewis & Clark NWR	1991	1	50.0	68.3	12.9	OC,Hg	GERG
CRRCG020	Canada gull	Longview	1991	1	142	63.3	14.3	OC,Hg	GERG
CRRCG022	Canada gull	Longview	1991	1	117	62.4	16.3	OC,Hg	GERG
CRRCG023	Canada gull	Longview	1991	1	143	65.8	14.2	OC,Hg	GERG
CRURG105	Ring-billed gull	Umatilla	1991	1	48.0	68.1	12.4	OC	GERG
CRURG106	Ring-billed gull	Umatilla	1991	1	38.0	66.5	14.7	OC	GERG
CRURG108	Ring-billed gull	Umatilla	1991	1	41.0	70.0	10.1	OC	GERG
CRURG110	Ring-billed gull	Umatilla	1991	1	40.0			Hg	ETSL
CRURG112	Ring-billed gull	Umatilla	1991	1	45.0			Hg	ETSL
CRURG113	Ring-billed gull	Umatilla	1991	1	47.0			Hg	ETSL
CRURG114	Ring-billed gull	Umatilla	1991	1	40.0		8.8	TCDD/F	TLI
CRURG115	Ring-billed gull	Umatilla	1991	1	39.0		8.3	TCDD/F	TLI
CRURG116	Ring-billed gull	Umatilla	1991	1	40.0		8.7	TCDD/F	TLI
CF10	Forster's tern	Umatilla	1991	1	17.5			TCDD/F	PA
CF19	Forster's tern	Umatilla	1991	1	16.0			TCDD/F	PA
CF24	Forster's tern	Umatilla	1991	1	15.4			TCDD/F	PA
CF3	Forster's tern	Umatilla	1991	1	19.5		9.6	PCDD/F	MRI
CF5	Forster's tern	Umatilla	1991	1	18.5			TCDD/F	PA
CT19	Caspian tern	Umatilla	1991	1	56.9	76.5	7.5	OC-PCB,TCDD/F,Hg	GERG,TLI,GERG
CT20	Caspian tern	Umatilla	1991	1	54.5	74.7	7.6	OC-PCB,Hg	GERG
CT21	Caspian tern	Umatilla	1991	1	61.6	73.8	9.2	OC-PCB,TCDD/F,Hg	GERG,TLI,GERG
CT22	Caspian tern	Umatilla	1991	1	56.2	76.8	7.7	OC-PCB,TCDD/F,Hg	GERG,TLI,GERG
CT24	Caspian tern	Umatilla	1991	1	54.5	72.2	8.3	OC-PCB,Hg	GERG

[a] Analyses include TCDD/F (analyzed for 2,3,7,8-tetraclorodibenzodioxin and furan congeners); PCDD/F (analyzed for polychlorinated dibenzodioxins and furans); Tot. CDD/F (analyzed for total chlorinated dibenzodioxins and furans); OC (analyzed as part of an organochlorine pesticide scan including polychlorinated biphenyls [PCBs] measured as Aroclor PCBs); OC-PCB (analyzed for organochlorine pesticides and individual PCB congeners, with total PCBs reported as summation of congeners); Hg (analyzed for total mercury by cold-vapor atomic absorption spectroscopy); and Hg by ICP (analyzed for total mercury by inductively coupled plasma-atomic emission spectroscopy).

[b] Laboratories contracted to conduct chemical analyses include 1) Patuxent Analytical Control Facility (PACF) in Patuxent, Maryland; 2) Mississippi State Chemical Laboratory (MSCL) in Mississippi State, Mississippi; 3) Geochemical and Environmental Research Group (GERG) in College Station, Texas; 4) North Coast Laboratories (NCL) in Arcata, California (subcontracted by Alta Analytical Laboratory [Alta] in Eldorado Hills, California); 5) Triangle Laboratories (TLI), Research Triangle Park, North Carolina; 6) Pacific Analytical (PA), Carlsbad, California; 7) Midwest Research Institute (MRI), Kansas City, Missouri; 8) Radian Analytical Services (Radian), Austin, Texas; 9) Columbia Environmental Research Center (CERC), U.S. Geological Survey, Biological Research Division, Columbia, Missouri; 10) Environmental Trace Substances Laboratory (ETSL) in Rolla, Missouri; and 11) Hazleton Environmental Services, Inc., (HES) in Madison, Wisconsin. Each laboratory listed in the column conducted the analysis listed respectively in the previous column (commas separate the analysis group conducted by a laboratory).

Appendix B. Samples collected from the Columbia River in 1990 and 1991 and re-analyzed for 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF) after initial data failed quality control (QC) limits. Blank cells indicate analysis type was not conducted.

Sample number	Species or Sample Type	Sample location	Year	Catalog[a]	Initial Result[b] TCDD/TCDF (pg/g) RTX-200	Additional Cleanup[c] TCDD/TCDF (pg/g) RTX-200	Re-extraction[d] TCDD/TCDF (pg/g)	Re-extraction column used[e]	Data Useability[f]
CRBSD174	Sediment	Baker Bay	1991	18	<2.0/<2.0				DA
CRBMC143	Macoma clam	Baker Bay	1991	18	<4.0/<5.0	<9.0/<20E[g]			EX/IM
CRACC206	Corbicula clam	Cathlamet Bay	1991	18	<10/<17	<2.0/10E			DA
CRACF220	Crayfish	Cathlamet Bay	1991	16	<11/<15		1.2/4.0	DB-5	DA
CRACF223	Crayfish	Cathlamet Bay	1991	16	<6.0/<11		<1.0/2.2	DB-5	DA
CRMCC146	Corbicula clam	Lewis & Clark NWR	1991	18	<8.0/<21		<1.0/2.5E	RTX-200	DA
CRMCF208	Crayfish	Lewis & Clark NWR	1991	16	<19/<18				EX/IM
CRMCF209	Crayfish	Lewis & Clark NWR	1991	16	<8.0/<11		<1.0/3.9	DB-5	DA
CRMCO140	Corophium	Lewis & Clark NWR	1991	16	<24/<25		1.4/3.5E	RTX-200	DA
CRMCO141	Corophium	Lewis & Clark NWR	1991	16	<27/<24		<1.0/2.0	DB-5	DA
CRJCC110	Corbicula clam	Julia Butler Hansen NWR	1991	18	<8.0/11				EX/IM
CRJCF100	Crayfish	Julia Butler Hansen NWR	1991	16	<5.0/<10	<4.0/4.0E	<1.0/3.9	DB-5	DA
CRJCF109	Crayfish	Julia Butler Hansen NWR	1991	16	<4.0/4.0		<1.0/4.9	DB-5	DA
CRLCC125	Corbicula clam	Longview	1991	18	<4.0/6.0				EX/IM
CRLCF170	Crayfish	Longview	1991	16	<10/<9.0		<1.0/5.7	DB-5	DA
CRLCF219	Crayfish	Longview	1991	16	<8.0/<6.0		<1.0/3.6	DB-5	DA
CRCCC212	Corbicula clam	Camas Slough	1991	18	<13/<26		<1.0/4.5E	RTX-200	DA
CRCCF156	Crayfish	Camas Slough	1991	16	<7.0/<11		<1.0/4.2	DB-5	DA
CRCCF157	Crayfish	Camas Slough	1991	16	<7.0/<18		<1.0/4.6	DB-5	DA
CRRCC161	Corbicula clam	Ridgefield	1991	18	<7.0/11		<1.0/1.3E	RTX-200	DA
CRRCF134	Crayfish	Ridgefield	1991	16	<15/<13		<1.0/2.7	DB-5	DA
CRRCF158	Crayfish	Ridgefield	1991	16	<14/<17		<1.0/3.0	DB-5	DA
CRUCC233	Corbicula clam	Umatilla	1991	18	<5.0/9.0		<1.0/4.4E	RTX-200	DA
CRASC094	Sucker (bridgelip)	Cathlamet Bay	1991	16	<59/NLF	<5.0/<4.0E	1.5/14	DB-5	DA
CRASC095	Sucker (largescale)	Cathlamet Bay	1991	16	<29/<170		<1.0/6.3	DB-5	DA
CRMPM183	Peamouth chub	Lewis & Clark NWR	1991	16	NLF/NLF	<2.0/<4.0E			DA
CRMPM185	Peamouth chub	Lewis & Clark NWR	1991	16	<99/<400		2.5/28	DB-5	DA
CRMSC186	Sucker	Lewis & Clark NWR	1991	16	NLF/NLF	<5/<3E			EX

Sample number	Species or Sample Type	Sample location	Year	Catalog[a]	Initial Result[b] TCDD/TCDF (pg/g) RTX-200	Additional Cleanup[c] TCDD/TCDF (pg/g) RTX-200	Re-extraction[d] TCDD/TCDF (pg/g)	Re-extraction column used[e]	Data Useability[f]
CRMSC187	Sucker	Lewis & Clark NWR	1991	16	<18</85		1.1/6.6	DB-5	DA
CRJSC102	Sucker	Julia Butler Hansen NWR	1991	16	<70/<110		<1.0/2.8	DB-5	DA
CRJSC113	Sucker (bridgelip)	Julia Butler Hansen NWR	1991	16	<29/<25		1.1/4.3	DB-5	DA
CRLCP182	Common carp	Longview	1991	18	NLF/NLF	<7.0/<2.0E	4.3/6.0	DB-5	DA
CRLCP234	Common carp	Longview	1991	18	<84/<190		2.2/4.5	DB-5	DA
CRLCP235	Common carp	Longview	1991	18	NLF/NLF		<1.0/34E	RTX-200	DA
CRLPM123	Peamouth chub	Longview	1991	16	<99/50		1.6/11E	DB-5	DA
CRLPM181	Peamouth chub	Longview	1991	16	<130/<180		1.1/18	DB-5	DA
CRLSC178	Sucker	Longview	1991	16	<75/<270		2.6/13	DB-5	DA
CRLSC179	Sucker	Longview	1991	16	<170/<180		1.3/8.6	DB-5	DA
CRRCP114	Common carp	Ridgefield	1991	18	<18/<47		1.2/3.1	DB-5	DA
CRRCP115	Common carp	Ridgefield	1991	18	<22/<26		<1.0/2.1	DB-5	DA
CRRCP116	Common carp	Ridgefield	1991	18		<3.0/<2.0E	1.4/5.0	DB-5	DA
CRRPM127	Peamouth chub	Ridgefield	1991	16	<39/<1000		<1.0/64E	RTX-200	DA
CRRPM166	Peamouth chub	Ridgefield	1991	16	<17/<240		1.9/50	DB-5	DA
CRRSC168	Sucker	Ridgefield	1991	16	<21/<150		1.6/8.7	DB-5	DA
CRRSC169	Sucker	Ridgefield	1991	16	<17/<15		1.3/7.3	DB-5	DA
CRCCP150	Common carp	Camas Slough	1991	18	NLF/NLF	<3.0/<2.0E	3.5/7.8	DB-5	DA
CRCCP154	Common carp	Camas Slough	1991	18	<38/<44		1.5/7.4	DB-5	DA
CRCCP230	Common carp	Camas Slough	1991	18	<93/<160		<1.0/<1.0E	RTX-200	DA
CRCSC213	Sucker	Camas Slough	1991	16	<66/<29		<1.0/<1.0	DB-5	DA
CRCSC222	Sucker	Camas Slough	1991	16	<40/<32		<1.0/1.9	DB-5	DA
CRUCP131	Common carp	Umatilla	1991	18	NLF/NLF	<19/<17E	12/25	DB-5	DA
CRUCP132	Common carp	Umatilla	1991	18	<140/<59		3.5/16	DB-5	DA
CRUCP221	Common carp	Umatilla	1991	18	<350/<360	<24/<38E	33/110	DB-5	DA
CRUSC224	Sucker	Umatilla	1991	16	NLF/NLF		<1.0/14E	RTX-200	DA
CRUSC225	Sucker	Umatilla	1991	16	<30/<30				EX
CRUWF227	Whitefish	Umatilla	1991	16	<66/140				EX
CRUWF228	Whitefish	Umatilla	1991	16	<33/96				EX
CRBDC064	Double-crested cormorant	Baker Bay	1991	16	<230/NLF	<1.0/<1.0E[h]			DA
CRBDC069	Double-crested cormorant	Baker Bay	1991	16	<220/NLF	<3.0/<5.0E	5.7/3.4[h]	DB-5	DA

Sample number	Species or Sample Type	Sample location	Year	Catalog[a]	Initial Result[b] TCDD/TCDF (pg/g) RTX-200	Additional Cleanup[c] TCDD/TCDF (pg/g) RTX-200	Re-extraction[d] TCDD/TCDF (pg/g)	Re-extraction column used[e]	Data Useability[f]
CRADC052	Double-crested cormorant	Lewis & Clark NWR	1991	16	<67/NLF	<1.0/<2.0E[h]			DA
CRADC053	Double-crested cormorant	Lewis & Clark NWR	1991	16	<50/<18		11/<1.0[h]	DB-5	DA
CF10	Forster's tern	Umatilla	1991	16	<270/NLF		<2.0/<2.0E[h]	RTX-200	DA
CF19	Forster's tern	Umatilla	1991	16	<400/<620		<2.0/<2.0E[h]	RTX-200	DA
CF24	Forster's tern	Umatilla	1991	16	<830/<480		1.3/2.3[h]	DB-5	DA
CF5	Forster's tern	Umatilla	1991	16	<310/<99		<1.0/<1.0[h]	DB-5	DA
CRBCO136[i]	Corophium	Baker Bay	1991	16	<22/<23				EX/IM
CRACO203[i]	Corophium	Cathlamet Bay	1991	16	<35/<52				EX/IM
CRACO204[i]	Corophium	Cathlamet Bay	1991	16	<18/<38				EX/IM

[a] Catalog number used to track sample groups sent in to contract laboratories for analysis. Most catalogs are submitted electronically through the U.S. Fish and Wildlife Service's Environmental Contaminant Data Management System (ECDMS).

[b] Result initially reported by laboratory that failed QC limits. An RTX-200 chromatography column was used for separation of TCDD and TCDF in this method (see Table 5 for specific analytical methods). Concentrations in the table column are presented as TCDD/TCDF. A "<" sign indicates value was below specified detection limit.

[c] Result reported following additional cleanup procedures used by laboratory to improve detection and reduce interferences. An RTX-200 chromatography column was used for separation of TCDD and TCDF in this method (see Table 5 for specific analytical methods). Concentrations in the table column are presented as TCDD/TCDF. A "<" sign indicates value was below specified detection limit.

[d] Result reported following re-extraction of sample material by laboratory to further improve detection and reduce interferences. An RTX-200 or DB-5 chromatography column was used in this analysis for separation of TCDD and TCDF (see Table 5 for specific analytical methods). Concentrations in the table column are presented as TCDD/TCDF. A "<" sign indicates value was below specified detection limit.

[e] Chromatography column used with high resolution gas chromatography/high resolution mass spectrometry to separate TCDD and TCDF for samples that were re-extracted.

[f] Use of data in final report; DA=data acceptable (passed QC limits) and used in report; EX=data failed QC limits and excluded from report; IM=insufficient material remained for re-analysis.

[g] E=estimated maximum possible concentration. Interference from co-eluting diphenyl ethers occurred during analysis and confirmation column was not effective for positive identification or not used in quantification. All TCDF results from the RTX-200 column were reported as estimated.

[h] Bird egg results are presented raw and were not adjusted for moisture or lipid loss in this table.

[i] Corophium sample was excluded from the data set (and not included in the total 274 samples from this study) because sample results failed QC limits and insufficient sample material remained to conduct analysis for any contaminant, so the sample was considered unusable.