EXHIBIT B

DEPARTMENT OF
ECOLOGY
State of Washington

Fish Consumption Rates

Technical Support Document

A Review of Data and Information About Fish Consumption in Washington

September 2011
Publication no. 11-09-050
Version 1.0

Publication and Contact Information

This report is available on the Department of Ecology's website at
www.ecy.wa.gov/biblio/1109050.html

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Technical Support Document

Toxics Cleanup Program
Washington State Department of Ecology
Olympia, Washington

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Table of Contents

Page

List of Figures and Tables iv
Tables iv
Figures vi

Acronyms & Abbreviations vii

Acknowledgments 1

Executive Summary 3

Chapter 1 : Introduction and Purpose 9
Introduction 9
Intended audience 10
Purpose of this document 10
Organization of this document 12

Chapter 2 : Washington Fish Resources and Fish-Consuming Populations 15
Introduction 15
Washington's significant fish resources 15
Washington fish resources 16
Salmon in Washington 17
Washington's commercial fishery 18
Washington's recreational fishery 19
Washington population demographics 21
Estimated fish consumers in Washington 22
Estimated number of high fish consumers 24
Estimated number of high fish-consuming children 25
Discussion 26
High fish-consuming populations 26
Asian and Pacific Islanders 26
Washington Native American Tribes 27
Subsistence fishers 28
Summary and conclusions 28
Estimates of high fish consumers 29

Chapter 3 : Methodology for Assessing Fish Consumption Rate Information 31
Introduction 31
Surveys and other approaches used to estimate fish consumption 32
Creel surveys 32

Personal interviews....33
Diary surveys....35
Telephone surveys....36
Recall mail surveys....37
Survey selection criteria....37
Evaluating survey vehicles....39
General survey design....39
Survey questionnaire....41
Population surveyed....41
Description of water body....41
Survey results....42
Factors to consider....42
Measures of technical defensibility....43
Standards applied to establishing defensibility....45

Chapter 4 : Fish Consumption Survey Data Applicable to Washington Fish Consumers....47
Introduction....47
Surveys and information considered by Ecology....47
Pacific Northwest Native American fish consumption data....48
Columbia River Inter-Tribal Fish Commission survey: the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin....48
Tulalip and Squaxin Island Tribes of the Puget Sound Region (Toy et al., 1996)....52
Suquamish Indian Tribe....55
Asian and Pacific Islanders....58
Additional fish consumption rate information evaluated by Ecology....62
Variability and uncertainty....64
Factors that contribute to variability and uncertainty....65
Estimated United States per capita fish consumption....68
Summary and conclusions....70

Chapter 5 : Regulatory Context for Using Fish Consumption Rates....73
Introduction....73
The Model Toxics Control Act Cleanup regulation....74
Reasonable maximum exposure defined under MTCA....75
Sediment management standards....76
Water quality standards....77
EPA Region 10 framework....78
Washington State Department of Health fish advisories....84
Examples of fish consumption rates used in various regulatory contexts....86
Summary and conclusions....89

Chapter 6 : Site-Specific Fish Consumption Rates....91

Introduction 91
When to use a site-specific fish consumption rate 92
Factors to consider 93
Environmental considerations 94
Available resources and habitat 94
Shellfish growing areas 95
Suppression effects 96
Exposure parameters 96
Body weight 97
Fish diet fraction 98
Exposure duration 99

Chapter 7 : Recommendations 101
Introduction 101
Regulatory dilemma 101
Statement of the regulatory question 102
Current rulemaking efforts 102
Questions remain 103
Preliminary recommendations 103
Reasons for the proposed preliminary recommendation 104
Rationale and basis for the preliminary recommendation 104
Key policy issues associated with developing a default fish consumption rate 107
The question of whether to include salmon 108
Choice of the reasonable maximum exposure 109
Options for the preliminary recommendation 110
Data analysis 110
Acceptable risk 111
Summary and conclusions 111

Appendices A-1
Appendix A Data Used to Develop Proposed Default FCR A-1
Appendix B Additional Supporting Information B-1
Appendix C Statistical Analysis C-1
Appendix D EPA Region 10 Framework D-1
Appendix E The Question of Salmon E-1
Appendix F Washington Tribes F-1
Appendix G Glossary G-1
Appendix H References H-1

List of Figures and Tables

Tables

Page

Table 1. Summary of Fish Consumption Rate Survey Data 6

Table 2. Commercial Fish Landings From Washington Nontreaty Fisheries in 2006 19

Table 3. Number of Recreational Finfish Caught in Washington Waters in 2006 by Species and Region 21

Table 4. Pounds of Shellfish Taken From Washington Waters in 2006 by Species and Region 21

Table 5. Estimated Washington Fish Consumers Based on Washington DOH Survey Data....24

Table 6. Estimates of Fish Consumption Among the Washington Adult Population 25

Table 7. Estimated Number of Washington Children High Fish Consumers....26

Table 8. Strengths and Weaknesses of Creel Surveys 34

Table 9. Strengths and Weaknesses of Personal Interviews 35

Table 10. Strengths and Weaknesses of the Diary Method 36

Table 11. Strengths and Weaknesses of Telephone Surveys....36

Table 12. Strengths and Weaknesses of Recall Mail Surveys 37

Table 13. Comparison of Five Consumption Survey Methodologies Using EPA's Selection Criteria 38

Table 14. Survey Design Evaluation Criteria 40

Table 15. Measures of Technical Defensibility 44

Table 16. Evaluation of Technical Defensibility 51

Table 17. A Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region....54

Table 18. Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservation, Puget Sound Region 57

Table 19. Asian and Pacific Islander Seafood Consumption Study 59

Table 20. Fish Consumption Information Relevant to Washington and Considered by Ecology.....63

Table 21. Summary of Fish Consumption Rate Surveys Considered by Ecology 71

Table 22. Tulalip Tribe's Fish Consumption Rate (grams/day) 79

Table 23. Suquamish Tribe's Fish Consumption Rate (grams/day) 80

Table 24. Examples of Fish Consumption Rates and Regulatory Context.....87

Table 25. EPA Region 10 Tribal Fish Consumption Rates Related to Water Quality Standards.....88

Table 26. EPA Region 10 State Fish Consumption Rates Related to Water Quality Standards.....89

Table A-1. Summary of Fish Consumption Rate Data A-1

Table B-1. Fish Consumption Rates of Native American Children 5 or 6 Years of Age or Less B-1

Table B-2. Tribal Fish Consumption Rates B-3

Table B-3. Fish Consumption Rate Data for Asian and Pacific Islanders.....B-3

Table B-4. EPA Data on Children's Fish and Shellfish Consumption Rates for the U.S. General Population B-4

Table B-5. Seafood Consumed by Adult Members of the Tulalip Tribe.....B-4

Table B-6. Seafood Consumed by Adult Members of the Suquamish Tribe B-5

Table B-7. Seafood Consumed by Adult Asian-Pacific Islanders (API).....B-5

Table C-1. Published Descriptive Statistics of Fish Consumption Rate for Selected Pacific Northwest Fish-Consuming Populations, grams/day.....C-1

Table C-2. Weighting Factors Used to Generate Probability and Cumulative Density Functions.....C-5

Table C-3: Information Used to Derive Weighting Factors C-5

Table C-4. Results: Derived Descriptive Statistics for various Weighting Schemes C-12

Table D-1. Tulalip Tribe's Fish Consumption Rate (grams/day) D-2

Table D-2. Suquamish Tribe's Fish Consumption Rate (grams/day)..... D-3

Table E-1. Pacific Salmon Life Cycle E-5

Table E-2. Average PCB Concentrations For Coho & Chinook Salmon From In-River & Marine Locations, Puget Sound (µg/kg).....E-6

Table E-3. Status of Washington Salmon Stocks E-9

Table E-4. Status of Puget Sound Salmon Stock.....E-9

Table E-5. Life Histories of Pacific Coast Salmonids E-16

Table E-6. Biological Variability In Life Histories Of Pacific Salmonids E-17
Table E-7. 2001-2002 Freshwater Salmon Sport Catch For Puget Sound River Systems E-18
Table E-8. 2001-2002 Sport Salmon Catch For East Juan de Fuca (Port Angeles Areas) E-18
Table E-9. 2002-2003 Freshwater Salmon Sport Catch for Puget Sound River Systems E-18
Table E-10. 2002-2003 Sport Salmon Catch For East Juan de Fuca (Port Angeles Areas) E-19
Table E-11. Salmonid Stock Inventory For The Port Angeles Harbor & Adjacent Areas E-19
Table E-12. Salmonid Stock Inventory For The Port Angeles Harbor & Adjacent Areas E-20
Table E-13. Salmonid Stock Inventory For The Port Angeles Harbor & Adjacent Areas E-21

Figures

Page

Figure 1. MTCA Surface Water Cleanup Standards (Carcinogenic Risk) 74
Figure 2. Decision Logic Overview 93

Acronyms & Abbreviations

API	Asian and Pacific Islander
bw	body weight
BRFSS	Behavioral Risk Factor Surveillance System
CRITFC	Columbia River Inter-Tribal Fish Commission
CSF	cancer slope factor
CSFII	*Continuing Survey of Food Intakes by Individuals*
CWA	Clean Water Act
DOH	Washington State Department of Health
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
g/day	grams per day
FDF	fish diet fraction
LEKT	Lower Elwha Klallam Tribe
µg/L	micrograms per liter
µg/mg	micrograms per milligram
MTCA	Model Toxics Control Act
ODEQ	Oregon Department of Environmental Quality
OFM	Office of Financial Management
PAH	polycyclic aromatic hydrocarbon
PBDE	polybrominated diphenyl ether
PBT	persistent bioaccumulative toxic
PCB	polychlorinated biphenyl
PFMC	Pacific Fishery Management Council
RfD	reference dose
RME	reasonable maximum exposure
SaSI	salmon stock inventory
SMS	Sediment Management Standards
USDA	U.S. Department of Agriculture
WDFW	Washington Department of Fish and Wildlife
WRIA	water resource inventory area
WQS	Water Quality Standards for Surface Waters
WPA	Watershed Planning Act

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Acknowledgments

Department of Ecology gratefully acknowledges the significant contributions made by many people in the development of this document.

University of Washington

- Dr. William (Bill) Daniell, Associate Professor
- Dr. Elaine Faustman, Professor
- Dr. William (Bill) Griffith, Principal Research Scientist and Director of the Risk Assessment Core of the Institute for Risk Analysis and Risk Communication
- Alison Scherer, Research Assistant
- Anna Schmidt, Graduate Student, Environmental & Occupational Health Sciences

Washington State Department of Health (DOH)

- Maria C. Gardipee
- Dr. Joan Hardy
- David McBride
- Dr. Jim W. White

Selected Tribal Representatives

- Larry Dunn, Lower Elwha Klallam Tribe
- Don Hurst and Patti Bailey, Confederated Tribes of the Colville Reservation
- Fran Wilshusen, Northwest Indian Fisheries Commission

Washington State Office of Financial Management

- Yi Zhao, Chief Demographer

U.S. Environmental Protection Agency, Region 10, Seattle

- Lon Kissinger, Senior Toxicologist, EPA Region 10

Selected members of the Human Health Focus Group, Oregon Dept of Environmental Quality

- Dr. Patricia Cirone, Senior Toxicologist
- Dr. Bruce Hope, Senior Toxicologist
- DOH personnel identified above

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Executive Summary

September 16, 2011

Problem statement

Washington's aquatic resources provide tremendous benefit to the people of the state. Large quantities of fish and shellfish are caught annually, both recreationally and commercially, and many residents eat seafood harvested from our waters. In addition, tribal populations enjoy treaty fishing rights, and harvesting and eating seafood plays a significant role in their cultures.

PCBs (polychlorinated biphenyls), dioxins, mercury, and other persistent chemicals can accumulate in fish tissue and harm the health of people who consume fish. Adults who eat large amounts of fish or shellfish, children, and other sensitive populations may be particularly vulnerable. Current fish consumption rates that the Washington State Department of Ecology (Ecology) uses for regulatory decisions are not consistent with what we know about how much fish people in Washington eat.[1]

Ecology is considering revisions to the Sediment Management Standards (SMS) rule (Washington Administrative Code [WAC] 173-204). Over the next several years, we will also consider updates to the Water Quality Standards for Surface Waters (WAC 173-201A) and the Model Toxics Control Act (MTCA) Cleanup Regulation (173-340). During these efforts, Ecology will review a variety of policy, technical, and scientific issues.

One issue being considered is how fish and shellfish consumption should be taken into account when making regulatory decisions. Ecology currently considers the risks associated with eating contaminated fish and shellfish when making regulatory decisions under the Clean Water Act and the MTCA. The regulations implementing these two statutes include fish consumption rates based on information about the general population and recreational anglers. However, based on recent available scientific information, Ecology has concluded that a significant number of Washington residents likely consume fish and shellfish at rates higher than the rates used in these two regulations.

Working with external advisory groups, Ecology has been considering revisions to the sediment cleanup goals under the SMS rule. These revisions would account for risk from consuming contaminated fish and shellfish.

[1] Ecology has the ability to make site-specific decisions and use site-specific information, including fish consumption rates protective of tribal populations. One of the questions being addressed here is identifying a default fish consumption rate that can be considered generally protective of Washington fish consumers.

Furthermore, Ecology plans to revise the Water Quality Standards for Surface Waters (WQS) to adopt human health-based criteria that incorporate Washington fish consumption rates in a later process. The information in this report and the SMS rule revision will likely strongly influence the rates included in future human health-based water quality criteria.

Current laws

Ecology currently recognizes two separate default fish consumption rates used to establish regulatory requirements:

- The MTCA Cleanup Regulation includes a default fish consumption rate of 54 grams (1.9 ounces) per day. This value was established in 1991. It is based on information from a survey of Washington recreational anglers in Commencement Bay.
- The WQS reference the National Toxics Rule, which includes water quality standards for human health protection based on a fish consumption rate of 6.5 grams (0.22 ounces) per day. This value is based on technical evaluations completed by the U.S. Environmental Protection Agency (EPA) in the mid-1980s.

Regulatory question

There have been many scientific and regulatory developments related to fish consumption rates over the past 20 years. Ecology is evaluating this information in order to update the default fish consumption rates (or rates) used in regulatory decision making.

Key considerations are:

- Recent scientific data on fish and shellfish consumption rates for different population groups.
- Approaches used by other state and federal agencies.
- Uncertainty and variability in fish and shellfish consumption rates for different population groups and individuals within those groups.
- Current and potential future exposures resulting from fish and shellfish consumption.
- State laws and policies, including MTCA and the Water Pollution Control Act.
- Widespread tribal and recreational fishing in virtually all of Washington waters.

The aquatic environment challenge

Washington is famous for fish and shellfish, especially salmon and oysters. There are many species of fish and shellfish in Washington waters, each with a unique life history and preferred habitat. The various salmon species, like other anadromous fish, migrate between river and open ocean environments, spending only a portion of their life near shore.

Fish and shellfish are exposed to contaminants, but determining how much or where that exposure occurs is difficult. In an aquatic environment, contaminants move between water and sediment and from one location to another.

The questions about salmon are particularly complex. Because salmon are an integral part of life in the Pacific Northwest, it may seem odd to wonder about including salmon in a fish consumption rate. However, most salmon leave Washington waters when they are a couple of inches long, spend years in the open ocean, and return to Washington waters at the end of their life cycle. Consequently, contaminants in salmon predominantly come from food they eat while at sea. Thus, Washington regulations may have little effect on salmon contaminant levels.

Ecology recognizes the complexity of addressing this issue. We acknowledge the uncertainty around exactly where salmon are obtaining contaminants and anticipate further discussion as we work toward identifying default values for regulatory use. This report looks into multiple aspects of salmon life history. Furthermore, the range proposed for a default fish consumption rate was developed from survey data that includes salmon consumption.

Purpose of this technical support document

This Technical Support Document provides useful background information for discussions related to fish and shellfish consumption rates. A number of questions are considered:

- Among the general population, how many people in Washington can be identified as "high fish consumers?"
- What is currently known about the fish consumption habits and rates for different population groups in Washington? That is, how much fish do people in various population groups eat, what kinds of fish do they eat, and where do they obtain the fish?
- What information should Ecology look at when considering establishing one or more statewide default fish consumption rates?
- What factors should be considered in establishing site-specific fish consumption rates?

Ecology recognizes that other exposure parameters (such as exposure duration) are part of the equations used in calculating protective standards and may be relevant to the rule update discussions. This particular document, however, focuses primarily on technical information related to fish consumption rates.

Washington fish consumers

Ecology evaluated available survey information on fish consumption in the Pacific Northwest. We based evaluations on specific measures of technical defensibility, including:

- Survey methodology.

- Survey execution.
- Publication of results.
- Applicability and utility for regulatory decisions (for example, representativeness of the population surveyed relative to the regulatory decision).
- Technical suitability for the decisions.

Ecology concluded that these surveys should be considered when establishing a statewide default fish consumption rate:

1. *A Fish Consumption Survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin* (Columbia River Inter-Tribal Fish Commission, 1994).
2. *A Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region* (Toy et al., 1996).
3. *Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservations, Puget Sound Region* (Suquamish Tribe, 2000).
4. *Asian and Pacific Islander Seafood Consumption Study* (Sechena et al., 1999).

These surveys were well designed and well conducted. They are directly applicable to Washington population groups. Fish consumption rates based on these four surveys are unlikely to underestimate fish consumption rates for recreational anglers or the general Washington population.

Table 1. Summary of Fish Consumption Rate Survey Data

Population Surveyed		Type of Fish Included in Survey	Number of Adults Surveyed	Descriptive Statistics (g/day)					
				Mean	Median	Percentiles			
						75th	90th	95th	99th
Data from dietary recall surveys	Tulalip Tribe	Finfish (anadromous & estuarine) Shellfish	73	72	45	85	186	244	312
	Suquamish Tribe	Finfish (anadromous & estuarine) Shellfish	284	214	132	-	489	-	-
	Squaxin Island Tribe	Finfish (anadromous & estuarine) Shellfish	117	73	43	-	193	247	-
	Columbia River Tribes	Finfish (anadromous & Freshwater)	512	63	40	60	113	176	389
	Asian & Pacific Islanders	Finfish (anadromous & estuarine) Shellfish	202	117	78	139	236	306	-

Source: Adapted from Table 3, page 28, Human Health Focus Group Report, Oregon Fish and Shellfish Consumption Rate Project, Oregon Department of Environmental Quality, June 2008.[2]

[2] To provide context and comparison with Pacific Northwest fish dietary information, the Oregon DEQ Human Health Focus Group Report included U.S. general adult fish consumption rate information: 90th percentile of 248 grams per day, 95th percentile of 334 grams per day, and 99th percentile of 519 grams per day.

The selection of a default fish consumption rate is a “risk-management” decision. This decision requires consideration of scientific data and other factors, including statutory requirements, policies and guidance regarding protection of human health, and the choice of other exposure factors. There are various options and choices to be considered when developing one or more default fish consumption rates for use in regulatory decision making.

Preliminary recommendation

Ecology has concluded that available scientific studies support the use of a default fish consumption rate in the range of 157 to 267 grams per day (g/day). The preliminary recommendation of this report is that default fish consumption rates should be within this range for state regulatory purposes.

This preliminary recommendation takes into account results from all four surveys. It reflects variation in rates among the different groups and variation among individuals within the same group. It is consistent with Ecology’s current policies regarding the protection of both the general population and high exposure groups.

Ecology believes that a default fish consumption rate (or rates) should be protective of all people in Washington who eat fish, including those individuals that eat a lot of fish, such as Native Americans, Asian and Pacific Islanders, and some recreational fishers.

Furthermore, we think these rates should be based on scientific information, informed by risk-management decisions, and reflect state and federal law and policy. The final determination and recommendations will be established following discussion with the people of Washington regarding the factors affecting their fish and shellfish consumption.

Open questions

Ecology acknowledges a number of open questions regarding developing default fish consumption rates for use in regulatory decisions.

- How should the default rates take into account the consumption of fish species like salmon that spend much of their life outside of Washington waters?
- How should the complex life cycle and biology of the different salmon species be considered when making regulatory decisions?

Fish, shellfish, and especially salmon are part of the culture of the Pacific Northwest. This report does not intend to provide answers; rather it presents information and is intended as a starting point for further discussion.

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Chapter 1: Introduction and Purpose

Introduction

This report addresses fish consumption among Washington fish consumers, including recreation anglers, the general population, tribal populations, and other groups known to eat lots of fish, such as Asian and Pacific Islanders.[3] Washington State Department of Ecology (Ecology) will use this information to decide whether to revise state requirements and, if so, how to update them.

Ecology currently recognizes two separate default fish consumption rates used to establish regulatory requirements:

- The Model Toxics Control Act (MCTA) Cleanup Regulation includes a default fish consumption rate of 54 grams (1.9 ounces) per day. This value was established in 1991. It is based on information from a survey of Washington recreational anglers in Commencement Bay.
- The Water Quality Standards for Surface Waters (WQS) reference the National Toxics Rule, which includes water quality standards for human health protection based on a fish consumption rate of 6.5 grams (0.22 ounces) per day. This value is based on technical evaluations completed by the U.S. Environmental Protection Agency (EPA) in the mid-1980s.

The methodologies used to develop these two rates differ in a number of exposure assumptions.

There have been many scientific and regulatory developments related to fish consumption rates over the past 20 years. Ecology is evaluating this information to answer this question:

> What is a technically defensible default fish consumption rate (or rates) appropriate for use in regulatory decision making?

Key considerations are:

- Recent scientific data on fish and shellfish consumption rates for different population groups.
- Approaches used by other state and federal agencies.

[3] For the purposes of this report, fish consumers include all people in Washington who eat fish. While there is variability among how much fish is consumed by—both within and among—various population groups, some people never include fish in their diets. These people are considered nonconsumers.

- Uncertainty and variability in fish and shellfish consumption rates for different population groups and individuals within those groups.
- Current and potential future exposures resulting from fish and shellfish consumption.
- State laws and policies, including MTCA and the Water Pollution Control Act.
- Treaty-reserved fishing rights.

Over the next several years, Ecology will be considering changes to several environmental regulations. These include the Sediment Management Standards (SMS) rule, the WQS, and the MTCA Cleanup Regulation. Ecology anticipates that the SMS rule will be revised first. As part of the process, Ecology will review various policy, technical, and scientific issues.

This report provides a summary, evaluation, and analysis of the technical, regulatory, and scientific information being considered by Ecology.

Intended audience

Ecology intends to use this document to engage multiple audiences in discussions on issues related to deriving a statewide default fish consumption rate. This report is meant to facilitate discussions with the following interested parties:

- Pacific Northwest Native American tribal representatives and tribal organizations. Tribes have consistently expressed to Ecology that this is an important issue.
- Ecology's Sediment Cleanup Advisory Committee (to consist of members from the MTCA/SMS Advisory Group and Sediment Workgroup, expected to begin meeting in late summer or early fall 2011).
- Federal and state agencies (for example, EPA, Washington State Department of Health [DOH], Washington Department of Fish and Wildlife [WDFW]).
- Cleanup action and water quality standards and permitting stakeholders and stakeholder groups, including local governments and ports, water quality advocates and Washington businesses.
- Other interested persons.

Purpose of this document

Again, this report was prepared to support discussions regarding a fish consumption rate (or rates) appropriate for use as a default value in a regulatory context. Ecology plans to use this document to support discussions on a number of questions, including:

- What is the status of resources pertaining to the harvest of fish and shellfish in Washington?
- How many people in Washington consume fish? How many people in Washington can be considered high fish consumers?
- What are scientifically defensible methods for characterizing fish consumption rates?
- What is currently known about the fish consumption habits and rates for different fish-consuming populations in Washington?
- What are the current statutes, regulations, and policies that guide cleanup and source control decisions in Washington?
- Would establishing a statewide default fish consumption rate (or rates) be a useful step toward consistency among regulatory programs (for example, MTCA cleanups and water quality-based permitting)?
- What is an appropriate statewide default fish consumption rate (or rates) given available data, uncertainties and variability in fish consumption habits, and current statutes, regulations, and policies?

This report describes and documents information reviewed by Ecology, as well as the process used by Ecology in developing preliminary recommendations. The report also identifies factors considered in evaluating fish consumption survey results. The approach described in this report is also applicable and appropriate for evaluating data related to site-specific evaluations.

The discussions and data presentations in this report are largely modeled on work done in Oregon. In particular, Ecology relied heavily on work by the Oregon Department of Environmental Quality Fish Consumption Rate Review Project, especially the Human Health Focus Group Report, published in June 2008.[4]

In preparing this document Ecology benefited from input by numerous knowledgeable persons and organizations, including:

- MTCA Science Panel[5].
- Pacific Northwest Native American tribal representatives and tribal organizations (dialog is in progress and continuing).
- Oregon Department of Environmental Quality. (Ecology acknowledges and appreciates input from individuals involved with Oregon's Fish and Shellfish Consumption Rate Project.)

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[4] Oregon Department of Environmental Quality, Human Health Focus Group, *Oregon Fish and Shellfish Consumption Rate Project Report*, June 2008.

[5] The MTCA Science Advisory Board was dissolved by the legislature in 2009. Ecology currently receives scientific advice on cleanup matters by a panel of scientists.

- Representatives from the University of Washington Department of Environmental and Occupational Health Sciences.
- U.S. Environmental Protection Agency, Region 10.
- Washington Department of Health.
- Washington Office of Financial Management.

Ecology recognizes that the topic of fish consumption rates is a broad topic and that the treatment in this report is not exhaustive. It is our hope that this document encourages interested and knowledgeable persons to provide input and contribute to an ongoing statewide discourse.

Organization of this document

This document is organized as follows.

Chapter 2 – Washington Fish Resources and Fish-Consuming Populations

Available information indicates that Washington residents consume some amount of local fish or shellfish. In addition, several population subgroups (including Native Americans, Asian and Pacific Islanders, and subsistence fishers) consume large amounts of fish and shellfish. This chapter summarizes available information on state water resources that support fishing practices. Regional differences are acknowledged and the size and demographic characteristics of Washington fish and shellfish consumers and consuming populations are identified.

Chapter 3 – Methodology for Assessing Fish Consumption Rate Information

Several approaches are available for developing estimates of fish and shellfish consumption. Although surveys are generally considered to be the best approach for developing these estimates, a number of design features determine whether a particular survey provides a technically defensible basis for agency decision-making. This chapter reviews those design features and outlines the factors considered when evaluating studies.

Chapter 4 – Fish Consumption Survey Data Applicable to Washington Fish Consumers

Over the last several years, Ecology and other agencies have evaluated and used available fish consumption surveys in the context of site-specific regulatory decisions. The purpose of this chapter is to (a) identify these evaluations and summarize the fish consumption rates derived from each survey and (b) provide an initial determination as to which studies Ecology believes should be used in identifying an appropriate default fish consumption rate or rates.

Chapter 5 – Regulatory Context for Using Fish Consumption Rates

Ecology currently establishes water quality standards, surface water cleanup standards, and sediment cleanup standards based on protecting human health according to the Model Toxics Control Act and the Water Pollution Control Act. The fish consumption rate can make a significant difference in the stringency of those requirements. The choice of a default fish consumption rate for use throughout Washington leads to questions about the scientific information and policies within the laws and regulations. This chapter summarizes the Washington regulatory framework.

Chapter 6 – Site-Specific Fish Consumption Rates

Using a default fish consumption rate may not be appropriate in all situations. Cleanup is about removing health risks associated with the consumption of contaminated fish and shellfish. Exposure parameters used in setting cleanup levels, including the fish consumption rate, may need adjusting to account for site-specific needs. This chapter identifies elements appropriate to consider in setting (for cleanup purposes) a site-specific fish consumption rate protective of human health.

Chapter 7 – Recommendations

Over the next several years, Ecology will be considering revisions to the SMS rule, the Water Quality Standards for Surface Waters, and the MTCA Cleanup Regulation. This chapter reviews options Ecology considered and provides the rationale behind the recommendation that the default rate or rates be within an identified range. Ecology views this preliminary recommendation as a starting point for discussions. Subsequent proposals for rule revision will be evaluated according to regulatory analyses required under the Washington Administrative Procedures Act and the State Environmental Protection Act.

Appendices

Included here are tables that summarize fish consumption survey information, other fish consumption information used for regulatory decision making, fish species found in Washington, information on Washington tribes, a description of the EPA Region 10 decision framework, a glossary of terms, and references.

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Chapter 2: Washington Fish Resources and Fish-Consuming Populations

Introduction

Washington is home to a wide range of water resources that support commercial, recreational, and subsistence fishing. Most Washington residents consume some local fish or shellfish. Several population groups consume larger amounts of fish and shellfish than the general population. These include members of Native American tribal nations, Asian and Pacific Islanders, and subsistence fishers.

This chapter is organized into the following sections:

- *Fish resources*. A summary of fish and shellfish resources in Washington.
- *Washington's population demographics.* A summary of current demographic information.
- *Estimated number of Washington fish consumers.* This section provides rough estimates on the number of adults and children in Washington who regularly eat fish and/or shellfish.
- *High fish-consuming populations.* This section defines *high fish consumers* and identifies and describes subpopulations in Washington generally known to be high fish consumers.

Washington's significant fish resources

Washington waters support large finfish and shellfish populations and commercial, tribal, and recreational harvests.

Ecology reviewed available data on fish harvests. In summary, commercial, tribal, and recreational harvests include many fisheries for multiple species, including groundfish, Pacific halibut, coastal pelagic species, highly migratory species, salmon, other anadromous species and eggs, and shellfish. Similarly, recreational sport fishing is structured around a multispecies fishery, and hundreds of thousands of sport anglers harvest fish throughout Washington.

According to WDFW (2008), the following amounts were harvested in 2006:

- Over 100 million pounds of finfish and shellfish. Salmon represented about 10 percent of the commercial catch (over 11 million pounds).
- Close to 8 million pounds of shellfish (dungeness crab, shrimp, razor clams, and other types of clams).

- Over 650,000 oysters.
- Over 3 million pounds each of dungeness crab and razor clams, accounting for approximately 50 percent of the recreational shellfish harvest.

Salmon are of particular importance in Washington, and questions about salmon are discussed at several points in this report. Salmon are harvested from both fresh and marine waters. The Puget Sound basin and the Columbia River basin dominate the areas of harvest. Steelhead and salmon (from both fresh and marine waters) accounted for about half of the recreational sport harvest (close to 400,000 fish) in 2006.

Washington fish resources

Washington has more than 500 miles of Pacific coast shoreline and over 2,000 combined miles of Puget Sound, San Juan Islands, Strait of Juan de Fuca, and Hood Canal shoreline. This shoreline provides habitat for marine fish and shellfish. In addition, the state has 4,000 rivers and streams, stretching over 50,000 miles. Many streams and rivers have seasonal salmon and steelhead runs. State waters also include more than 7,000 lakes, with over 2,500 lakes at alpine elevations, and more than 200 reservoirs that provide additional fishing opportunities. Many freshwater areas are open for fishing year-round.[6]

A large variety of fish and shellfish are available for harvesting in Washington.[7] WDFW has identified more than 50 species of edible freshwater fish and almost as many in marine waters.[8] (See Appendix B for information on fish and shellfish species harvested in Washington.)

Governor Gregoire requested a study to summarize the economic benefits of Washington's nontreaty commercial and recreational fisheries for 2006. This study provides information on the valuation and numbers of commercial and recreational fish and shellfish harvested throughout Washington. In 2006, commercial fish landings from nontreaty fisheries totaled more than 109 million pounds. The Washington coastal area is the largest contributor to commercial fish harvesting, accounting for 85 percent of total pounds landed.[9]

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[6] Washington Department of Fish and Wildlife, *2010 Washington Fishing Prospects, Where to Catch Fish in the Evergreen State,* http://www.wdfw.wa.gov/fish/prospects/index.htm.

[7] Ibid., pages 17 to 30.

[8] Ibid., pages 17 to 30.

[9] Washington Department of Fish and Wildlife, *Economic Analysis of the Non-Treaty Commercial and Recreational Fisheries in Washington State. Final Report*, December 2008, http://wdfw.wa.gov/commission/econ_analysis.html.

Salmon in Washington

The salmon industry is significant both culturally and economically in Washington. The people of the state have invested considerable resources in restoring and protecting the rivers and streams that provide spawning grounds for salmon, along with the nearshore habitat for growing juvenile salmon and sheltering returning adults. [10]

WDFW and tribes together manage fish resources in Washington. Every year, state, federal, and tribal fishery managers meet to plan the Pacific Northwest's recreational and commercial salmon fisheries and harvests. The preseason harvest planning process is generally referred to as the "North of Falcon" process. This process coincides with the March and April meetings of the Pacific Fishery Management Council (PFMC), the federal authority responsible for the ocean salmon season 3 to 200 miles off the Pacific coast. In addition to the PFMC meetings, Washington and Oregon and the treaty tribes sponsor additional meetings to discuss alternative fishing seasons that meet conservation and allocation objectives.

These meetings require pre-season forecasts for wild and hatchery run sizes for all salmon species throughout Washington. For example, the 2010 pre-season forecast for summer and fall chinook in Puget Sound was:

- For the lower south sound, total over 111,000.
- For the north sound, total over 66,700.
- For the upper south sound, total over 53,000.

Similar data is available for chinook in other locations of Washington and for coho, chum, pink, and sockeye salmon. [11]

Salmon consumption is not considered in many risk assessments conducted under the Comprehensive Environmental Response, Compensation, and Liability Act. This exclusion is based on an assumption that salmon contamination (the "body burden") primarily comes from open ocean waters and is not attributable to site-specific contaminants.[12] Ecology acknowledges the complexity of the issue and has identified factors to consider regarding salmon and default fish consumption rates:

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[10] A large percentage of salmon migrate to the ocean where they spend their adult years, and Ecology recognizes uncertainty around how to quantify risk associated with eating salmon. See Appendix D.

[11] Washington Department of Fish and Wildlife, *North of Falcon Q & A*, http://wdfw.wa.gov/fish/northfalcon/faq.htm.

[12] EPA Region 10 and Washington State Department of Ecology, *Lower Duwamish Waterway Remedial Investigation*, *Final Report,* Appendix B: Baseline Human Health Risk Assessment, November 12, 2007.

- The life cycle and life history of salmon results in recycling the contaminant body burden to future generations of salmon.
- Salmon are harvested from fresh as well as marine/estuarine waters throughout Washington.
- Salmon are consumed by all Washington fish-consuming populations.
- Some salmon (the "resident" populations) never leave Puget Sound; they are harvested and consumed after spending their entire adult life in Puget Sound waters.
- Some salmon species migrate out of Puget Sound but remain along the Pacific continental shelf.
- For persistent, bioaccumulative, and toxic chemicals with a global distribution (i.e., PCBs [polychlorinated biphenyls] and methyl mercury), no unique chemical signature associates salmon contaminant body burden with site-specific contaminants.

(See Appendix E for more information on salmon in Washington and factors affecting the inclusion of salmon in fish consumption rates.)

Washington's commercial fishery

Washington's commercial fisheries include harvest of groundfish, Pacific halibut, coastal pelagic species, highly migratory species, salmon (including eggs), other anadromous species, and shellfish. In 2006, nontribal commercial fish landings from Washington fisheries totaled approximately 109.4 million pounds.

In 2006, groundfish (bottom-dwelling fish) composed the state's largest commercial fishery. Groundfish accounted for 54 percent of the commercial catch from Washington waters, with approximately 59.2 million pounds landed. Shellfish landings represented the state's second-largest commercial fishery, accounting for almost 25 percent of the commercial catch, with approximately 25.8 million pounds landed in 2006.

Salmon is a major contributor to Washington's commercial fishing industry. Salmon landings from Washington waters totaled about 11 million pounds, accounting for about 10 percent of the commercial catch in 2006.

Table 2 illustrates the extent of Washington's commercial fishery, showing pounds of fish harvested from Washington nontreaty fisheries in 2006. (Refer to Appendix B for additional information.)

Table 2. Commercial Fish Landings From Washington Nontreaty Fisheries in 2006

Species	Pounds Landed
Groundfish (excluding halibut)	59,217,924
Total shellfish	25,789,641
Salmon	11,020,228
Coastal pelagic species	8,233,078
Highly migratory species	4,802,666
Other anadromous fish and eggs	158,621
Pacific halibut	135,868
Total commercial pounds landed of finfish/shellfish	109,358,026

Source: *Economic Analysis of the Non-Treaty Commercial and Recreational Fisheries in Washington State*. *Final Report*. Washington Department of Fish and Wildlife. December 2008. Adapted from Table 1, page 6.

Washington's recreational fishery

Traditionally, Washington's most intense freshwater fishing starts the last weekend in April. Based on estimates from WDFW, over 300,000 anglers fish during opening weekend of trout season. To meet this demand, WDFW stocks about 19 million trout and kokanee fry annually. Another 3 million catchable trout are planted in lakes and streams. In addition, many lakes receive additional sterile triploid rainbow trout. Most rivers and streams throughout Washington are managed to produce wild trout, coastal and westslope cutthroat, salmon, and steelhead.[13,14]

An estimated total of 824,000 anglers fished (both finfishing and shellfishing) in Washington in 2006. An estimated 725,000 anglers (88 percent of the total) were state residents who fished about 8.5 million days that year. This amount equals 93 percent of all fishing days available for licensed recreational sport fishing.[15]

Marine recreational fishing and shellfishing occurs along more than 500 miles of the Pacific Coast shoreline and more than 2,000 combined miles of shoreline throughout Puget Sound, San Juan Islands, Strait of Juan de Fuca, and Hood Canal.[16] As previously noted, freshwater recreational fish inhabit more than 4,000 rivers and streams extending over 50,000 miles, 7,000 lakes, and 200 reservoirs.[17] The following are selected highlights of recreational sport fishing and shellfishing that identify the quantity of species available for recreational anglers across Washington:

[13] Washington Department of Fish and Wildlife, *Fishing Prospects,* 2010.

[14] Ibid.

[15] Washington Department of Fish and Wildlife, *Economic Analysis of Fisheries in Washington State,* 2008.

[16] Ibid.

[17] Washington Department of Fish and Wildlife, *Fishing Prospects,* 2010.

- Recreational fishing for shad on the Columbia River with several million shad passing through Bonneville Dam annually.
- Recreational sturgeon fishing on the Columbia River.
- Marine recreational seasonal fishing for lingcod, halibut, and rockfish as well as other marine bottomfish.
- Recreational shellfishing for oysters, clams, shrimp, and crab available throughout Puget Sound, Hood Canal, San Juan Islands, and the Strait of Juan de Fuca.

Recreational sport anglers harvest finfish in fresh and marine waters and shellfish along marine shorelines. Approximately 22 million trout and kokanee are stocked annually in lakes and inland streams and are available to recreational anglers. Table 3 and Table 4 list information on the 2006 sport finfish and shellfish harvests, respectively. These numbers demonstrate the extent of recreational fishing in Washington.

Approximately two-thirds of the 2006 catch for bottomfish were harvested in coastal waters, with the remaining one-third harvested from the marine waters of Puget Sound. Approximately 74 percent of the steelhead and 95 percent of the sturgeon harvested from Washington waters in 2006 were from the Columbia River and its tributaries.

Salmon were harvested in both fresh and marine waters, with approximately 60 percent of the salmon harvest occurring in marine waters. Puget Sound salmon accounted for approximately 60 percent of all salmon harvested in marine waters. In freshwaters, approximately 57 percent of salmon are harvested in Puget Sound streams, and 38 percent are from the Columbia River and its tributaries.

Dungeness crab taken from north Puget Sound waters accounted for more than 85 percent of the 2006 statewide harvest. Razor clams are only harvested from coastal beaches. Tens of thousands of recreational sport clammers harvest razor clams on weekends during clamming season.[18]

[18] Washington Department of Fish and Wildlife, *Economic Analysis of Fisheries in Washington State,* 2008.

Table 3. Number of Recreational Finfish Caught in Washington Waters in 2006 by Species and Region[19]

Species/Group	Catch Region				
	Puget Sound	Coast	Columbia River[20]	Unknown	Total
Bottomfish	112,457	295,151	---	---	407,608
Salmon – freshwaters	98,576	7,186	65,817	1,227	172,806
Steelhead	12,709	15,415	80,294	477	108,895
Salmon – marine	65,423	43,027	---	---	108,450
Albacore	---	18,941	---	---	18,941
Sturgeon	203	456	15,695	182	16,536
Pacific halibut	2,727	6,977	692	---	10,400
Total	292,095	387,153	162,498	1,886	843,636

Table 4. Pounds of Shellfish Taken From Washington Waters in 2006 by Species and Region[21]

Species/Group	Catch Region					
	North Puget Sound	South Puget Sound	Strait	Coast	Columbia River	Totals
Dungeness crab	3,330,004	271,167	261,540	---	---	3,862,711
Razor clams	---	---	---	3,601,000		3,601,000
Oysters	19,129	632,966	---	---	---	652095
Other clams	93,038	252,628	---	---	---	345666
Shrimp	23,520	87,996	1,950	---	---	113,466

Washington population demographics

Washington is home to a cultural and ethnically diverse population that is projected to become more diversified over the next 20 years. The Washington Office of Financial Management (OFM) provides the following demographic information.[22]

[19] Washington Department of Fish and Wildlife, *Economic Analysis of Fisheries in Washington State,* 2008, adapted from Table 6, page 17.

[20] Columbia River region includes the Columbia Rivers and all tributaries and the Snake River

[21] Washington Department of Fish and Wildlife, *Economic Analysis of Fisheries in Washington State,* 2008, adapted from Table 7, page 17. All values are in pounds except oysters, which are in number of oysters harvested.

[22] U.S. Census Bureau, Census 2000 Redistricting Data (Public Law 94-171), summary file, Table PL1, and 2010 Census Redistricting Data (Public Law 94-171), summary file, Table P1, http://www.ofm.wa.gov/pop/census2010/data.asp.

Total Washington Population as of April 1, 2010	6,724,540
Adults (74 percent of the population is estimated at over 18)	5,143,186
Children (between 0 and 18 years of age)	1,708,318

OFM projects that the Washington population will increase by 1.8 million people in the next 20 years.

Projected Total Washington Population, 2030	8,544,700
Projected children (between 0 and 18 years of age) 2030	2,063,883

Estimated fish consumers in Washington

People consume fish and shellfish obtained from a variety of sources. Information about fish from Washington waters consumed by the general Washington population is available only through estimates. To estimate the number fish consumers in Washington, and how much fish they consume, Ecology considered multiple approaches.

First, the total number of fish consumers was estimated. Then a definition of *high fish consumer* was used to suggest the number of people in the general population at the high end of the exposure distribution. These estimates provide a rough number of fish consumers but only limited information about the source of the fish. Ecology also reviewed available information on certain ethnic groups that consume fish from local waters. This data, together with the information about the commercial and recreational fisheries, demonstrates the importance of fish and fish consumption in Washington.

Ecology estimated the total number of fish consumers in Washington using two distinct methods. The two approaches (described below) provide a lower and upper estimate.

Using 2010 demographic information provided by the Washington OFM, Ecology estimates that between 1.4 and 3.8 million Washington adults (and approximately 290,000 Washington children 0 to 18 years old) are fish consumers. The range of adult consumers was established as follows:

- *Estimate I: Based on national survey data.* The first approach resulted in the lower of the two estimates. It was developed using Washington population data and information on the percentage of fish consumers reported in *Estimated Per Capita Fish Consumption in the United States* (EPA, 2002). For this estimate of fish consumers in Washington, Ecology assumed Washington dietary habits are similar to those for the United States as a whole. The Oregon DEQ's Human Health Focus Group used this approach to prepare estimates of fish

consumers in Oregon. (See Chapter 4 for additional information on estimated United States per capita fish consumption.)

- *Adults.* EPA found that 28 percent of the adults interviewed in the national survey were fish consumers.[23] Assuming that a similar percentage of Washington's 5,143,186 adults also consume fish, Ecology estimates that approximately 1,440,092 adults in Washington currently eat some amount of fish.
- *Children.* EPA found that 16 to 19 percent of children (ages 0 to 18) included in the national survey were fish consumers.[24] Assuming that 17 percent of Washington's 1,708,318 children also consume fish, Ecology estimates that there are approximately 290,000 children in Washington who currently eat some amount of fish.

- *Estimate II: Based on DOH Survey.* The second approach resulted in the higher estimate. It was developed using Washington population data and information compiled by DOH. DOH used the Behavioral Risk Factor Surveillance System (BRFSS) to compile information on fish consumption habits of randomly selected Washington residents. [25] This work was done over a 4-year period; it was designed to improve DOH's understanding of what percent of the Washington population consumes fish.
  - DOH found that in 2002 and 2004, 78 percent and 74 percent, respectively, of adults in Washington consumed store-bought fish. In 2005, 57 percent of the adults surveyed reported eating fresh fish purchased at a local grocery store or fish market (frozen fish excluded). Among Washington fish consumers, 44 percent consumed salmon, 20 percent consumed halibut, 13 percent consumed cod, and 6 percent consumed tuna.
  - Although this data was intended for use by DOH in developing fish consumption advisory programs, Ecology, after consultation with DOH, determined that the information is appropriate for estimating the total number of fish consumers in Washington as needed for this report.
  - Working with DOH, Ecology estimated that between 2.9 and 3.8 million Washington adults currently consume some amount of fish and/or shellfish. Table 5 provides estimates of Washington fish consumers calculated by Ecology using the DOH data.

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[23] U.S. Environmental Protection Agency (EPA), *Estimated Per Capita Fish Consumption in the United States*, EPA-821-C-02-003, August 2002, http://www.epa.gov/waterscience/fish/consumption_report.pdf, Table 4, Section 5.1.1.1.

[24] Moya, Jacqueline (EPA), personal communication with Craig McCormack (Ecology), April 11, 2011. Approximately 18 percent of the U.S. general population ages 16 – 21 are fish consumers; approximately 31 percent of the U.S. general population ages 20 – 50 are fish consumers. Information based on EPA's reexamination of the National Health and Nutrition Examination Survey (NHANES) and the 2002 per capita fish consumption report.

[25] The BRFSS is sponsored by the U.S. Centers for Disease Control and Prevention (CDC) and is a probability-based telephone survey of noninstitutionalized adults, ages 18 years and over.

Table 5. Estimated Washington Fish Consumers Based on Washington DOH Survey Data

Years for Projected Population Estimates	Estimated number of Washington adults who consume:		
	Store-bought fish	Fish from local stores or markets	Salmon
2010	3,805,958 [26]	2,931,616 [27]	1,674,622
2030	4,876,809	3,756,461	2,899,725

Population projections are included to illustrate that estimates of total fish consumers in Washington are expected to increase as the population grows.

Estimated number of high fish consumers

For purposes of this report, *high fish consumers* are persons who consume fish at or above the 90th national per capita percentile fish consumption rate, as reported in *Estimated Per Capita Fish Consumption in the United States* (EPA, 2002).

For adults, 250 g/day corresponds to the 90th percentile of the estimated national per capita fish consumption rate for adults. (250 grams is approximately 0.55 pounds.) This value is used to define high fish-consuming adults. For children, 190 g/day corresponds to the 90th percentile of the estimated national per capita fish consumption rate for children. This value is used to define high fish-consuming children.

Ecology estimates that between 146,000 and 384,000 Washington adults are high fish consumers. Based on OFM population projections, this number could increase by 27 percent over the next 20 years.

This estimate is based on a number of assumptions:

- It is reasonable to assume that between 1,440,000 and 3,806,000 Washington adults consume some amount of fish on a regular basis. As described in the previous sections, this range is based on current population data and estimates indicating that between 28 and 74 percent of Washington adults regularly consume fish.
- It is reasonable to define *high fish consumers* as people (adults) who consume more than 250 grams of fish and/or shellfish per day. This value represents the 90th percentile fish consumption rate reported in the national consumption survey conducted by EPA in 2002. In other words, EPA found that 90 percent of the people who reported that they consumed fish or shellfish ate less than 250 g/day, while 10 percent ate more than 250 g/day.

[26] This estimate assumes 74 percent of the total adult population consuming store-bought fish, per the DOH 2004 data.

[27] This estimate assumes 57 percent of the total adult population consuming fresh fish from local stores or markets, per the DOH 2005 data.

- It is reasonable to assume that the dietary habits and patterns for Washington fish consumers are similar to those reported for the United States fish consumers.[28]

Table 6. Estimates of Fish Consumption Among the Washington Adult Population

Year	Total Population (Adults)	Estimates of All Washington Adult Fish Consumers		Estimates of Washington Adult High Fish Consumers (over 250 g/day)	
		Low (28%)	High (74%)	Low	High
2010	5,143,185	1,440,092	3,805,958	144,009	380,596
2030	6,590,283	1,845,279	4,876,809	184,528	487,680

For purposes of this report, Ecology estimates the range of high fish-consuming adults in Washington as between 144,000 and 381,000.

Estimated number of high fish-consuming children

For purposes of this report, Ecology defines as *high fish consumers* children who consume fish at or above the 90th percentile of the estimated national per capita fish consumption rate for children as reported in the U.S. EPA 2002 publication *Estimated Per Capita Fish Consumption in the United States*. This value, 190 g/day, is used to define high fish-consuming children.

Ecology estimates that there are approximately 29,000 Washington children who are high fish consumers. Based on OFM population projections, this number could increase by 83 percent over the next 20 years. This estimate is based on the following assumptions:

- It is reasonable to assume that approximately 290,000 Washington children eat some amount of fish on a regular basis. As discussed in an earlier section, this estimate is based on current population estimates and national survey results that indicate that 16 to 19 percent of children reported eating some amount of fish or shellfish.
- It is reasonable to define *high fish consumers* as children who consume more than 190 grams of fish and/or shellfish per day. This value represents the 90th percentile fish consumption rate for children reported in the national consumption survey conducted by EPA in 2002.[29] In other words, EPA found that 10 percent of the children who reported that they ate fish or shellfish consumed more than 190 g/day.
- It is reasonable to assume that the dietary habits and patterns for Washington fish consumers are similar to those reported for the United States fish consumers.

[28] This assumption is discussed further in the conclusions to this chapter.

[29] EPA, *Estimated Per Capita Fish Consumption,* 2002, Section 5.2.1.1, Table 4.

Table 7. Estimated Number of Washington Children High Fish Consumers (Children Younger Than 18 Years Consuming Large Amounts of Fish or Shellfish)

Year	Total Population of Children (18 and younger)	Estimated Number of Children Who Consume Some Amount of Fish and Shellfish	High Fish Consumers: Estimated Number of Children who Consume over 190 g/day
2010	1,708,318	290,000	29,000
2030	2,063,883	351,000	35,100

Discussion

A number of observations are pertinent to estimates of both adult and children's fish consumption (Moya, 2004).

The estimated number of high fish consumers in Washington would be higher if lower rates were used to define high fish consumers. The median adult fish consumption rate for the U.S. population of fish consumers is approximately 100 g/day. This is higher than the current default fish consumption rates (6.5 and 54 g/day) used in Washington by Ecology in a regulatory context. Ecology estimates that there are between 730,000 and 1,920,000 Washington adults who consume more than 100 g/day.

High fish-consuming populations

Some population groups consume especially large amounts of fish and shellfish as part of traditionally influenced diets. These include Asian and Pacific Islanders and Native Americans.

Asian and Pacific Islanders

Asian and Pacific Islander (API) populations include Native Hawaiians and peoples from other Pacific islands. The Washington OFM estimates there are approximately 521,542 Asian and Pacific Islanders currently residing in Washington. [30] Fish and shellfish consumption among this population in Washington has been documented.[31] Approximately 75 percent of the current API population is 18 years of age or older (405,158 adults). [32] There are 137,917 Asian and Pacific Islanders between the ages of 0 to 18 years.[33]

[30] U.S. Census Bureau, Census 2000 Redistricting Data 2010 Census Redistricting Data, Table 2.

[31] Sechena, R., et al., *Asian and Pacific Islander Seafood Consumption Study in King County, WA*, EPA Region 10, Seattle, Washington, 1999.

[32] Ibid.

[33] 2010 population numbers are based on the 2010 Census redistricting data. 2030 estimates are as of the OFM 2006 Population Projections by Age, Sex, and Race. Update is expected to be completed in summer 2012.

OFM projects that the total number of Asian and Pacific Islanders in Washington will increase from 521,542 in 2010 to approximately 825,000 by the year 2030.[34]

Population of Asian and Pacific Islanders in Washington	521,542
Adults (75% of the population is estimated at over 18) [35]	405,158
Children (between 0 and 18 years of age) [36]	137,917
2030 API Population Projection[37]	825,000

Washington Native American Tribes

Washington is home to 29 federally recognized and seven nonfederally recognized Native American tribes.[38] Traditional fishing areas for tribes cover essentially all of Washington. (See Appendix F.)

The Washington OFM estimates there are approximately 103,869 American Indian and Alaska natives in Washington.[39] Approximately 70 percent of the American Indian and Alaska native population is 18 years of age or older (73,523 adults). [40] OFM estimates there are 33,599 American Indian and Alaska natives between the ages of 0 to 18 years. [41]

OFM projects that the total number of Native Americans in Washington will increase from 103,869 in 2010 to approximately 146,000 by the year 2030.

Population of American Indian and Alaska natives in Washington	103,869
Adults (70 percent of population is estimated at over 18) [42]	73,523
Children (between 0 and 18 years of age) [43]	33,599
2030 Population Projection[44]	146,000

[34] Ibid.

[35] Ibid.

[36] Ibid.

[37] Ibid.

[38] Governor's Office of Indian Affairs, "Federally Recognized Tribes of Washington State," http://www.goia.wa.gov/tribal_gov/documents/WAStateTribalMap.pdf.

[39] U.S. Census Bureau, Census 2000 Redistricting Data 2010 Census Redistricting Data, Table 2.

[40] Ibid.

[41] 2010 population numbers are based on the 2010 Census redistricting data. 2030 estimates are as of the OFM 2006 Population Projections by Age, Sex, and Race. Update is expected to be completed in summer 2012.

[42] 2010 population numbers are based on the 2010 Census redistricting data. 2030 estimates are as of the OFM 2006 Population Projections by Age, Sex, and Race. Update is expected to be completed in summer 2012.

[43] Ibid.

[44] Ibid.

Subsistence fishers

Ecology recognizes that Washington is home to some number of persons engaged in a subsistence lifestyle. Considerations related to subsistence fishing for Native Americans tribes in the Pacific Northwest have been identified.[45,46] However, due to a lack of data, at this time Ecology is unable to estimate the number of subsistence fishers in Washington.

Summary and conclusions

Current demographic information allows estimating the total number of Washington fish consumers.

Ecology estimates that between 1.4 and 3.8 million Washington adults and approximately 290,000 children regularly consume fish.

Ecology reached this conclusion after working with OFM to use census data and applying national and Washington fish consumption rate estimates to the general Washington population. According to this Ecology analysis, there are between 1.4 and 3.8 million Washington adults (18 years of age or older) who are fish consumers.[47] The number of adult fish consumers is projected to increase by up to 27 percent as Washington's population grows over the next 20 years.

Ecology estimates that approximately 290,000 Washington children (0 to 18 years of age) consume fish. It should be noted that this estimate was developed using national survey data for the general population. Studies have shown that people living in coastal states tend to consume fish and shellfish at a higher frequency and higher rates than inland states.[48] [49] Ecology is not aware of Washington surveys that have examined child fish consumption frequency for the general population. The number of Washington children who eat some type of fish is also projected to increase as Washington's population grows over the next 20 years.

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[45] Donatuto, Jamie, and Barbara L. Harper, "Issues in Evaluating Fish Consumption Rates for Native American Tribes," *Risk Analysis*, Vol. 28, No. 6, 2008, pages 1497-1506.

[46] Harper, B., and S. Harris, "A possible approach for setting a mercury risk-based action level based on tribal fish ingestion rates," *Environmental Research,* 107 (2008) 60-68.

[47] This includes a large number of recreational anglers. For example, the Washington Department of Fish and Wildlife estimates there were 824,000 recreational anglers (both fin-fishing and shell-fishing) in Washington in 2006.

[48] Moya, *Human and Ecological Risk Assessment,* 2004.

[49] National fish consumption studies are typically carried out over a broad geographical area, including multiple states. Consequently, national studies may underestimate the rates and frequencies for states like Washington.

Estimates of high fish consumers

For this report, Ecology defined *high fish consumers* as all Washington adults who consume more than 250 grams of fish and/or shellfish per day and all Washington children who consume more than 190 g/day. These values represent the 90th percentile fish consumption rates for adults and children reported in the national consumption survey conducted by EPA in 2002.

- Ecology estimates that there are between 146,000 and 384,000 Washington adults who are high fish consumers. Ecology believes that the high end of this range provides a reasonable estimate of high fish consumers in Washington. The high end of the range is based on information collected by the Department of Health on fish consumption habits of Washington residents.
- Ecology estimates that there are approximately 29,000 Washington children who are high fish consumers.

Certain population groups, including Asian and Pacific Islanders and Native Americans, consume large amounts of fish and shellfish.[50]

- According to OFM estimates there are approximately 103,869 Native American and Alaska natives in Washington.
- According to OFM estimates, approximately 521,542 Asian and Pacific Islanders live in Washington.

Ecology concludes that Washington harvests considerable quantities of fish and shellfish for consumption, both recreationally and commercially, and that Washington residents consume fish and shellfish with a significant amount likely coming from local sources. High fish consumers include several population groups known to consume larger amounts of fish and shellfish than the general population.

[50] 0 discusses further the consumption rates, patterns, and species consumed by Native Americans and Asian and Pacific Islanders.

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Chapter 3: Methodology for Assessing Fish Consumption Rate Information

Introduction

Researchers use a variety of methods for estimating the amount of fish and shellfish consumed. Surveys are generally considered to be the best approach for collecting data; however a number of design features determine whether a particular survey will provide a technically defensible basis for agency decision-making.

Different surveys are designed for different purposes. This chapter reviews the design features of various methods for collecting information about fish and shellfish consumption. The purpose of this review is to identify the specific factors that Ecology considered when evaluating fish consumption rate surveys.

This chapter is organized into three components:

Surveys and other approaches used to estimate fish consumption. This section reviews the various mechanisms that have been used or are available for collecting data about dietary habits and patterns surrounding fish consumption.

Factors to consider when evaluating survey results. This section identifies key design or implementation features that impact the quality of individual surveys.

Establishing technical defensibility. This section sets out the methodology Ecology used in assessing the technical defensibility of fish consumption survey information and results. The methodology explained here is then applied in the next chapter to surveys pertinent to Washington.

With the analysis in this report, Ecology is proposing to establish a range for statewide default fish consumption rates for use in certain regulatory decisions. To that end, Ecology has evaluated available data on fish consumption in Washington. To establish which studies are appropriate for the purposes of deriving a default fish consumption rate, Ecology identified factors to consider in establishing the technical defensibility a particular survey.

Surveys and other approaches used to estimate fish consumption

The various approaches to collecting information on fish/shellfish dietary habits and patterns include telephone surveys, mail surveys, food diaries, personal interviews, and creel surveys.[51] Each method has certain limitations, including bias, error, and variability.[52,53] Ecology conducted a thorough examination of the methodology used in fish consumption surveys. In order to determine quality and ensure utility for each survey examined, Ecology evaluated experimental design, target population, sample size, location, and potential bias.[54] We believe that this analysis aids general understanding and identifies the limitations and utility of the data available.

Fish dietary survey methodologies and limitations described in this report are consistent with EPA guidance for fish consumption. [55,56] Dietary "market basket" surveys are used by EPA's Office of Pesticide Programs to evaluate aggregate exposure to pesticide residues in food to which consumers may be exposed. This is a different approach that involves analysis of exposure to a single chemical by multiple pathways and routes of exposure. Market basket surveys conducted by EPA's Office of Pesticide Programs are statistically designed and executed on a single-serving basis at the point of sale to the consumer.[57]

Brief descriptions of fish consumption survey methodologies, including the strengths and weaknesses of each approach, are provided below.

Creel surveys

Creel surveys estimate fish consumption through on-site interviews of anglers. A fish consumption rate is determined by using the number of fish caught at a given location divided by the number of people who will consume the catch.[58]

A number of creel surveys have been conducted in Washington. Examples are:

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[51] EPA, *Consumption Surveys for Fish and Shellfish, A Review and Analysis of Survey Methods,* EPA 822/R-92-001, February 1992.

[52] Ibid.

[53] Moya, Jacqueline, et al., "Estimates of Fish Consumption Rates for Consumers of Bought and Self-Caught Fish in Connecticut, Florida, Minnesota, and North Dakota," *Science of the Total Environment*, 403 (2008) 89-98.

[54] Washington State Department of Ecology, Leslie Kiell and Lon Kissinger, *DRAFT: Analysis and Selection of Fish Consumption Rates for Washington State Risk Assessments and Risk-Based Standards,* March 1999.

[55] EPA, *Guidance for Conducting Fish and Wildlife Consumption Surveys*, EPA-823-B-98-007, November 1998.

[56] EPA, *Consumption Surveys for Fish and Shellfish*, 1992.

[57] EPA, *Choosing a Percentile of Acute Dietary Exposure as a Threshold of Regulatory Concern*, Office of Pesticide Programs. March 16, 2000, http://www.epa.gov/oppfead1/trac/science/trac2b054.pdf.

[58] Moya, *Human and Ecological Risk Assessment,* 2004.

- Landolt, M.L., A. Nevissi, G. van Belle, K. Van Ness, and C. Rockwell, *Potential Toxicant Exposure among Consumers of Recreationally Caught Fish from Urban Embayment's of Puget Sound*. National Oceanic and Atmospheric Administration Technical Memorandum. Rockville, Maryland. 1985 (Final Report).
- Pierce, D., D.T. Noviellow, and S.H. Rogers. *Commencement Bay Seafood Consumption Study. Preliminary Report*. Tacoma-Pierce County Health Department. Tacoma, Washington. 1981.
- McCallum, M. *Recreational and Subsistence Catch and Consumption of Seafood from Three Urban Industrial Bays of Puget Sound: Port Gardener, Elliott Bay, and Sinclair Inlet*. Washington Department of Health, Epidemiology Section. January 1985.

As with any type of survey, creel surveys have both strengths and weaknesses.[59] One advantage of creel surveys is that the interviews are usually conducted at fishing locations, which provides water-body specific information about species caught.

Personal interviews

Personal interviews can be used to estimate fish consumption rates by asking participants questions about their dietary patterns, particularly about how much fish they consume over a given amount of time. A useful type of personal interview survey considers 24-hour dietary recall. In this type of interview, participants are asked by a trained interviewer to report what they ate during the previous 24 hours. Although the 24-hour dietary recall format avoids recall bias, the short time period of recall is unable to show consumption variation over the course of a year. [60]

[59] EPA, *Consumption Surveys for Fish and Shellfish*, 1992.

[60] Ibid.

Table 8. Strengths and Weaknesses of Creel Surveys

Strengths	Weaknesses
* Can assess site-specific consumption rates. * Can target specific at - risk populations who fish at contaminated sites. * The interviewer can observe the participant's fishing behaviors and catch as well as the condition of the interview site. * Recall bias is minimized using visual aids and by having the interviewer refer to the fish caught around the time of the interview as a reference. * Results can be verified by looking at the daily catch of the participant. * Response rate is high. * More information can be gained by using visual aids and probing. * Creel surveys are routinely done for fishery management purposes, adding fish consumption questions to the surveys can be done with little added cost.	* Only a limited number of questions so that survey time is minimized. * Language barriers may exist between participants and interviewers. * Surveys require well trained staff that must be monitored for quality control. * If interviews are occurring at fishing sites, answers about consumption are hypothetical because the fish have not yet been consumed. * Participants who fish more frequently are more likely to be interviewed than those who fish less frequently. [61] * Cannot be generalized to the entire population. * May miss anglers if not all fishing locations and times are surveyed. * May under- or overestimate yearly consumption if survey is not conducted throughout the year. * Pilot testing for a target population not as effective as is the case with personal interview surveys. * Anglers may not be as receptive to engaging in interviews as preselected personal interview survey interviewees. * Fears of contact with government officials may inhibit responses of minority groups. * Anglers in the field may not be as inclined or ready to respond as individuals that have been contacted and readied to participate in a personal interview survey. * Visual aids for unique seafood preparations are difficult to develop without knowledge of the target population. * If the water body is known to have chemical contamination, rates may be impacted by a "suppression effect," and hence may not result in protective risk estimates or cleanup levels.

[61] Moya, Jacqueline, et al., *Science of the Total Environment*, 2008.

Examples of personal interview surveys include the Native American fish consumption surveys conducted for tribes residing along the Columbia River basin and throughout the Puget Sound. (See Chapter 4.)

Table 9. Strengths and Weaknesses of Personal Interviews

Strengths	Weaknesses
* Can assess site-specific consumption rates. * Can identify and get information from vulnerable subpopulations (those populations at a disproportionate risk) by collecting data from participants who are close to contaminated sites and by asking community agencies who should be interviewed. * Responses can be validated and supported with information gathered by the interviewer. * Literacy and language barriers are minimized by face-to-face interaction. * Visual aids can be used to estimate meal size or fish species, reducing recall bias. * High response rate. * Interviewer can clarify questions for respondents. * Possible to select a random sample that is representative of the population. * Pilot testing of interview with target population is possible. * Possible to incorporate unique seafood preparations into the dietary survey. * Possible to tailor survey to specific groups. * Avoids issues associated with missing fishing locations or times that are encountered in creel surveys.	* Time restrictions may limit the number and types of questions. * Requires coordinated and supervised interviewers. * If interviews are occurring at fishing sites, answers about consumption are hypothetical because the fish have not yet been consumed. * Responses may be biased by fishing practices at the time the interview is being administered.

Diary surveys

Diary surveys use questionnaires, in the form of logbooks, diaries, or catch cards, to record fish consumption over time. Information is filled out by the participant ideally at the end of a fishing day or at the time of consumption, to minimize possible recall bias.

The Connecticut Department of Environmental Protection used diary surveys to find out about fish meals and portion sizes eaten by Connecticut families. The families received the surveys in the mail.[62,63]

Table 10. Strengths and Weaknesses of the Diary Method

Strengths	Weaknesses
* Can assess site-specific consumption rates. * Information collected over long periods of time, * Less expensive than personal interviews. * Large numbers of participants possible. * Recall bias is reduced. * Visual aids can be used to improve accuracy of answers.	* Respondents must be taught how to complete the survey by a trained interviewer. * Participants must be literate. * Participants must be monitored during the study to maintain consistency. * Keeping a dietary record may change a participant's dietary practices. * Participants may not maintain daily record keeping. * Language barriers may affect how participants are recruited and how their diary responses are interpreted. * Questionnaire design is more complicated than other types of surveys.

Telephone surveys

Telephone interview surveys estimate recent fish consumption or information about recent fishing trips. Answers are recorded on preprinted questionnaires.[64]

Table 11. Strengths and Weaknesses of Telephone Surveys

Strengths	Weaknesses
* Can assess region-specific consumption rates. * Can target and identify specific subpopulations of concern. * Less expensive and time-consuming than personal interviews. * High rate of success for completion of interviews. * Sensitive information may be obtained more easily. * Provides immediate response to questions.	* Interviewers cannot reach people who do not have phones. * Interviews are limited in scope and length. * Difficult to verify information. * Can't use visual aids. * Inability to reach people by phone may be of concern for low-income individuals who harvest more fish than more affluent people.

[62] Moya, Jacqueline, et al., *Science of the Total Environment*, 2008.

[63] EPA, *Consumption Surveys for Fish and Shellfish*, 1992.

[64] EPA, *Consumption Surveys for Fish and Shellfish*, 1992.

Recall mail surveys

Recall mail surveys are self-administered questionnaires used to estimate fish consumption. Most commonly they are used to obtain information from recreational anglers.[65]

Table 12. Strengths and Weaknesses of Recall Mail Surveys

Strengths	Weaknesses
* Can assess region-specific consumption rates. * Can target and identify specific subpopulations of concern. * Least expensive since no interviewers are required. * Large numbers of respondents may be contacted over a large area. * Most likely to provide honest answers. * Complex technical data may be obtained if respondent takes the time to consider the questions and/or consult other sources. * Survey can cover broad areas of inquiry.	* Cannot reach people without mailing addresses. * Questions must be carefully designed to compensate for lack of personal interaction. * Questions should be limited in scope and complexity. * Requires substantial followup efforts or incentives to achieve reasonable response rate. * Higher number of inaccurate and incomplete responses. * May miss respondents who are illiterate, or have difficulty in understanding questions, or who cannot read the language.

Survey selection criteria

Both dietary recall interviews and creel surveys have been used in Washington in various contexts to estimate fish consumption rates. (See Chapter 4, Table 16.)

Certain criteria are useful for comparing survey methodologies and key factors influence the selection of a particular survey type.[66] These selection criteria assist in discriminating between different survey approaches. In addition, how different survey methodologies compare based on these criteria highlights the various strengths and weaknesses.

[65] EPA, *Consumption Surveys for Fish and Shellfish*, 1992.

[66] EPA, *Guidance for Conducting Fish and Wildlife Consumption Surveys*, 1998.

Table 13. Comparison of Five Consumption Survey Methodologies Using EPA's Selection Criteria[67]

Survey type Selection Criteria	Telephone	Mail	Diary	Interview	Creel
Time Frame					
Immediate data from respondent	Yes	No	No	Yes	Yes
Resources					
Interviewer burden	Moderate	Low	Low	High	High
Respondent burden	Low	Moderate	High	Low	Low
Relative cost	Moderate	Low/moderate	Low	High	High
Target Populations/Subpopulations					
Survey sample known prior to conducting survey	Yes/no[a]	Yes	Yes	Yes/no[b]	Yes/no[c]
Can be used with low literacy-rate populations	Yes	No	No	Yes	Yes
Accuracy					
Reliability: Potential for response reliability	Moderate/high	Low/moderate	Low/moderate	Moderate/high	Moderate/high
Validity: Validity of consumption estimates	Low	Low/high[e]	Moderate	Moderate[f]	Low/Moderate[f]
Validity: Validity of species identification	Low	Moderate	Moderate	Moderate/high[g]	High
Bias: Potential to minimize recall bias	Moderate	Low/high[e]	Moderate	Moderate/high[g]	Not applicable
Bias: Potential to minimize prestige bias	Moderate	Low	Low	Moderate	Moderate
Measurement error: opportunity for respondent to ask for clarification	Moderate/high	Low	Low	High	High
Measurement error: potential for respondent participation	Moderate	Moderate	Low	High	High
Harvest Characteristics					
Many access points	Yes	Yes	Yes	Yes/no[b]	Yes/no[h]
High fishing or hunting pressure	Yes/no[i]	Yes	No	Yes	Yes/no[j]
Large geographic area	Yes	Yes	Yes	Yes[k]	No
Account for seasons and times	Yes	Yes	Yes	Yes	No

a. Yes if phone numbers are obtained after sample population has been preselected; no if random digit dialing.
b. No for interviews conducted at fish/hunting access points; yes for off-site interviews.
c. Depends on ability to estimate total site usage using random sampling of all access points.
d. Given sufficient resources, all five survey approaches can generate accurate data.
e. Dependent on the recall method employed.
f. On– site interviews result in valid catch estimates, but consumption estimates are hypothetical because they measure only the intent to consume. Off-site interviews result in catch and consumption estimates with potentially low validity depending on the period of recall.
g. Moderate for off-site interviews; high for on-site interviews. Administering the survey at regular intervals can reduce bias associated with the availability of different seafood resources throughout the year.
h. Yes for roving creel survey; no for access point survey.
i. Yes for random telephone numbers; no for known telephone numbers.
j. Yes for access point survey; no for roving creel survey.
k. Yes when interviewees are preselected so they can tell interviewer where they have fished.

[67] EPA, *Guidance for Conducting Fish and Wildlife Consumption Surveys*, 1998,Table 3, page 3-3.

Consistent with this approach, Ecology established key considerations for selection criteria: time frame, resources, target populations, subpopulations, accuracy, and harvest characteristics. Although many of these considerations are discussed separately, the table provides a useful tool for comparing different survey methodologies.

Evaluating survey vehicles

Large differences in survey objectives combined with the high variability in fish consumption patterns make it difficult to make generalizations about surveys. To compare and evaluate both the survey vehicle and the data obtained, a number of factors should be considered. Also, to establish the appropriateness for using a particular survey, each factor needs to evaluated and documented. [68]

General survey design

Survey design is fundamental, and identifying the target population is important when both choosing a survey method and effectively executing the survey. The design establishes the type of information collected and the level of detail provided.[69] Survey accuracy improves when the following seven factors are considered during the design phase. Ecology considered these as essential in a well-designed survey:

- Timing of interviews
- Training interviewers
- Consideration of all fish species
- Identification of the source
- Random selection of participants, sample size, and statistical analysis
- Appropriate quality assurance and quality control
- Accuracy
- Representativeness of the population
- How high end consumers were identified

[68] Moya (2004) and EPA (1992, 1998) identify important elements of survey design.

[69] Moya, *Human and Ecological Risk Assessment,* 2004.

Table 14. Survey Design Evaluation Criteria

* Timing of interviews: For a survey to adequately capture fish consumption, an appropriate time frame must have been chosen that minimizes the effect of recall bias yet captures the dietary variations.[70] (Additional discussion on survey recall error and bias are provided in the Glossary[Appendix G].)
* Training of interviewers: Interviewers should be trained for the study protocol to avoid potential interviewer bias. Interviewers must stick to the questionnaire wording and format and be culturally sensitive when interacting with the study participants. If possible, interviews should be conducted by members of the target population to avoid cultural differences, language barriers, and participation refusals.[71]
* Consideration of all fish species: The types of fish consumed can be highly variable depending on seasonal and geographic availability, market prices, and cultural preferences. Surveys should identify and record each type of fish consumed and any unique preparation methods.[72]
* Identification of the source: If known, identify either the water body where the fish was caught or the purchase location (for example, grocery store or fish market). In an effort to improve exposure assessment, include both locally caught fish and store bought fish in fish consumption rate estimates. This distinction allows the risk assessor to better account for regional and seasonal variations in fish consumption estimates.[73]
* Random selection of participants, sample size, and statistical analysis: During the planning phase, statistical analysis helps identify the ideal sample size and how to randomly select participants. This analysis helps minimize bias and sampling error and ensures statistical rigor. After the data has been collected, sound descriptive statistical analysis should ensure that the data is presented accurately. The range of data should be presented with confidence intervals and appropriate distribution values. Weighting schemes should be clearly described in order to apply survey results to populations of interest. Statistical treatment of perceived outliers should be discussed.
* Appropriate quality assurance and quality control: The study design should include appropriate quality assurance and quality controls into the planning and execution of the survey. For example, types of quality control measures would include checking of questionnaires for completeness and proper entry of recorded responses, verifying correct data entry, and checking the manual coding operations and comparisons of results and error rates. This reduces bias and random error, improving accuracy.[74]
* Accuracy: The study design can affect the overall accuracy of the study. Accuracy can be split into five components. Reliability (the variability or repeatability of the response), validity (the ability of the respondent to provide the correct answer), measurement errors (which are associated with the interviewer, the respondent, the questionnaire, and the mode of data collection), bias (the consistent overestimation or underestimation due to survey design and sample selection), and random errors.[75]

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[70]Washington State Department of Ecology. DRAFT: Analysis and Selection of Fish Consumption Rates for Washington State Risk Assessments and Risk-Based Standards. By Leslie Kiell and Lon Kissinger. March 1999.

[71]Ibid.

[72]Ibid.

[73] Ebert, Ellen S., et al., "Selection of Fish Consumption Estimates For Use In the Regulatory Process," *Journal of Exposure Analysis and Environmental Epidemiology,* 4:373-393, 1994.

[74] EPA, *Guidance for Conducting Fish and Wildlife Consumption Surveys*, 1998.

[75] Ibid.

Survey questionnaire

The following information should be collected from study respondents. This list provides the necessary understanding of the respondent and what they eat.[76])

- Frequency and quantity (how much fish is consumed per day, week, or month)
- Parts of the fish consumed
- Species consumed
- Source of the fish
- Seafood preparation and cooking methods
- Respondent's body weight
- Exposure duration
- Approximate age (child or adult)

Clear and correct answers require clarity in the survey vehicle. Questions should be unambiguous and well understood.

Population surveyed

The sample population must be representative of the target population. This is particularly important because fish consumption rates may be affected by the sociodemographic characteristics of a population.[77] Furthermore, the type of survey used may influence or determine a number of things, including what population will respond to the survey, the response rates, and the level of detail obtained. [78]

Description of water body

The survey must identify and understand the characteristics of all relevant water bodies, including location, size, species habiting the water, and fish advisory status. These characteristics influence the quantity of fish available. In addition, this information is critical to produce results that can be used to compare with or extrapolate to other populations.[79]

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[76] Strauss, Harlee, "Sportsfish Consumption Surveys: A Risk Assessment Practitioner's Wish List," *Human and Ecological Risk Assessment: An International Journal,* 10: 6, 1213-1225, 2004. See this article for details regarding complexities and variability.

[77] Moya, *Human and Ecological Risk Assessment,* 2004.

[78] Ibid.

[79] Ibid.

Survey results

Ecology considered it important to evaluate how the survey results are presented and what they are meant to represent. This included identifying and considering goals of the survey.

Estimating the size of a meal is subject to error, especially with a survey vehicle lacking visual aids.

Sound descriptive statistical analysis is required to ensure that the data is presented accurately. The range of data should be presented with confidence intervals and appropriate distribution values.[80] Weighting schemes should be clearly described in order to apply survey results to populations of interest. Statistical treatment of perceived outliers should be discussed.

Factors to consider

Ecology identified the following factors as appropriate and necessary when evaluating survey results:

- Cultural factors. Does the population group of interest (for example, Native Americans or Asian and Pacific Islanders) have cultural characteristics that should be considered when designing or evaluating fish consumption? Native American ways of life may influence fish consumption habits and patterns; salmon is of particular significance in the diet of Northwest Pacific Native American tribal peoples. Asian and Pacific Islanders may consume parts of organisms that differ from those preferred by other populations. Also, is the survey designed to identify subsistence fishing practices?
- Fish diet fraction. Have sources of fish tissue contamination been considered in the design and/or evaluation of the survey? Are the fish consumed harvested from local waters? Does the survey distinguish between store-bought fish or fish consumed in restaurants and fish harvested from local waters?
- Types of seafood (fish and shellfish) consumed from marine, freshwater, and estuarine habitats. This information may be useful in characterizing risks for consumption of aquatic biota that have different contaminant levels as a result of their feeding behaviors (for example, bottom feeding fish or top predator species). Has the fish consumption survey considered both the range of types of fish/shellfish consumed and where they are harvested?
- Cooking methods. Using cooked weights or uncooked weights to measure fish consumed must be standardized. Cooking fish can reduce the weight of a fillet by 20 percent or more.[81]

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[80] Moya, *Human and Ecological Risk Assessment,* 2004.

[81] EPA, *Guidance for Conducting Fish and Wildlife Consumption Surveys*, 1998.

Have the methods of food preparation and cooking methods been considered in the fish consumption survey design and/or evaluating the survey?

- Cultural differences. Are there cultural practices or customs that may confer a disproportionate risk for high fish consumers?
- Are there historical and traditional fishing areas and practices that should be identified?
- Environmental justice. How have historically underrepresented populations and disproportionately impacted communities been considered in the design and evaluation of fish consumption surveys?

Measures of technical defensibility

It is important to establish the scientific defensibility of survey data used in a regulatory context. For purposes of this report, Ecology developed several "measures of technical defensibility" to help guide the evaluation of individual surveys (Table 15).

These measures are based on:

- EPA *Exposure Factors Handbook*, (2009 Update).[82]
- EPA Guidance for Conducting Fish and Wildlife Consumption Surveys.[83,84]
- Consultations with the University of Washington, Environmental and Occupational Health Sciences.[85]

The measures include elements of survey method development, the execution of the survey, publication of the results of the survey, survey standards of relevance, applicability and utility, as well as consideration of suitability to support risk-based decisions. These measures help respond to questions regarding survey development and execution, publication of the survey results, and relevance and suitability to help support regulatory decision making. As described in Chapter 4, Ecology applied these measures to evaluate available fish consumption surveys to determine appropriateness for use in establishing a technically defensible default fish consumption rate for regulatory use.

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[82] EPA, *Exposure Factors Handbook: 2009 Update*, EPA/600/R-09/052A, July 2009.

[83] EPA, *Guidance for Conducting Fish and Wildlife Consumption Surveys*, 1998.

[84] EPA, *Consumption Surveys for Fish and Shellfish*, 1992.

[85]Ecology acknowledges input from the University of Washington, Seattle, Environmental and Occupational Health Sciences and Departments of Medicine and Internal Medicine.

Table 15. Measures of Technical Defensibility

1. Survey Method Development

* Was the survey design based on sound scientific survey methods recognized either in guidance or other technical publications?
* For surveys dealing with unique populations (for example, tribes or ethnic minorities), was the survey vehicle reviewed by tribal staff and tribal governments. Did it include review and collaboration with state and federal agencies?
* Was the survey tested and modified before it was conducted?

2. Execution of Survey Vehicle

* Was the execution of the survey based on sound survey methods recognized either in guidance or other technical publications?
* Were the personnel conducting interviews provided adequate training?
* Were fish /shellfish models used to help participants estimate approximate amounts and types of fish consumed?

3. Publication of Results

* Was the publication of survey results based on sound survey methods recognized either in guidance or other technical publications?
* Was the study methodology clearly defined and reported?
* Was the study methodology consistent with sound survey practices?
* Were the survey results tabulated and reported clearly?
* Were statistical approaches (including weighting and treatment of outliers) clearly explained?
* Were the study conclusions clearly reported and supported by study findings?
* Were variability and uncertainty recognized?
* Were uncertainties identified and reported?
* Did the survey design take into account and/or discuss factors that might contribute to bias in the study results?

4. Applicability and Utility for Regulatory Decision-Making

* Is the sample population representative of the population of concern, and does the survey provide sufficient information about the population?
* Is the information current?
* Are exposure estimates sufficiently identified and is data sufficient for descriptive statistics to define statistical distributions?

5. Overall Technical Suitability to Support Regulatory Decision-Making

* Are the results of the survey suitable and can they be used in a regulatory context?
* What is the range of technical defensibility based on the above criterion?
* Can the results be considered appropriate for establishing risk-based standards?

Also of significance is whether a survey is designed to look at short-term or long-term behaviors. This is relevant when comparing results of different surveys.

Standards applied to establishing defensibility

Most fish dietary surveys that address the habits and patterns of ethnic groups (Asian and Pacific Islanders; Native American populations) are funded either through state or federal cooperative agreements or grants. Survey questionnaires are generally developed in close collaboration with an organization that represents the ethnic group or technical personnel associated with the tribal governments or tribal natural resource offices. Surveys are conducted by trained tribal personnel or people representative of the ethnic population being surveyed. The resulting data may be owned by the tribal government or the ethnic group that collaborated on the survey. Survey design and methodology is generally reviewed by the funding organization (federal or state) as well as the technical tribal personnel or ethnic group representatives.

Pacific Northwest Native American fish consumption surveys are designed and executed as government-to-government collaboration with state and federal governments. They are generally published under the authority of the tribal governments.

There are a number of ways to establish the defensibility of data. Scientific journals use peer review to establish scientific defensibility of reported results. A recent *Science Magazine* editorial noted the importance of making data available for scrutiny so that other researchers can verify results and test conclusions.[86] Using independent statisticians for review and analysis may circumvent the need to release the raw data.

Many Pacific Northwest tribal organizations or tribal governments do not provide their raw seafood dietary data to researchers outside of their sovereign tribal government or organizations. They may consider survey data as confidential and not allow independent evaluations. Data evaluation typically occurs through government-to-government agreements or tribal technical personnel.

For example, the fish consumption survey of the four tribes that reside throughout the Columbia River basin was initiated through a cooperative agreement between EPA and the Columbia River Inter-Tribal Fish Commission (CRITFC). The development, design, and execution of the CRITFC fish consumption survey vehicle were conducted through the respective tribal governments that compose CRITFC. The fish consumption data was collected and evaluated by tribal members and technical staff and is retained by CRITFC. Other Pacific Northwest Indian tribes follow a similar pattern where the data is retained by tribal governments or Pacific Northwest Indian commissions.

Ecology evaluated the Native American fish consumption surveys, as well as other available surveys conducted in the Pacific Northwest, based on the measures of technical defensibility discussed above. That evaluation is described in the following chapter.

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[86] *Science Magazine*, 11 February 2011, page 649.

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Chapter 4: Fish Consumption Survey Data Applicable to Washington Fish Consumers

Introduction

Over the last several years, Ecology has evaluated available fish consumption surveys to support site-specific regulatory decisions. This chapter reviews and summarizes this and other data regarding fish consumption in Washington or data relevant to Washington. The goal of this inquiry is to identify and evaluate the currently available data on fish consumption rates and apply measures of technical defensibility to identify which are appropriate for use in establishing a default fish consumption rate (or rates) for the state.

This chapter:

- Identifies earlier evaluations and summarizes available surveys and fish consumption rates derived from each survey.
- Provides an initial determination on which studies Ecology identifies as providing a sound basis for establishing a statewide default fish consumption rate (or rates) appropriate for use in regulatory decisions.

This chapter also identifies the surveys considered by Ecology. Metrics establishing technical defensibility follow the discussion of each qualifying survey.

Surveys and information considered by Ecology

Ecology considered a range of information that describes fish consumption rates and patterns for fish consumers in Washington. In general, Ecology examined:

- Dietary surveys of Washington Native American populations.
- Dietary surveys of Washington Asian and Pacific Islander populations.
- Various evaluations or assessments used for regulatory decisions (for example, the *Lower Duwamish Water Baseline Human Health Risk Assessment*).
- Technical publications, assessments, and/or evaluations on fish consumption specific to the Pacific Northwest.
- Washington water-body specific evaluations, assessments, or health advisories issued by DOH.

Table A-1 in Appendix A summarizes fish consumption survey information that Ecology identified as relevant and suitable for establishing a default fish consumption rate for Washington. In developing this list, Ecology reviewed available information on consumption rates, habits, customs, and patterns for the fish-consuming populations of Washington. The review resulted in identifying the scientific and technical data available for specific evaluation; that is, which data could appropriately be used to establish default fish consumption rates.

The rest of this chapter describes the qualifying surveys and information and presents results of the evaluation.

Pacific Northwest Native American fish consumption data

As of the writing of this report, results of three tribal-specific fish/shellfish dietary surveys of tribes along the Columbia River basin and in the Puget Sound area of Washington were available for review.

In addition, several technical publications provide tribal fish consumption related information. These publications have been used to define a tribal reasonable maximum exposure for various regulatory decisions.[87,88,89]

Although these technical publications provide useful information for specific regulatory decisions, the published tribal fish consumption surveys provide the best information on fish consumption. Furthermore, these surveys employed a well-defined standardized dietary survey methodology, data analysis, and reporting of results.

This section describes the three surveys, along with an evaluation of technical defensibility.

Columbia River Inter-Tribal Fish Commission survey: the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin

The Columbia River Inter-Tribal Fish Commission surveyed fish consumption among four Native American tribes that reside along the Columbia River basin.[90] The survey of adult tribal

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[87] Harper, Barbara L., et al., "The Spokane Tribe's Multipathway Subsistence Exposure Scenario and Screening Level RME," *Risk Analysis*, Vol 22, No. 3, 2002, pages 513-526.

Table 11, page 521 notes 885 – 1,000 g/day for those with a high fish diet (fish consumers) and 175 g/day for shellfish consumption for fish consumers and nonconsumers of fish.

[88] Harris, Stuart G., and and Barbara L. Harper. "A Native American Exposure Scenario," *Risk Analysis*, Vol. 17, No. 6, pages 789-795, 1997.

[89] Harris, Stuart, and Barbara L. Harper, "Lifestyles, Diets, and Native American Exposure Factors Related to Possible Lead Exposures and Toxicity," *Environmental Research,* Section A 86, pages 140-148, 2001.

members who lived on or near the Yakama, Warm Springs, Umatilla, or Nez Perce Reservations was conducted during the fall and winter of 1991–1992.

The survey identified individual tribal members' consumption rates, habits, and food preparation methods of anadromous and resident fish species caught from the Columbia River basin. A random sampling was taken based on respondents selected from patient registration files of the Indian Health Service. The survey questionnaire included a 24-hour diet recall and questions regarding seasonal and annual fish consumption. Food models were used to help respondents estimate the amounts of fish consumed.

Information obtained included age-specific fish consumption rates, the fish species and parts of the fish consumed, and the methods used to prepare the fish for consumption.

Personal interviews conducted on the four tribal reservations achieved an overall response rate of 69 percent from a sample size of 513 tribal members 18 years of age or older. Tribal adult respondents provided information for 204 children 5 years of age or younger. Since tribal population sizes were unequal, weighting factors were applied to the pooled data in proportion to tribal population size, so that survey results would reflect the overall population of the four tribes for adults only. An unweighted analysis was performed for children, since the sample size for children was small. Consumption rates were derived by averaging consumption for both consumers and nonconsumers of fish, to be more representative of the adult tribal population as a whole.

All interviews were conducted at tribal offices, which could potentially select against individuals with mobility problems. It is possible that tribal elders, who may be more likely to practice subsistence consumption, were omitted from the survey. Since adults answered questions regarding children's fish consumption, the adult respondents may have mistakenly answered questions as if they were providing their own survey responses. Selected outliers were removed from the datasets.

CRITFC consumption rates represent consumption from all sources. Salmon and steelhead were consumed by the largest number of adult respondents, followed by trout, lamprey, and smelt. Most fish were consumed during April through July. The mean fish consumption rate was 108 grams/day. There was a large seasonal variation in fish consumption. The reported mean rate of consumption during the high months (April–July) was three times the mean rate of consumption in low months (November–February).

The mean fish consumption rate for all surveyed tribal adults (consumers and nonconsumers) throughout the year was 58.7 grams/day. Seven percent of survey respondents did not consume

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[90] Columbia River Inter-Tribal Fish Commission (CRITFC), *A Fish Consumption Survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin*, Technical Report 94-3, Portland, Oregon, 1994.

fish. Excluding nonconsumers of fish, the mean fish consumption rate for surveyed tribal adult fish consumers was 63.2 grams/day. The average consumption rate for children (5 years old and younger) was 24.8 g/day. About 83 percent of the 204 children consumed fish. The 99th percentile fish consumption rates of adults and children (5 and younger) who consume fish were 389 g/day and 162 g/day, respectively.

	Number of Adults Surveyed	Descriptive Statistics (g/day)					
				Percentiles			
		Mean	Median	75th	90th	95th	99th
Columbia River Tribes	512	63	40	60	113	176	389

Technical defensibility: Ecology concludes that the 1994 survey is relevant to Washington and satisfies measures of technical defensibility.

Additional information reviewed

- Harris and Harper (1997) report that a fish consumption rate of 540 g/day represents a reasonable subsistence fish consumption rate for CRITFC's member tribes who pursue a traditional lifestyle.[91] They base this on their review of several nonsubsistence Native American studies, two subsistence studies, and personal interviews of members of the Umatilla and Yakama Tribes.
- A further examination of Columbia River basin tribal populations used information and data collected from the 1994 Columbia River Inter-Tribal Fish Commission's fish consumption survey.[92] Because of concerns due to chemical contaminants in water and fish for tribal fish=consuming populations along the Columbia River basin, the tribal populations' characteristics were examined for children, women of child-bearing age, and tribal elders who may be susceptible to adverse health effects from exposure to contaminants due to high fish consumption. A multivariate analysis showed a positive association between fish consumption rates and factors including breastfeeding after the most recent births, percent of fish obtained noncommercially for women who recently gave birth, living off the reservation, and fish consumption for children and the elderly. About 50 percent of women, 80 percent of tribal elders, and at least 40 percent of children consume nonfillet fish parts. Although this reevaluation did not result in any changes or corrections in Columbia River basin tribal consumption rates, it provided additional information regarding susceptible tribal populations that consume fish.

[91] Harris and Harper, *Risk Analysis*, 1997.

[92] Sun Rhodes, Neil A., *Fish Consumption, Nutrition, and Potential Exposure to Contaminants Among Columbia River Basin Tribes*, Master of Public Health Thesis, Department of Public Health and Preventive Medicine, Oregon Health & Science University, April 2006.

Table 16. Evaluation of Technical Defensibility

An Evaluation of Technical Defensibility and Suitability of Washington Fish Consumption Rate Surveys by the Washington State Department of Ecology for Use in Regulatory Decision Making
Survey Name: Columbia River Inter-Tribal Fish Commission (CRITFC) Consumption Survey
Survey Author: Columbia River Inter-Tribal Fish Commission (CRITFC), 1994

Metric	Observations & Comments	Evaluation
1. Survey Method Development		
a. Type and description of survey vehicle	24-hour & seasonal dietary recall personal interview survey; respondents were randomly selected from Indian Health Service records; a large range of fish were considered in the survey (salmon, lamprey, smelt.)	The survey method and vehicle were developed in a technically defensible manner.
b. Collaboration and review	CRITFC staff developed the survey in collaboration with Washington DOH, EPA HQ & Region 10 staff, IHS staff; it was reviewed by tribal governments of the CRITFC member tribes (Nez Perce Tribe, Confederated Tribes and Bands of the Yakama Indian Nation, Confederated Tribes of the Warm Springs and Umatilla Indian Reservations).	
c. Beta testing	The survey was tested by tribal staff in consultation with EPA.	
2. Survey execution		
a. Establish & document execution standards	Execution of survey vehicle by native population documented; data gathered on adult respondents 18 years or older and children 5 years or younger.	The survey vehicle was appropriately executed and documented; use of fish models was documented.
b. Document staff training	Native staff trained personnel in collaboration with and with technical oversight provided by state/federal agencies.	
c. Fish/shellfish Models used	Fish models were employed to aid in identifying the amount of fish and shellfish consumed.	
3. Publication of results		
a. Where were results published? Are they clear and complete?	Results were published in a CRITFC tribal government publication. The population surveyed, method used, conclusions, and tabulations were well defined, presented, and documented. The highest fish consumers were considered outliers and were dropped from the survey data and, therefore, were not statistically evaluated.	The data presented is sufficient to develop consumption distributions with percentiles.
b. Methodology reported	The methodology used is clearly described and documented.	
c. Results tabulated & stated	Survey results are reported and summarized in a tabular format suitable for distributional descriptive statistics; the report documents an acceptable response rate (69%).	
d. Conclusions clearly reported	Conclusions are stated and correspond to data tabulated.	
e. Variability and uncertainty	Variability and uncertainty were qualitatively recognized and noted.	
f. How is the potential for bias addressed?	The possibility for bias in the survey methodology is recognized and discussed.	
4. Applicability and utility for regulatory decision making		
a. Representation of target population	The survey provides a reasonable estimate of fish consumption for CRITFC member Native populations within the Columbia River Basin (Nez Perce Tribe, Confederated Tribes and Bands of the Yakama Indian Nation, Confederated Tribes of the Warm Springs & Umatilla Indian Reservations).	This survey meets the standards of relevance, applicability, and utility and is appropriate for use in regulatory decision making
b. Currency of information	Surveys were conducted in the early to mid-1990s; more recently, the CRITFC estimates were used by Oregon DEQ for in developing water quality standards (2011).	
c. Sufficiency of data	The fish consumption estimates are sufficient to provide descriptive statistics for defined distributions and percentiles for risk-based decision making. However, it is unclear as to what portion of seafood consumed is harvested from local sources. CRITFC fish consumption rates are for seafood from all sources and include anadromous (migratory) species.	
5. Overall technical suitability for regulatory decision making		
a. Range of technical defensibility	Survey design, development of methodology, execution of survey, data interpretation, and conclusions for fish consumption provide a reasonable quantitative exposure estimate of fish consumption rates for target populations.	Ecology concludes survey is technically defensible.
b. Appropriateness for use in risk-based standards	The data is sufficient to provide distribution and percentile estimates of fish consumption as required for risk-based decision making.	

Source: Columbia River Inter-Tribal Fish Commission. (CRITFC). 1994. *A Fish Consumption Survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin*, Technical Report 94-3. Portland, Oregon.

Tulalip and Squaxin Island Tribes of the Puget Sound Region (Toy et al., 1996)

A survey of fish and shellfish consumption for the Tulalip and Squaxin Island tribes living in the Puget Sound region was conducted in 1994. [93]

The target populations included adult tribal members (18 years or older) randomly selected from tribal enrollments who lived on or within a 50-mile radius of the reservation and children aged five years or younger who lived in the enrolled member's household. The survey reported consumption rates of anadromous, pelagic, bottom fish, and shellfish in grams per kilogram body weight per day over a one-year period and the portion size of each meal. Adults who did not consume fish (less than 1 percent of those contacted) were not included in the survey. Fish/shellfish models were used to estimate portion sizes. Fish/shellfish preparation methods were identified, and sources of fish and shellfish consumed were reported by tribe and species groups.

Species groups included:

Anadromous fish (Group A)	Salmon (chinook, pink, sockeye, coho, chum); smelt; steelhead
Pelagic fish (Group B)	Cod, dogfish, greenling, herring, perch, pollock, rockfish, sablefish, spiny
Bottom fish (Group C)	Halibut, sole/flounder, sturgeon
Shellfish (Group D)	Butter clam, clams (manila/littleneck), cockles, dungeness crab, horse clam, moon snail, mussels, oyster, scallops, sea cucumber, sea urchin, shrimp, squid
Other (Groups E and F)	Abalone, barnacles, bullhead, chitons, crayfish, eel, geoduck, grunters, limpets, lobster, mackerel, manta ray, octopus, razor clam, shark, skate, trout

A total of 190 successful interviews were completed during March through mid-May for adult tribal respondents. A tribal parent or guardian answered questions about the fish consumption for children from the same household. Only one child per household, selected randomly, was included in the survey, for a total of 69 children. Results from half of the adult respondents in the Tulalip tribe were dropped because one of the tribal interviewers did not follow the survey interview protocol. However, repeat interview were conducted by telephone as a followup with 10 percent of the survey respondents.

Anadromous fish and shellfish were most frequently consumed. The main source for the most frequently consumed fish (anadromous fish and shellfish) was local water bodies of the Puget Sound. Fish fillets with skin were consumed by up to 40 percent of the tribal respondents with mean percent consumption of fish parts (head, bones, eggs, organs, and skin) for up to 11 percent

[93] Toy, K.A., et al., *A Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region*, Tulalip Tribes, Department of Environment, Marysville, Washington, 1996.

of tribal respondents consuming anadromous fish. Although the survey identified fish parts consumed by respondents, it did not include complex tribal seafood recipes.

Weight adjusted consumption rates were calculated and reported by tribe, age, gender, income, and species group. The adult mean and median consumption rates for all forms of fish combined were 0.89 and 0.55 g/kg/day for the Tulalip tribes and 0.89 and 0.52 g/kg/day for the Squaxin Island tribe, respectively. Age-adjusted median fish consumption rates for the Tulalip Tribes were 53 g/day for males and 34 grams/day for females. Age adjusted median fish consumption rates for the Squaxin Island tribe were 66 g/day for males and 25 g/day for females. The mean and median consumption rate for children, five years and younger for both tribes combined, were 0.53 and 0.17 g/kg-day, respectively.

Tribe	Number of Adults Surveyed	Descriptive Statistics (g/day)					
		Mean	Median	Percentiles			
				75th	90th	95th	99th
Tulalip	73	72	45	85	186	244	312
Squaxin Island	117	73	43	-	193	247	-

Technical defensibility: The survey of Tulalip and Squaxin Island Tribes of the Puget Sound Region (Toy et al., 1996) is relevant to Washington and is technically defensible.

Table 17. A Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region

Survey Author: Toy et al., 1996

Metric	Observations & Comments	Evaluation
1. Survey method development		
a. Type and description of survey vehicle	Personal interview survey; 24-hour and seasonal dietary recall; fish/shellfish identification, portion, frequency, preparation, and harvest locations.	The survey method and vehicle were developed in a technically defensible manner.
b. Collaboration and review	Survey was developed in collaboration with Washington DOH, Washington Dept of Ecology, EPA Region 10, Tulalip Tribal Dept of Environment, Suquamish Tribal Fisheries Dept, Board of Directors for Tulalip & Squaxin Island Tribes, Columbia River Inter-Tribal Fish Commission, Fred Hutchinson Cancer Research Center in Seattle.	
c. Beta testing	Pilot survey and repeat interviews conducted	
2. Survey execution		
a. Establish & document execution standards	Execution of survey questionnaire documented with identifiable QA/QC procedures.	The survey vehicle was appropriately executed and documented; use of fish models was documented.
b. Document staff training	Two members from each tribe trained to conduct interviews.	
c. Fish/shellfish models used	Fish and shellfish models used for multiple species.	
3. Publication of results		
a. Where were results published? Are they clear and complete?	Fish/shellfish identification, portion, frequency, preparation, and harvest locations documented and reported.	The data presented in the Joint Tulalip and Squaxin Island tribal publication is sufficient to develop consumption distributions with percentiles.
b. Methodology reported	All phases of method development documented and reported.	
c. Results tabulated & stated	Tabulated species-specific consumption with descriptive statistics.	
d. Conclusions clearly reported	Conclusions reported with followup interviews for reliability and representation	
e. Variability and uncertainty	Noted and documented with note of "outliers" with reported rates for Squaxin & Tulalip tribes.	
f. How is the potential for bias addressed?	The possibility for bias in the survey methodology is recognized and discussed. Survey results from one interview did not follow protocol and were eliminated.	
4. Applicability and utility for regulatory decision making		
a. Representation of target population	Included range of different rates for enrolled Tulalip & Squaxin tribal members	This survey meets the standards of relevance, applicability, and utility and is appropriate for use in regulatory decision making.
b. Currency of information	Survey conducted in 1996; more recently the consumption estimates were used by Oregon DEQ in developing water quality standards (2011).	
c. Sufficiency of data	The data is sufficient to provide distribution and percentile estimates of fish consumption for Tulalip & Squaxin tribal populations	
5. Overall technical suitability for regulatory decision making		
a. Range of technical defensibility	Technically defensible dietary survey of the Squaxin Island Indian Tribe.	Ecology concludes the survey is technically defensible.
b. Appropriateness for use in risk-based standards	Data was reanalyzed by Nayak Polissr to provide consumer-only consumption rates. It is sufficient to provide distribution and percentile estimates of fish consumption as required for risk-based decision making.	

Source: Toy, K.A., Polissar, N.L., Liao, S., and Mittelstaedt, G.D. 1996. *A Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region*. Tulalip Tribes, Department of Environment, 7615 Totem Beach Road, Marysville, Washington 98271.

Suquamish Indian Tribe

The Suquamish Tribal Council conducted a fish consumption survey of Squamish tribal members living on and near the Port Madison Indian reservation in the Puget Sound area. [94] The survey was conducted to determine the fish/shellfish consumption rates, habits and patterns of the Suquamish tribe. Also, the study was conducted to identify fish consumption related cultural practices and tribal characteristics that might affect fish consumption rates, patterns and habits.

Consumption data was based on a random sample of adults (16 years and older) selected from the tribal enrollment roster. Consumption data for children was collected through adult respondents with children younger than 6 years old living in the household at the time of the survey. Consumption data was collected for 31 children under 6. Some children were from the same household. The survey has a 64.8 percent participation rate based on 92 respondents out of a total of 142 potentially eligible tribal adults. The survey questionnaire was administered by trained tribal members using personal interviews and included:

- 24-hour dietary recall (fish meals eaten per day, per week, per month, or per year over a 1-year period and the portion size of each meal).
- Identification, portions, frequency of consumption, methods of preparation, harvest locations.
- Shellfish consumption, methods of preparation, harvest location.
- Changes in consumption over time, cultural information, physical information, and socioeconomic information.

Fish/shellfish models were used to assist tribal respondents regarding amounts and types consumed. Booklets were used to assist in identifying harvest locations of seafood consumed. Fish/shellfish were grouped into categories based on similarities in life history and practices of tribal members who fish for subsistence, ceremonial, and commercial purposes. The majority of fish/shellfish consumed by the Suquamish Tribe was harvested from the Puget Sound, with Pacific salmon and shellfish consumed more than other fish.

[94] Suquamish Tribe, *Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservation, Puget Sound Region*, August 2000.

All 92 tribal respondents reported consuming some type of fish; hence, no nonconsumers of fish were surveyed. Survey results were recorded as grams/kg/day along with the respondent's body weight. Adult respondents reported a mean consumption rate of all finfish and shellfish consumption rate of 2.71 g/kg/day. For children under 6 years old, the mean consumption all finfish and shellfish was 1.48 g/kg/day. Below are weight-adjusted survey results for Susquamish adult fish consumers.

	Number of Adults Surveyed	Descriptive Statistics (g/day)					
				Percentiles			
		Mean	Median	75th	90th	95th	99th
Suquamish Tribe	284	214	132	-	489	-	-

Technical defensibility: The 2000 survey of Suquamish Indian Tribe of the Port Madison Indian Reservations of Puget Sound is relevant to Washington and satisfies measures of technical defensibility.

Table 18. Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservation, Puget Sound Region

Survey Author: The Suquamish Tribe, 2000

Metric	Observations & Comments	Evaluation
1. Survey method development		
a. Type and description of survey vehicle	Personal interview survey; 24-hour & seasonal dietary recall; fish/shellfish identification, portion, frequency, preparation, and harvest locations	The survey method and vehicle were developed in a technically defensible manner.
b. Collaboration and review	Survey was developed in collaboration with Washington DOH, Washington Dept of Ecology, ATSDR, University of Washington, EPA Region 10, Suquamish Tribal Fisheries Dept.	
c. Beta testing	Beta testing documented.	
2. Survey execution		
a. Establish & document execution standards	Execution of survey questionnaire documented with identifiable QA/QC procedures.	The survey vehicle was appropriately executed and documented; use of fish models was documented.
b. Document staff training	Training of personnel was conducted by trained Suquamish Tribe members.	
c. Fish/shellfish models used	Seafood models and a display booklet of seafood illustrations for multiple species were used to aid in identifying the amount of seafood consumed.	
3. Publication of results		
a. Where were results published? Are they clear and complete?	Fish/shellfish identification, portion, frequency, preparation and harvest locations documented & reported.	Suquamish Tribe publication with well-defined method, analysis of species consumed, clear data analysis and interpretation.
b. Methodology reported	The methodology used is clearly described and documented.	
c. Results tabulated & stated	Survey results are reported and summarized in a tabular format suitable for distributional descriptive statistics.	
d. Conclusions clearly reported	Conclusion reported with followup interviews for reliability and representation.	
e. Variability and uncertainty	Noted and documented with "outliers" identified.	
f. How is the potential for bias addressed?	The possibility for bias in the survey methodology is recognized and discussed.	
4. Applicability and utility for regulatory decision making		
a. Representation of target population	Included range of different rates for enrolled Suquamish Tribe members.	This survey meets the standards of relevance, applicability, and utility and is appropriate for use in regulatory decision making.
b. Currency of information	The survey was conducted in 1999; more recently, the consumption estimates were used by Oregon DEQ for developing water quality standards (2011).	
c. Sufficiency of data	The fish-consumption estimates are sufficient to provide descriptive statistics for defined distributions and percentiles for Suquamish Tribal population.	
5. Overall technical suitability for regulatory decision making		
a. Range of technical defensibility	Technically defensible dietary survey of the Suquamish Indian Tribe.	The survey is technically defensible
b. Appropriateness for use in risk-based standards	The data is sufficient to provide distribution and percentile estimates of fish consumption as required for risk-based decision making. Seafood consumption data provided is for consumption of seafood from all sources. EPA Region 10's tribal seafood consumption framework provides an approach for developing consumption rates of regionally harvested seafood.	

Source: The Suquamish Tribe. 2000. *Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservation, Puget Sound Region*. The Suquamish Tribe. 15838 Sandy Hook Road, Post Office box 498, Suquamish, WA 98392.

Asian and Pacific Islanders

An API seafood consumption study was conducted in King County, Washington, to obtain information on consumption rates, species and seafood parts consumed, and preparation methods for first- or second-generation members of the API community. [95] Survey participants were API seafood consumers 18 years or older. The study was conducted in three phases:

- Phase I: Identify target API ethnic groups and develop appropriate questionnaires in the language required to administer the questionnaire to each API ethnic group.
- Phase II: Characterize seafood consumption for 10 API ethnic groups within the King County study area[96]
- Phase III: Develop culturally appropriate health messages on risks related to seafood consumption and disseminate to API community

Of the 202 respondents, 89 percent were first API generation (born outside the United States). API participants were interviewed by trained representatives from each of the 10 API ethnic communities represented and asked to report on the number of annual servings and portion size of the servings. Participants reported their own body weights with results reported as grams per kilogram per day. Because the survey was based on dietary recall, the authors selected 20 API respondents to interview a second time, to assess the reliability of the responses. The results suggest that the estimated consumption rates are reliable for the API community study area.

Survey results indicate that shellfish were consumed more by the API community than any other group of fish. More than 75 percent of the respondents consumed shrimp, crab, and squid. Salmon and tuna were the most frequently consumed finfish. For all fish groups, 79 to 97 percent of the seafood consumed came from either groceries/street vendors or restaurants. Japanese consume a greater percentage of finfish than shellfish (52 percent), while Vietnamese consume more shellfish (50 percent). The mean and median consumption rates for all seafood combined for the 10 API ethnic groups were 1.9 grams/kg body weight (bw)/day and 1.4 grams/kg bw/day, respectively. The average shellfish consumption rate for the API community was 0.87 grams/kg bw/day. The API community consumed more shellfish than all of the combined categories of finfish consumed (average finfish consumption is 0.82 grams/kg bw/day).

[95] Sechena, R., C. Nakano, S. Liao, N. Polissar, R. Lorenzana, S. Truong, and R. Fenske. 1999. Asian and Pacific Islander Seafood Consumption Study in King County, Washington. EPA 910/R-99-003. May 1999. http://www.epa.gov/r10earth/offices/oea/risk/a&pi.pdf

[96] The 10 API ethnic groups are Cambodian, Chinese, Filipino, Hmong, Japanese, Korean, Laotian, Mien, Samoan, and Vietnamese.

Table 19. Asian and Pacific Islander Seafood Consumption Study

Survey Author: Sechena et al., 1999

Metric	Observations & Comments	Evaluation
1. Survey method development		
a. Type and description of survey vehicle	Personal interview survey; 24-hour dietary recall; conducted in three phases	The survey method and vehicle were developed in a technically defensible manner.
b. Collaboration and review	Survey was developed in collaboration with a Community Steering Committee (representatives of the Asian/Pacific Islander community, Washington DOH, Washington Dept of Ecology, EPA Region 10, University of Washington, Seattle Refugee Federation Service Center)	
c. Beta testing	The testing of the survey was conducted in phases with followup re-interviews to assess reliability of responses.	
2. Survey execution		
a. Establish & document execution standards	Seafood consumption studies for 10 API groups in King County, Washington. Technical execution guided by Community Steering, Technical, & Advisory Committees.	The survey was appropriately executed and documented; use of fish models was documented.
b. Document staff training	Trained bilingual interviewers from API community.	
c. Fish/shellfish models used	Seafood models were used to represent approximate portion sizes.	
3. Publication of results		
a. Where were results published? Are they clear and complete?	Information on types of seafood consumed, source of seafood, preparation methods, frequency & portion size consumed, demographic information clearly reported.	Robust analysis & evaluation of API community fish consumption habits and patterns
b. Methodology reported	Phase II (fish consumption) followed from identification target API populations with ethnic and language specific questionnaires.	
c. Results tabulated & stated	Tabulated species-specific consumption across 10 different API ethnic populations; included food preparation methods.	
d. Conclusions clearly reported	Conclusions clearly reported with followup interviews.	
e. Variability and uncertainty	Variability and uncertainty were qualitatively recognized and noted.	
f. How is the potential for bias addressed?	The possibility for bias in the survey methodology is recognized and discussed.	
4. Applicability and utility for regulatory decision making		
a. Representation of target population	The survey included a range of different API ethnic groups to evaluate consumption representative of API population.	This survey meets the standards of relevance, applicability, and utility and is appropriate for use in regulatory decision making
b. Currency of information	The survey was conducted in 1999; more recently, the consumption estimates were used by Oregon DEQ in developing water quality standards (2011).	
c. Sufficiency of data	The consumption estimates are sufficient to provide descriptive statistics for defined distributions and percentiles for different API populations	
5. Overall technical suitability for regulatory decision making		
a. Range of technical defensibility	Technically defensible dietary survey of API populations in King County, Washington.	Ecology concludes the survey is technically defensible.
b. Appropriateness for use in risk-based standards	The data is sufficient to provide distribution and percentile estimates of fish consumption as required for risk-based decision making. The API survey did not correct for cooking weight loss or regionally harvested seafood. -See write-up on EPA Region 10's reanalysis of the API survey (Kissinger, 2005).	

Source: Sechena, R., Nakano, C., Liao, S., Polissar, N., Lorenzana, R., Truong, S., Fenske, R. 1999. *Asian and Pacific Islander Seafood Consumption Study in King County, WA*. U.S. Environmental Protection Agency, Region 10, Seattle, Washington, EPA/910/R-99-003.

Below are weight-adjusted survey results for API adult fish consumers:

	Number of Adults Surveyed	Descriptive Statistics (g/day)					
				Percentiles			
		Mean	Median	75th	90th	95th	99th
Asian & Pacific Islanders	202	117	78	139	236	306	-

Technical defensibility: The 1999 survey of King County Asian and Pacific Islanders is relevant to Washington and satisfies measures of technical defensibility.

Reanalysis by EPA Region 10

EPA Region 10 (Kissinger, 2005) reanalyzed the API data to correct for cooking weight loss, regionally seafood harvest, and extrapolation from the survey to King County API populations.[97] This reanalysis was used to develop API fish consumption rates to establish cleanup levels in the Lower Duwamish Waterway.[98] The EPA Region 10 reanalysis of the API 1999 survey included only data for individuals consuming seafood from King County. Weighting factors for King County consumers for various ethnic groups were a function of the percentage of that ethnic group as determined in the census and the number of individuals in that ethnic group that consumed seafood from King County. The 95th percentile ingestion rate (defined as the reasonable maximum exposure [RME] scenario) was developed from the consumer-only dataset of weighted ingestion rates. Adjustments were made to account for some of the shellfish consumption reported on a cooked-weight basis rather than on a wet-weight basis. Revised estimates of average raw shellfish consumption were made by using 25 and 50 percent cooking loss correction factors for those shellfish species for which consumption was reported on a cooked-weight basis. EPA calculated demographically weighted mean ingestion rates for each seafood category for individuals who consumed some seafood caught in King County. To derive the percentage of consumption of each seafood category, they used demographically weighted mean ingestion rates. These percentages were then applied to the total consumption rate (95th percentile of total King County API seafood consumption of 57.1 g/day) to derive consumption rates for each seafood category.

[97] Kissinger, L. 2005. *Application of data from an Asian and Pacific Islander (API) seafood consumption study to derive fish and shellfish consumption rates for risk assessment.* Office of Environmental Assessment, US Environmental Protection Agency Region 10, Seattle, WA.

[98] Lower Duwamish Waterway Group. Remedial Investigation Report Appendix B: Baseline Human Health Risk Assessment. Final. U.S. Environmental Protection Agency, Region 10, and Washington Department of Ecology, Northwest Regional Office. November 12, 2007.

Anadromous fish were not included in the fish consumption scenario because it is problematic to apportion salmon (anadromous fish) contaminant body burden to site-specific chemical contaminants. To estimate the API central tendency consumption rate, the 50th percentile of total King County API consumption was multiplied by the percentage of consumption for the various seafood categories. Total nonanadromous seafood consumption for the API exposure scenarios was 51.1 g/day and 5.3 g/day for the RME and central tendency estimates, respectively.

Demographically Weighted Adult API Seafood Consumption for Different Seafood Categories			
Seafood Category	Percentage of Consumption	RME Consumption Rate (grams/day)	Central Tendency Rate (grams/day)
Anadromous fish	9.6	5.5	0.56
Pelagic fish	8.6	4.9	0.5
Benthic fish	4.2	2.4	0.24
Shellfish	77.5	44.2	4.6

Source: U.S. Environmental Protection Agency Region 10 and Washington State Department of Ecology. 2007. *Lower Duwamish Waterway Remedial Investigation*. Appendix B: Baseline Human Health Risk Assessment. Final. November 12. Adapted from Table B.3-31.

Reanalysis of the consumption of shellfish (mussels, crabs, and clams) for the API exposures used average demographically weighted consumption of these shellfish species harvested only from King County. These shellfish consumption estimates were used to calculate the percentage of each shellfish type consumed. The demographic weighting factor was used to estimate the consumption of clams, mussels, and crabs. The crab consumption rates were apportioned among crab whole body and edible meat, and the benthic fish consumption rates were apportioned among benthic fish fillet and whole body. EPA Region 10 provided demographically weighted average percentages of crab whole-body and crab edible-meat consumption by API populations consuming at least some King County seafood. Also, EPA Region 10 provided average demographically weighted percentages of whole-body and fillet consumption by API members consuming at least some King County seafood.

Demographically Weighted Adult API Shellfish Consumption			
Shellfish type	Percentage of Total Shellfish Consumption	RME Consumption Rate, grams/day	Central Tendency Consumption Rate, grams/day
Crabs	24.0	10.6	1.1
Clams	65.6	29.0	3.0
Mussels	10.4	4.6	0.47

Source: U.S. Environmental Protection Agency Region 10 and Washington State Department of Ecology. 2007. *Lower Duwamish Waterway Remedial Investigation*. Appendix B: Baseline Human Health Risk Assessment. Final. November 12. Adapted from Table B.3-31.

Demographically Weighted Adult API Shellfish Consumption of Benthic and Crab			
Shellfish type	Percentage of Total Shellfish Consumption	RME Consumption Rate (grams/day)	Central Tendency Consumption Rate(grams/day)
Crab, edible meat	53.3	5.7	0.59
Crab, whole body	46.7	4.9	0.51
Benthic fish, fillet	82.3	2.0	0.20
Benthic Fish, Whole Body	17.7	0.39	0.04

U.S. Environmental Protection Agency Region 10 and Washington State Department of Ecology. 2007. *Lower Duwamish Waterway Remedial Investigation*. Appendix B: Baseline Human Health Risk Assessment. Final. November 12. Adapted from Table B.3-31.

Technical defensibility: The EPA Region 10 reanalysis of the 1999 API survey is relevant and technically defensible approach for a site-specific evaluation (Lower Duwamish Waterway).

Additional fish consumption rate information evaluated by Ecology

Ecology considered a range of other related information. Although not all of it applies to deriving default fish consumption rates, it provides information on resource use and historical information about fish consumption. This additional information helps provide a larger and more complete view of fish and shellfish harvest and consumption in Washington.

Table 20. Fish Consumption Information Relevant to Washington and Considered by Ecology

Tribal Surveys	Description
A Fish Consumption Survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin (CRITFC, 1994)	Fish consumption habits & patterns of selected Native American tribes that reside and harvest fish in the Columbia River Basin. Includes Yakama and Umatilla tribes from Washington; Nez Perce and Warm Springs tribes from Oregon State.
A Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region (Toy et al., 1996)	Puget Sound regional survey for two tribes. Provides information on both finfish and shellfish consumption
Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservations, Puget Sound Region (Suquamish, 2000)	Puget Sound regional survey for two tribes. Provides information on both finfish and shellfish consumption
Survey of Asian and Pacific Islander	
Asian and Pacific Islander Seafood Consumption Study (Sechena et al., 1999)	King County specific fish consumption estimates for Asian and Pacific Islanders. Survey information has been used by EPA Region 10 to estimate rates for Asian and Pacific Islander for other Puget Sound areas. Using Sechena et al, 1999, EPA Region 10 reanalyzed data for site-specific Lower Duwamish Waterway cleanup (Kissinger, 2005)
U.S. General Population	
Estimated Per Capita Fish Consumption in the United States (EPA, 2002)	Includes fish consumers & nonconsumers. (This data was used by Oregon DEQ to estimate the percentage of fish consumers and nonconsumers in Oregon.)
State Assessments, Evaluations, and Advisories	
Washington State Department of Health Fish Advisories	Various water body-specific fish consumption rates. DOH advisories provide information on fish meals that should be avoided or can be safely eaten for analytically determined contaminant levels in fish tissue.
Lower Duwamish Waterway Baseline Human Health Risk Assessment [99]	Provides fish consumption information based on Puget Sound surveys & EPA Region 10 framework. Develops sediment cleanup standards based on tribal RME scenarios.
Lower Elwha Klallam Tribe/Port Angeles[100, 101]	In collaboration with Ecology and using the EPA Region 10 framework developed tribal fish consumption rate. Cleanup standards are based on a tribal RME.
Lake Roosevelt, DOH [102]	DOH in cooperation with the Spokane Tribe, water body- and angler-specific creel survey; 42 fish meals/year; assuming 8 oz meal. This is approximately 26 g/day.
Sinclair Inlet Bremerton Naval Complex[103]	Risk-based screening levels based on Suquamish Tribe adult and children fish/shellfish ingestion rates and recreational sport fishers. (See Appendix B.)
Lake Whatcom, DOH [104]	Provided estimated species-specific fish meals sizes for commonly caught and consumed Lake Whatcom fish species (crayfish, cutthroat trout, kokanee, yellow perch, smallmouth bass) with median rates in grams/meal; from low (crayfish) of 24 g/meal and high (smallmouth bass) of 220 g/meal
Rhone-Poulenc [105]	Cleanup standards based on Tulalip tribal fish consumption and Asian and Pacific Islander seafood consumption. Range of fish consumption rates referred to and documented in Lower Duwamish Waterway Human Health Risk Assessment.
South Aberdeen-Cosmopolis Area [106]	Chinook, coho, chum; anadromous steelhead and cutthroat trout commonly found and available for harvest. Evaluates fish habitat and recommends habitat restoration and enhancement.
Naval Base Kitsap – Keyport, Washington [107]	Based on Suquamish Tribe shellfish (clams, mussels, crabs, oysters) consumption rate. Based on U.S. general population rate 54 gpd to Suquamish rate 632 gpd for clams.
Oakland Bay, Shelton [108]	Water body-specific evaluation. A range of shellfish consumption rates used, 17.5, 60, 175, 260 gpd; based in part on Squaxin Island tribal consultations.
Umatilla Tribal Water Quality Standard [109]	Consumption rate of 389 gpd approved by EPA Feb. 2010. (Lummi Nation, Shoshone-Bannock Tribe and the Swinomish Tribe are eligible to adopt tribal water quality for their respective reservations.)
Lake Washington[110]	Anglers rate 10.8 gpd; angler 95th percentile 30.2 gpd; children anglers 9.5 gpd with 95th percentile 86.2 gpd. Allowable meal limits determined for northern pikeminnow, yellow perch, cutthroat trout, sockeye salmon.

[99] EPA Region 10 and Washington State Department of Ecology, *Lower Duwamish Waterway Remedial Investigation*, 2007.

[100] Lower Elwha Klallam Tribe, "Local Seafood and Lower Elwha Klallam Tribal Health," May 30, 2007.

[101] Lower Elwha Klallam Tribe; "Lower Elwha Klallam Tribe Fish Consumption Rate, Additional Data," February 10, 2008.

[102] Washington State Department of Health (DOH), *Consumption Patterns of Anglers Who Frequently Fish Lake Roosevelt*, September 1997.

[103] Naval Facilities Engineering Command, *Technical Memorandum: Human Health Risk Evaluation of Mercury in Sinclair Inlet Seafood, OU B Marine*, *Final Report, Bremerton Naval Complex*, 12 August 2010.

[104] DOH, *Data Report Lake Whatcom Residential and Angler Fish Consumption Survey*, April 2001.

[105] EPA Region 10, *Statement of Basis for Remedy Selection and Corrective Action Complete Without Controls Determination at Rhone-Poulenc, Inc., East Parcel,* EPA ID # WAD 00928 2302, Administrative Order of Consent 1091-11-20-3008(h), November 2006.

[106] U.S. Department of the Interior, Fish and Wildlife Service, *Habitat Quality and Fish Usage of Five Cheahalis River Tributaries in the South Aberdeen-Cosmopolis Area*, October 1994.

[107] Agency for Toxic Substances and Disease Registry, *Health Consultation, Naval Base Kitsap, Keyport, Health Consultation, EPA Facility No. WA1170023419*, September 15, 2009.

[108] DOH, *Health Consultation, Evaluation of Dioxins in Shellfish from the Oakland Bay Site Shelton, Mason County, WA*, July 27, 2010.

[109] EPA Region 10, *Tribal Water Quality Standards in the Pacific Northwest and Alaska*, http://yosemite.epa.gov/r10/water.nsf/Water+Quality+Standards/Tribal+WQS+Inv.

[110] DOH, *Final Report, Evaluation of Contaminants in Fish from Lake Washington, King County, Washington*, September 2004.

Variability and uncertainty

The measures of technical defensibility presented in this chapter relied on EPA's examination of different survey methodologies.

EPA examined different survey methodologies, important methodological considerations for fish consumption survey design, selection of respondents, quality assurance, and statistical analysis.[111] Additional EPA guidance has been provided for fish and wildlife consumption surveys that thoroughly examine survey instrument design, execution, and analysis.[112]

In the context of the reviews and guidance documents on survey design methodologies and the execution and analysis of survey results, different fish consumption rates have been reported and used by federal and state agencies. These differences may result from a variety of factors associated with study design and data analysis from various surveys.

When survey information for a specific local fish-consuming population is not available, the assessor must select a reasonable surrogate population and default rates from applicable surveys (if available). EPA Region – 10 has developed guidance that addresses this situation, and Ecology has employed this guidance to derive fish consumption rate based on applicable surrogate population characteristics, fish/shellfish habitat characteristics, and fish/shellfish abundance characteristics.[113] (See Appendix D for a description of the EPA Region 10 framework.)

Numerous types of survey methods have been used to estimate fish consumption rates. Each type survey has inherent biases, strengths, and weaknesses that may contribute to variable results demonstrated across different surveys. These strengths and weaknesses have been considered by Ecology when evaluating the fish consumption rates.[114,115] It should be noted that regulatory policies that influence the initial stages of planning a survey will influence the nature of the results and conclusions reached. Furthermore, policy choices may not be consistent across various federal and state agencies and academic institutions.

Resource limitations and differences in objectives influence the survey design and execution of the survey vehicle. For regulatory risk management decisions, knowledge of the objectives of a survey, how the survey was conducted, and how the survey data was evaluated can be used to

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[111] EPA, *Consumption Surveys for Fish and Shellfish*, 1992.

[112] EPA, *Guidance for Conducting Fish and Wildlife Consumption Surveys*, 1998.

[113] EPA Region 10, Office of Environmental Assessment, *Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia*, August 2007.

[114] Ebert et al., *Journal of Exposure Analysis and Environmental Epidemiology,* 1994.

[115] EPA, *Consumption Surveys for Fish and Shellfish*, 1992.

assess the reliability of the results, providing information about whether the results are applicable to a particular exposure scenario of interest.

Factors that contribute to variability and uncertainty

A number of factors may contribute to potential sources of variability and uncertainty in fish and shellfish consumption survey results.[116]

Target populations and characteristics of populations. Different population groups may express different fish consumption rates. Recognizing differences between characterizing exposures of whole populations and estimating exposure to contaminants in actual consumers of fish is a critical distinction. For example, Oregon's Human Health Focus Group made the clear distinction between per capita fish consumption based on consumers and nonconsumers of fish. Often, populations that are high fish consumers are relatively small, with these consumers represented by extreme upper percentiles in a distribution defined by both consumers and nonconsumers of fish. Hence, using either per capita estimates or a consumption rate derived from a low percentile of the consumption distribution would not accurately estimate contaminant exposure.

Differences in design, terminology, and definitions. Some fish dietary surveys may not include all relevant species in the questionnaire. Terminology across different fish consumption surveys may be highly variable. A lack of a consistent terminology can contribute to variability and uncertainty. For example, *shellfish* usually refers to aquatic invertebrate organisms with a shell. Clams and oysters are easily identified as shellfish. However, selected aquatic animals (squid) have evolved such that the shell has become internal and/or reduced, while in others, the shell has disappeared (octopus). Furthermore, crustaceans have exoskeletons instead of true shells.

Seafood consumption may include fish and/or shellfish obtained from a variety of sources. Surveys may not differentiate the sources of the fish and/or shellfish. Indeed, some surveys may consider consumption of fish harvested from a single water body (e.g., Commencement Bay) while other studies determine rates for fish consumption from multiple water bodies. Also, consumption rates reported in different studies may or may not distinguish between consumption of marine, estuarine, and freshwater fish and shellfish. These differences and their contributions to variability were summarized by Ebert et al., 1994. This study noted that the consumption rate of an individual comprises the sum of the rates from different sources. It does not differentiate among sources of seafood. Estimates may vary substantially depending on how these different sources are evaluated.[117]

Types of data and methods of collection. Ecology has recognized different methods to collect fish consumption data. For example, data collected from creel surveys involve interviewing anglers at

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[116] Ebert et al., *Journal of Exposure Analysis and Environmental Epidemiology,* 1994.

[117] Ibid.

fishing locations to provide water-body specific data about fishing frequency, fish species, and sizes caught and/or consumed. Hence, the creel survey method may only be representative of specific seasons or targeted species. Creel surveys, like other surveys methods, are subject to biases in that poor catches or catches below legal size limits or above total allowable limits may not be reported. Ecology's measures of technical defensibility account for variability across relevant studies and the survey methods employed. An important element that Ecology considered in the survey design is whether a survey adequately represents its target population. A number of factors can affect the ability of a survey design to reach the target population and represent it accurately. Elements to consider for specific target populations include literacy, language, and cultural sensitivities.

Study duration. Surveys designed to cover specific seasons or time periods may be subject to biases. Data obtained from single days are subject to potential biases from the effects of the day of the week or seasonal variations. Consumption data obtained on consecutive days may be biased due to the consumer correlation with the fish consumed on adjacent days. The timing of the survey may or may not account for seasonal variations. Recall surveys may suffer from recall bias which may either overestimate or underestimate fish consumption. Contributions to recall bias include how commonly or frequently the fish is consumed, actual time frames that are covered in the survey, and survey methods (such as the use of fish models) to enhance memory. These factors and other noted by Ebert et al. (1994) may contribute to bias and hence variability in fish consumption rates.[118]

Regional variations. Fish consumption surveys conducted across the U.S. have shown regional variation including differences for coastal areas compared with inland areas, seasonal differences in available species, and regional preferences for certain types of fish and/or shellfish. Ebert et al. (1994) further noted that local differences in climate, fishing regulations, accessibility to fisheries, and availability of fish contribute to the variability in reported fish consumption rates. Comparing the results of different survey conducted in different geographic locations, with different methodologies, time frames, or other different survey design elements that are not comparable makes the interpretation of differences in fish consumption very problematic.

Data analysis and statistical considerations. Ecology has noted that careful definition of the target population is essential to reduce bias in the survey results. To avoid characterizing the consumption for a population that is not at risk from consuming contaminated fish, surveys are designed to evaluate consumers of fish only. Various statistical techniques have been described to analyze consumption data. For example, different methods of treating missing data or nonresponse data may contribute to bias. Identification and treatment of potential outliers may contribute to biased datasets (this includes recording outliers as multiples of standard deviations above the mean or eliminating them from the dataset). Defining subgroups within a larger population

[118] Ebert et al., *Journal of Exposure Analysis and Environmental Epidemiology*, 1994.

(stratification) differently can affect survey results and introduce different levels of bias. An important element of survey design is how well the survey (sample population represents the selected target population or population of concern. Weighting schemes designed to make a sample more representative of the population should be carefully defined. Statistical methods should consider sampling rate, differences in sampling days, and other factors that may influence the results. The fish consumption rates for a fish-consuming population should be sufficiently characterized to provide a population distribution such as the median and upper percentiles (90th or 95th percentile) or bounding estimates (99th or 99.9^{th} percentile). It is essential to understand how these distributions were derived. Distributions derived from consumers and nonconsumers of fish have different meanings and applications.

Summary of Potential Bias/Variability. Contributors to bias and hence different levels of variability and uncertainty are associated with a variety of factors. Some of these factors include:

- Survey methodology and design and execution.
- Response rates, literacy, language barriers, and cultural sensitivities.
- Coding errors, interviewer bias, different efforts by interviewers or respondents, cultural differences in interpretation, and recall bias.
- The working and sequencing of questions can affect responses.
- Accurately representing the target population.
- Unknown factors such as number of consumer in a household or amount of fish obtained and eaten.
- Different methods of analysis may yield different fish consumption estimates from the same dataset.

Specific for the Pacific Northwest fish-consuming populations, the EPA Region 10 framework highlighted uncertainties inherent with the application of the framework. Most of these uncertainties are not just related to the application of the EPA Region 10 framework but are associated with the uncertainties characteristic of fish consumption related information. Some of these uncertainties include:

- Use of a tribe-specific fish and shellfish consumption study as a surrogate for another Tribe's consumption rate.
- The degree to which traditional ways of life or subsistence fish and shellfish consumer are included in existing tribe consumption studies.
- Percentage of consumed fish and shellfish assumed to be adversely affected by site-related contamination.

- Exclusion or inclusion of salmon – the exclusion or inclusion of risks associated with salmon consumption on a contaminant/site-specific basis.
- Use of national fish/shellfish consumption data to characterize Washington fish-consuming populations.
- Consideration of vulnerable individuals and exposures to chemicals with selective toxicological endpoints.
- Use of uncooked fish/shellfish rates as representative of weight of fish/shellfish consumed.
- Exposure to contaminant in fish/shellfish other than by the consumption of contaminated fish.

Estimated United States per capita fish consumption

The EPA 2002 national estimates for fish consumption are based on analysis of the U.S. Department of Agriculture's 1994–96 *Continuing Survey of Food Intakes by Individuals* (CSFII) and its 1998 *Children's Supplement*. [119] (These USDA reports are collectively referred to as CSFII 1994–1996, 1998).

The USDA surveys were designed to provide estimates of food consumption across the United States and were conducted in all 50 states and Washington, D.C. They include consumers and nonconsumers and provide data for federal activities related to the nutritional status of the U.S. population. [120]

Over 20,000 survey participants provided two nonconsecutive days of dietary data. The 24-hour dietary recall survey was administered over a period of 4 years. (The survey was designed so that the second interview occurred three to ten days after the first interview but not on the same day of the week.)

The CSFII was conducted by interviewing respondents according to a stratified design that accounted for geographic location, degree of urbanization, and socioeconomics. Eligibility for the survey was limited to households with gross incomes at or less than 130 percent of the federal poverty guidelines. Survey weights were assigned to this dataset to make it representative of the U.S. populations.

The CSFII is the primary source of food consumption data used in dietary risk assessments. It is well suited to national-level dietary risk assessments, because it is statistically designed to

[119] EPA, *Estimated Per Capita Fish Consumption,* 2002.

[120] By definition, per capita fish consumption includes consumers and nonconsumers of fish. The per capita survey methodology is different than the Pacific Northwest fish dietary recall studies and is discussed below.

sample individuals of all ages and major ethnic subgroups to reflect various demographics. The CSFII is statistically designed so that the national estimate of consumption is not biased by seasons of the year or regions of the country. [121] The CSFII may be considered a variation of the dietary market basket survey approach but on a larger-scale with a more sophisticated design and execution.

Ecology notes, however, that the survey methodology limits its use. In particular, participants who did not eat fish on either of the two days surveyed would be considered nonconsumers. Consumption (or nonconsumption) rates for individual consumers were assumed to be their consumption rates for every day of the year. The resulting values may not be representative of long term consumption rates that have been averaged over time and presented as daily rate.

By definition, per capita fish consumption rates reflect fish dietary habits averaged over the general U.S. populations. Hence, per capita fish consumption rates do not necessarily describe actual fish consumption by consumers of fish and shellfish.

Although fish consumption rates derived for consumers would be preferable to per capita rates in describing the consumption of fish and shellfish in the U.S., there are limitations when "consumer only" rates are derived from national per capita surveys:

- The amount of fish and shellfish that a respondent ate on a given day during the two nonconsecutive days of the survey period would not be equivalent to the meal size when the amount of fish consumed is divided by the number of survey-period days for longer term fish dietary recall surveys.
- Although fish consumption estimates based on "consumers only" may be reported as grams/day, the fish consumption estimates are not actually representative of long-term consumption rates that have been averaged over times and presented as a daily rate.
- People who typically consume fish and shellfish, but did not do so during one of the two nonconsecutive days of the survey period were not captured by the survey and, thus, did not contribute to the national fish consumption estimates.
- It is not possible to determine the percentage of the fish- and shellfish-consuming population that was missed or whether the respondents who did consume fish or shellfish during the survey two nonconsecutive day reporting period adequately represents the total fish and shellfish consuming U.S. populations.

Ecology acknowledges the difficulty in evaluating the data from the EPA 2002 per capita estimates. We have considered this information in helping to estimate the number of fish consumers in Washington but not in estimating a fish consumption rate. We have also used the

[121] EPA, *General Principles for Performing Aggregate Exposure and Risk Assessments*, Office of Pesticide Programs, November 28, 2001, http://www.epa.gov/oppfead1/trac/science/aggregate.pdf.

per capita data to define high fish consumers in order to approximate the number of high fish consumers among the general population.

Consistent with EPA recommendations, Ecology prefers to rely on regional-specific survey information to develop fish consumption rates for Washington fish-consuming populations.

Summary and conclusions

Ecology reviewed fish/shellfish dietary survey information and fish consumption related information relevant to fish-consuming populations for Washington.

Ecology identified four surveys as appropriate for use in establishing a technically defensible default fish consumption rate (or rates) for use in Washington:

- Two Native American fish/shellfish dietary surveys for three tribal populations in Puget Sound
- One Native American finfish dietary survey for four tribal populations in and around the Columbia River basin
- One Asian and Pacific Islander fish/shellfish dietary survey from King County

These surveys provide fish and shellfish dietary information for fish-consuming populations for Washington and identify and quantify consumption habits.

The dietary survey methodologies employed are well documented, provide quantifiable dietary information useful for risk-based decision making, and include sufficient information to provide percentile fish consumption estimates. Ecology believes that these surveys provide sufficient information about fish consumption in Washington and can be used in establishing a default fish consumption rate (or range of rates) protective of high fish consumers and applicable for regulatory decision making.

Table 21. Summary of Fish Consumption Rate Surveys Considered by Ecology

	Population Surveyed	Type of Fish Included in Survey	Number of Adults Surveyed	Descriptive Statistics (g/day)					
				Mean	Median	Percentiles			
						75th	90th	95th	99th
Data from dietary recall surveys	Tulalip Tribe	* Finfish (anadromous & estuarine) * Shellfish	73	72	45	85	186	244	312
	Suquamish Tribe	* Finfish (anadromous & estuarine) * Shellfish	284	214	132	-[a]	489	-	-
	Squaxin Island Tribe	* Finfish (anadromous & estuarine) * Shellfish	117	73	43	-	193	247	-
	Columbia River Tribes	* Finfish (anadromous & freshwater)	512	63	40	60	113	176	389
	Asian & Pacific Islanders	* Finfish (anadromous & estuarine) * Shellfish	202	117	78	139	236	306	-

Source: Adapted from Table 3, page 28, Human Health Focus Group Report, Oregon Fish and Shellfish Consumption Rate Project, Oregon Department of Environmental Quality, June 2008. [122]

[122] To provide context and comparison with Pacific Northwest fish dietary information, the Oregon DEQ Human Health Focus Group Report included U.S. general adult fish consumption rate information: 90th percentile of 248 grams per day, 95th percentile of 334 grams per day, and 99th percentile of 519 grams per day.

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Chapter 5: Regulatory Context for Using Fish Consumption Rates

Introduction

Ecology currently establishes water quality requirements (water quality standards, surface water cleanup standards, and sediment cleanup standards) based on protecting human health under both the MTCA and the Water Pollution Control Act.[123]

The fish consumption rate used to establish these requirements can make a significant difference in the stringency of the requirements. This chapter briefly summarizes the regulatory frameworks and policies of the:

- MTCA Cleanup Regulation.[124]
- Sediment Management Standards.
- Water Quality Standards for Surface Waters.

This chapter discusses the use of fish consumption rates by EPA and DOH and provides fish consumption rates used in various regulatory contexts in Washington. [125] It also includes background information on the different approaches used in various regulatory contexts. MTCA provides a default fish consumption rate for use in setting surface water cleanup standards and allows the setting of site-specific fish consumption rates if sufficient information exists. The Sediment Management Standards are silent on specifics of protecting human health from contaminated sediments; the Water Quality Standards for Surface Waters use a fish consumption rate specified in the National Toxics Rule. EPA Region 10 provides a framework for site-specific CERCLA cleanup discussions, and DOH issues health advisories based, in part, on fish consumption rates.

This report does **not** examine the implications or results of updating the fish consumption rates in these various regulations. This report is focused solely on the data available on fish consumption in the state of Washington. Other materials being prepared concurrently will examine in detail the policy considerations and implications.

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[123] 70.105D Revised Code of Washington (RCW) and 90.48 RCW.

[124] Work on updating the MTCA Cleanup Regulation is on hold pending Executive Order 10-06, suspending for one year non-essential rulemaking (November 2010).

[125] In this report, the terms “rule” and “regulation” are used interchangeably.

The Model Toxics Control Act Cleanup regulation

The *reasonable maximum exposure* as defined in the MTCA Cleanup Regulation forms the basis for establishing cleanup levels protective of human health.

The MTCA Cleanup Regulation includes methods and policies for establishing cleanup standards.[126] MTCA cleanup standards are designed to protect both the general population and people who are more highly exposed and/or susceptible to the effects of hazardous substances (pregnant women, children, unborn children, etc.).[127] MTCA cleanup standards must be at least as stringent as applicable state and federal requirements (such as drinking water standards and surface water standards) and risk-based standards calculated using equations in the MTCA Cleanup Regulation.

Under MTCA, risk-based surface water cleanup levels (for carcinogenic risks) are calculated according to Figure 1 below. Key features of the MTCA equations include:

- Cleanup standards for individual chemicals are generally based on an incremental cancer risk of 1 in 1 million and, for noncancer risks, a hazard quotient of 1.
- Cleanup standards are generally calculated using toxicity values (cancer slope factors and reference doses) developed by EPA or other environmental agencies.
- Cleanup standards are based on estimates of RME.

$$CUL = \frac{(RISK * ABW * AT * UCF1 * UCF2)}{(CPF * FCR * FDF * ED * EF)}$$

Where:

CUL	=	Surface water cleanup standard (µg/L)
RISK	=	Acceptable cancer risk level (1 in 1,000,000) (unitless)
ABW	=	Average body weight during the exposure duration (70 kg)
AT	=	Averaging time (75 years)
UCF1	=	Unit conversion factor (1,000 µg/mg)
UCF2	=	Unit conversion factor (1,000 grams/liter)
CPF	=	Carcinogenic Potency Factor as specified in WAC 173-340-708(8) (kg-day/mg)

Figure 1. MTCA Surface Water Cleanup Standards (Carcinogenic Risk)

[126] Chapter 173-304 WAC.

[127] Washington State Department of Ecology, *Concise Explanatory Statement, MTCA Cleanup Regulation*, February 12, 2001, page 119.

Reasonable maximum exposure defined under MTCA

The MTCA Cleanup Regulation defines the RME as "the highest exposure that is reasonably expected to occur at a site under current and potential future site use."[128]

- The RME is designed to represent a high-end (but not worst-case) estimate of individual exposures.[129] It provides a health-protective estimate that falls within a realistic range of exposures.[130] For example, the preamble to the National Oil and Hazardous Substances Pollution Contingency Plan includes the following guidance:

  "EPA defines *reasonable maximum* such that only potential exposures that are likely to occur will be included the in the assessment of exposures. The Superfund program has always designed its remedies to be protective of all individuals and environmental receptors that may be exposed at a site; consequently, EPA believes it is important to include all reasonably expected exposures in its risk assessments…"

- The RME is defined as reasonable because it is a product of several factors that are an appropriate mix of average and upper-bound estimates. RME estimates typically fall between the 90th and 99.9th percentile of the exposure distribution.[131] [132]

- The RME takes into account both current and reasonably foreseeable future conditions.[133]

Under the current MTCA rule, surface water cleanup standards are established based on a default fish consumption rate of 54 g/day.[134] This default parameter used in establishing surface water cleanup standards is based on a recreational angler exposure scenario developed by Ecology the 1980s.

In 2008, Ecology asked the MTCA Science Advisory Board for advice on a site-specific fish consumption rate applicable to a cleanup action being conducted in the Port Angeles Harbor. The harbor is located within the usual and accustomed fishing area for the Lower Elwha Klallam Tribe.[135] The board agreed with Ecology's conclusion that the recreational default fish

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[128] See WAC 173-340-708 (3) (b). CERCLA provides a similar definition "…the highest exposure that is reasonably expected to occur at a Superfund site…"

[129] The worst-case exposure represents an extreme set of exposure conditions, usually not observed in an actual population, which is the maximum possible exposure where everything that can plausibly happen to maximize exposure does happen. This is discussed in EPA's *Guidelines for Exposure Assessment*, Federal Register Vol. 57, No. 104, May 1992, pages 22888-22938.

[130] EPA, *An Examination of EPA Risk Assessment Principles and Practices*, EPA/100/B-04/0001, March 2004.

[131] EPA, *An Examination of EPA Risk Assessment Principles and Practices*, 2004.

[132] Based on Ecology's analysis (see Appendix C) the 90th to 95th percentile of the exposure distribution falls between 210 and 267 grams per day.

[133] Washington State Department of Ecology, *Responsiveness Summary to the MTCA Cleanup Regulation*, 1991.

[134] The fish diet fraction is defined under MTCA as the fraction of the fish consumed estimated to come from the site.

[135] MTCA Science Advisory Board (SAB), Meeting Notes for SAB Meetings held December 14, 2007 and March 11 and June 2, 2008, http://www.ecy.wa.gov/programs/tcp/SAB/SAB_mtg_info/mtg_info.htm.

consumption rate currently used in MTCA rule does not represent an RME for Native American populations who typically eat higher amounts of fish and shellfish.

In 2005, Ecology asked the MTCA Science Advisory Board for advice on applying the API fish consumption dataset for cleanup actions considered for the Lower Duwamish Waterway. The Lower Duwamish Waterway is home to API populations that may harvest and consume fish from the waterway. EPA Region 10 conducted a reanalysis that corrected for cooking weight loss, regional seafood harvesting, and extrapolation from the survey dataset to King County API populations (Kissinger, 2005).[136] The resulting API fish consumption rates from the EPA reanalysis are provided elsewhere in this document.

Sediment management standards

The SMS were adopted in 1991 to implement Ecology's responsibilities to clean up contaminated sediments at hazardous waste sites under the Model Toxics Control Act.[137] Part V of the SMS rule establishes requirements for sediment cleanup standards; sediment cleanup actions conducted under an MTCA order, agreed order, or consent decree must comply with requirements in both the SMS rule and the MTCA Cleanup Regulation.

The SMS rule at 173-204-570 WAC identifies the sediment cleanup objective as "no significant health threat to humans." No details are provided in the SMS rule to determine sediment cleanup levels that are protective of human health. However, because both MTCA and SMS rules apply, sediment cleanup standards protective of human health are based on the MTCA Cleanup Regulation using MTCA acceptable risk levels and the highest concentration of:

- Risk-based cleanup concentration for the most sensitive receptor.
- Natural background concentration – a background concentration or background area not influenced by localized human activities.
- Practical quantitation limit – lowest concentration that can be reliably measured within specified limits of precision and accuracy.

Sediment cleanup levels protective of human health account for both potential contaminant bioaccumulation from contaminated sediments and the consumption of potentially contaminated fish. To derive most sediment cleanup levels protective of human health, Ecology considers recreational and tribal harvesting and consumption practices.

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[136] Application of data from an API seafood consumption study to derive fish and shellfish consumption rates for risk assessment. Office of Environmental Assessment, US Environmental Protection Agency Region 10, Seattle, WA.)

[137] Chapter 173-340 WAC.

Water quality standards

Washington's water quality standards for human health protection were issued to the state by EPA in 1992 (National Toxics Rule, 40 CFR 131.36) and further revised in 1999 (PCB criteria only). The human health-based ambient water quality criteria in the National Toxics Rule were calculated using a fish consumption rate of 6.5 g/day.

EPA completed the technical evaluations underlying the National Toxics Rule in the mid-1980s and early 1990s. Since then, EPA has revised its guidance for developing human health-based criteria and currently recommends using a higher default fish consumption rate (17.5 g/day developed for national use) (EPA, 2000).

Local or state-specific data is sometimes more appropriate to use in criteria calculations if fish and shellfish consumers ingest amounts of tissue in excess of the national default value. Current studies of fish consumption in the Pacific Northwest show that fish and shellfish consumers in Washington eat substantially more than the national default of 17.5 g/day, indicating that use of state-specific data should be considered as criteria are further examined.

Ambient water quality criteria are established under Section 304(a) of the Clean Water Act (CWA) of 1972 and are used by states and tribes to establish water quality standards that provide a basis for controlling discharges or releases of pollutants.[138] Ambient water quality criteria do not reflect considerations of economic impacts or the technological feasibility of reducing chemical contaminant concentrations in ambient water.[139]

EPA outlines a four-preference information hierarchy for states and authorized tribes to follow when deriving fish consumption rates (EPA, 2000). This hierarchy encourages the use of regional specific fish dietary information. Local data is preferred first, followed by (2) data reflecting similar geography and population groups, (3) data from national surveys, and (4) EPA's default fish consumption rates. EPA recommends that states and authorized tribes use either high-end values (such as 90th or 95th percentile values) or average values for an identified population that they plan to protect. EPA further recommends that arithmetic mean values be the lowest values considered when selecting fish consumption rates for regulatory purposes. When high-end values from regional specific studies are chosen, EPA recommends that they be compared with high-end fish intake rates for the general population. This comparison checks that

[138] EPA, *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health – Revised Methodology*, Fact Sheet, October 2000, http://water.epa.gov/scitech/swguidance/waterquality/standards/criteria/health/methodology/factsheet.cfm.

[139] EPA, *Aquatic Life Ambient Water Quality Criteria for Ammonia Update*, Fact Sheet, December 1999, http://water.epa.gov/scitech/swguidance/waterquality/standards/criteria/aqlife/pollutants/ammonia/Technical.cfm.

high-end consumers within the general population are protected by the selected fish consumption rates.[140]

EPA Region 10 framework

EPA Region 10 has published a decision-making framework to derive fish/shellfish consumption rates to help support the cleanup of contaminated sites in Puget Sound and the Strait of Georgia up to the Canadian border.[141] (See also Appendix D.) The framework provides EPA with a consistent starting point for consultations with tribes and in discussions regarding cleanup.

The framework was developed to aid decision making given limited site-specific seafood consumption information that could support regulatory cleanup decisions on hazardous waste sites located on tribal lands or within tribal fishing areas. The application of the EPA Region 10 framework provides a consistent and protective approach to establishing fish consumption rates for fish-consuming populations.

Similar to the tiered information hierarchy used in EPA 2000, the EPA Region 10 framework identifies a hierarchy of preferred data to be used:

- Fish/shellfish consumption surveys from local watershed representative of the population being addressed for a water body
- Fish/shellfish consumption surveys that reflect geography or population groups similar to those under evaluation
- National food consumption survey information
- Default values

The EPA Region 10 framework uses the seafood consumption information from the Suquamish and the Tulalip Tribes to support the development of fish consumption rates for other tribal or fish-consuming populations.[142] The selection of the Suquamish or the Tulalip consumption information to be used as a surrogate for other tribal or fish-consuming populations depends on the following:

- Fish/shellfish habitat quality
- Fish/shellfish habitat quantity

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[140] U.S Environmental Protection Agency, Office of Water and Office of Science and Technology. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000) EPA-822-B-00-004. October 2000.

[141]. EPA Region 10, *Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates,* 2007.

[142] Toy, K.A., et al., *A Fish Consumption Survey of the Tulalip and Squaxin Island Tribes*, 1996.

- Careful consultation with fish/shellfish tribal biologists to make an informed decision regarding the selection of the dataset
- Historical patterns of fish/shellfish abundance and habitat quality

Selection of the Suquamish Tribe's dataset is most applicable to cleanup sites with extensive current or potential high-quality intertidal habitat to sustain shellfish harvests. Selection of the Tulalip Tribe's dataset is most applicable where there is less shellfish habitat to sustain shellfish harvests. The EPA Region 10 framework assumes all of the fish/shellfish harvested from the Puget Sound may be affected by site contaminants. However, unless there is site-specific information attributing salmon contaminant body burden to site contaminants, salmon are not included in the overall fish consumption rate.

Consistent with EPA regulatory policies, procedures, and guidance, the fish consumption rates used in the Region 10 framework were based on the 95th percentile from the Suquamish or Tulalip consumption dataset (uncooked weight, harvested from Puget Sound). The fish consumption rates are categorized for various species: salmon, pelagic fish, bottom fish, and shellfish. The total fish/shellfish ingestion rates for the two tribes are adjusted to include only fish and shellfish harvested from Puget Sound.

The table below provides the Tulalip Tribe's fish consumption rate and percent of diet assumed by the species tabulated in the EPA Region 10 framework. The total unadjusted fish/shellfish consumption rate for the Tulalip Tribe is 243 g/day. The average Tulalip adult body weight used to derive the grams/day fish consumption rate was 81.8 kilograms.

Table 22. Tulalip Tribe's Fish Consumption Rate (grams/day)

Species Category	Fish Consumption Rate	Percent of Diet
Salmon	96.4	49.7
Pelagic fish	8.1	4.2
Bottom	7.5	3.9
Shellfish	81.9	42.2
Total ingestion rate with salmon	194	100
Total ingestion rate without salmon	98	

Source: U.S. Environmental Protection Agency. 2007. *Region 10 Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia.*" August. Adapted from Table B-1.

The table below provides the Suquamish Tribe's fish consumption rate and percent of diet assumed by the species tabulated in the EPA Region 10 framework. The total unadjusted fish/shellfish consumption rate for the Suquamish Tribe is 796 g/day. The average Suquamish Tribe adult body weight used to derive the grams/day fish consumption rate was 79 kilograms.

Table 23. Suquamish Tribe's Fish Consumption Rate (grams/day)

Species Category	Fish Consumption Rate	Percent of Diet
Salmon	183.5	23.9
Pelagic fish	56.0	7.3
Bottom	29.1	3.8
Shellfish	498.4	65
Total ingestion rate with salmon	766	100
Total ingestion rate without salmon	583	

Source: U.S. Environmental Protection Agency. 2007. *Region 10 Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia.*" August. Adapted from Table B-1.The EPA Region 10 framework has been applied to support the cleanups of several Washington sites:

- The Lower Duwamish Waterway and associated sites along the waterway
- Port Angeles ITT Rayonier
- Risk-based screening levels for Puget Sound Naval Shipyard

Accounting for exposure

Different approaches are used by different federal and state regulatory programs to account for patterns of exposure from different sources or to estimate the contribution of contaminants to food sources. A complete human exposure assessment would account for estimates of exposure to environmental contaminants from multiple sources including ambient water and consumption of fish and shellfish.

Three approaches are used in Washington in a regulatory context: relative source contribution, source contribution (or site use), and the MTCA fish diet fraction. These regulatory tools for evaluating exposures impact the discussion regarding exposure from salmon. Anadromous fish spend most of their lives in open marine-ocean environments where they accumulate most of their contaminant body burden. Bioaccumulative contaminant body burdens in adult salmon are primarily attributable to migratory behaviors located beyond reach of Washington regulations. Consequently, estimated risks associated with the consumption of adult salmon may be unrelated to site-specific contaminants.

Relative source contribution

EPA applies a relative source contribution stimate when establishing water quality standards protective of human health for some noncarcinogens.[143] The relative source contribution allocates the estimated oral exposure to the contaminant from drinking water and/or the consumption of fish alone. The relative source contribution (RSC) estimate is applied to ensure that the level of a contaminant in drinking water or ambient waters, when combined with other sources of exposure, will not result in a total exposure for an individual that exceeds the reference dose or some other allowable daily intake rate. The RSC is included in the calculation of only 17 of the current EPA recommended criteria.

Noncarcinogenic toxicological endpoints are set at a level believed to represent a minimal risk of a deleterious effect from a lifetime exposure even for sensitive populations. EPA assumes that such noncarcinogenic endpoints have a threshold response (that is, there is a dose below which the toxic effects will not occur). EPA does not use relative source contribution estimates for carcinogens because EPA assumes there is no safe level of exposure to a carcinogenic substance.

The relative source contribution estimate has a significant impact on health regulatory reference levels or standards for contaminants with noncancer adverse health effects. Lower relative source contributions result in lower (and more protective) regulatory standards. Conversely, higher relative source contribution estimates result in higher (and less protective) standards.

EPA uses two methods to estimate the relative source contribution to establish regulatory standards for surface waters or other allowable daily intakes. The percentage method compares multiple sources of exposure with one another to estimate their relative contribution to the total. The subtraction method allocates the entire reference dose to the known sources of exposure by subtracting the known nontarget sources of exposure and allocating the remainder of the reference dose to the target sources of exposure, such as drinking water or ambient water quality criteria.

Source contribution or site use factor

Source contribution refers to the percentage of consumed fish and shellfish that may be affected by site-related contaminates. The site use factor is the percent contribution of the site to the contaminant body burden of fish caught on or near the site. This is particularly relevant when considering risks from the consumption of salmon where the contaminant body burden may or may not be attributable to site-related contaminants.

EPA Region 10 made a risk management decision to exclude the consumption of adult salmon when assessing the risks from the Lower Duwamish Waterway. A human health risk assessment

[143] U.S. EPA. Office of Science Technology and Office of Water, Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health. EPA-822-B-00-004 (Washington DC, October 2000).

concluded that bioaccumulative chemical concentrations in adult salmon are not attributable to the contaminants in the Lower Duwamish Waterway.[144]

> "The adult salmon that migrate through the Duwamish estuary on their way to upstream spawning areas were exposed to chemicals within the LDW very briefly as juveniles. In addition, adult salmon could be exposed to chemicals transported from the LDW to Puget Sound. The magnitude of such exposure is highly uncertain but is likely to be small relative to other Puget Sound sources. The contribution of these exposures to adult body burdens is likely to be insignificant because the large majority of a salmon's growth occurs in Marine waters outside the LDW (O'Neill et al. 1998). [145] … less than 1% of the PCB body burden contained in adult salmon migrating through the LDW could have been obtained from prey items consumed in the LDW. Therefore, because this assessment is focused on the evaluation of risks from exposures to chemicals related to the LDW system, adult salmon were not included in the HHRA."

The EPA Region 10 framework explicitly recognizes source contribution issues by adjusting the Tulalip and Squaxin Island fish consumption rates to account for fish harvested and consumed from Puget Sound.[146]

The framework notes the complexities associated with salmon and sediment contamination when considering the exclusion or inclusion of risk associated with salmon consumption.

> "This Framework allows exclusion of risks associated with salmon consumption if warranted by site-specific and chemical-specific circumstances, particularly for persistent and bio-accumulative contaminants. Some of the uncertainties in this exclusion arise from the degree of historical contaminant transport offsite and from salmon residence time near the site.
>
> PCBs and other bio-accumulative and persistent chemicals found in contaminated sediments can be moved from their site of release via erosion, dredging, tidal currents, flood events, and vapor transport. Offsite transport is also possible when aquatic organisms become contaminated near a cleanup site and then migrate to distant locations, where they contribute to food chain effects that eventually affect fish, including adult salmon. However, adult salmon body burdens of bioaccumlative and persistent

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[144] Lower Duwamish Waterway Remedial Investigation. Remedial Investigation Report Appendix B: Baseline Human Heralth Risk Assessment, Final. US Environmental Protection Agency, Region 10, and Washington State Department of Ecology, NW Regional Office. Novmeber 12, 2007.

[145] O'Neill SM, West JE, Hoeman JC 1998. Spatial trends in the concentration of polychlorinated biphenyls (PCBs) in Chinook (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) in Puget Sound and factors affecting PCB accumulation: Results from the Puget Sound Ambi9ent Monitoring Program. Puget Sound Research 1998: 312-328.

[146] U.S. EPA Region 10. Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia. August 2007.

> contaminants typically come from many sources and cannot currently be apportioned with confidence to specific locations. An assumption that contaminants present in harvested salmon are not associated with the site, even when the same chemicals have been released from the site, is likely to underestimate the site's contribution to risks from consuming such fish. The degree of underestimation is unknown."[147]

Fish diet fraction

Fish diet fraction is defined by the MTCA cleanup regulation as "the percentage of the total fish and/or shellfish in an individual's diet that is obtained or has the potential to be obtained from the site."[148] It is the percentage of fish caught near the site in relation to the total amount of fish ingested. Fish diet fraction is used for human health risk evaluations only. MTCA assumes that 50 percent of the total fish and/or shellfish in an individual's diet is obtained or has the potential to be obtained from the site when calculating surface water cleanup levels.

The MTCA rule provides the flexibility to modify the fish diet fraction to establish surface water cleanup standards more protective of human health.

On a site-specific basis, factors considered when selecting a fish diet fraction for a particular fish consuming population include:

- Current tribal fish and shellfish harvesting and consumption habits and patterns.
- Reasonably anticipated future tribal fish and shellfish harvesting and consumption habits and patterns.
- Legal agreements, advisories, or restrictions that define or limit fish and shellfish harvesting at particular sites or areas.
- Sustainable levels of fish and shellfish harvesting relative to the fish consumption rates used to estimate tribal fish consumption exposures.
- Federal and state regulations and guidance materials.
- The combination of parameters used to estimate RME.
- Other factors that may need to be considered on a site-specific basis.

Fish diet fraction may be different for different types of fish—salmon, pelagic fish, bottom fish, and shellfish. Anadromous salmonids that migrate to the ocean are typically assumed to spend minimal time at a site due to their life history and, thus, site-specific contaminants may not be attributable to salmon contaminant body burdens. For site-specific and chemical-specific evaluations, anadromous salmonids may be excluded from the human health exposure and risk assessments.

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[147] IBID, pages 23 and 24.

[148] WAC 173-340-200 MTCA Definitions

For shellfish, one may also consider the potential future use of the site for shellfish habitat. Considerations of habitat quality, productivity, and limits of sustainable harvest rates may be taken into consideration, as well as site-specific information on harvesting patterns and habits. Use of a fish diet fraction of 1 in combination with Suquamish consumption rates could lead to exposure estimates that fall above the 95th percentile generally used by Ecology when establishing cleanup levels based on RME.

Regulatory use of fish consumption rate data by EPA

In 2002, EPA updated the *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health.* Based on the *Continuing Survey of Food Intakes by Individuals (*CSFII 1994-1996, 1998) EPA now recommends the following default fish consumption rates:[149]

General population: 17.5 g/day

Recreational fishers: 17.5 g/day

Subsistence fishers: 142.4 g/day

Children (protective of noncancer health effects): 156.3 g/day

Children (based on developmental toxicity): 235 g/day

EPA's default value for the general population and recreational fishers of 17.5 g/day reflects the 90th percentile values for freshwater and estuarine ingestion by adults from the USDA's CSFII Survey for the years 1994 to 1996.

Washington State Department of Health fish advisories

DOH fish advisories provide information about how much fish or shellfish can be safely consumed. This amount depends on contaminant levels in commercial, sport, or subsistence caught fish.

To answer these questions, DOH utilizes guidelines outlined in EPA's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories Vol. 1-4* for assessing mercury, PCBs, and other contaminants to determine whether an advisory is warranted.[150] These guidelines provide a framework from which states build and develop state or regional fish advisories based on sound science and established risk assessment paradigms. Fish tissue evaluation involves several steps: risk assessment, risk management, and risk communication.

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[149] EPA, *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health,* 2000.

[150] National Guidance: Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories – Vol. 1-4. http://water.epa.gov/scitech/swguidance/fishshellfish/outreach/es.cfm

- *Risk assessment* involves calculating allowable meal limits based on known fish contaminant concentrations. These calculations are conducted for both noncancer and cancer endpoints using the appropriate reference dose (RfD) or cancer slope factor (CSF), if available. These initial calculations are the starting point for evaluating contaminant data to determine whether a fish advisory is warranted. Additionally, known or estimated consumption rates help determine the potential magnitude of exposure and highlight the sensitive groups or populations that may exist due to elevated consumption rates.
- *Risk management* includes (but is not limited to) consideration of contaminant background concentrations, reduction in contaminant concentrations through preparation and cooking techniques, known health benefits from fish consumption, contaminant concentrations or health risks associated with replacement foods, and cultural importance of fish. Other considerations are possible health endpoints associated with a contaminant, strength or weaknesses of supporting toxicological or sampling data, and whether effects are transient or irreversible.
- *Risk communication* is the outreach component of the fish advisory. Interpretation of data from the risk assessment and risk management components drives how and when fish advisory recommendations are issued to the public, dependent on whether the message is targeted toward a sensitive group or a population or the general public. DOH's dual objective in communicating is determining how best to provide guidance to the public to increase fish consumption of fish low in contaminants, to gain the benefits of eating fish, while at the same time steering the public away from fish that have high levels of health-damaging contaminants.

At present, DOH has issued 14 fish consumption advisories, which include Puget Sound, and two statewide mercury fish advisories. As EPA guidance recommends, DOH does not configure fish advisories based on a specific default fish consumption rate. They use fish consumption rates for screening potential exposures and to estimate potential risks. DOH bases their advisories on noncancer effects.

DOH has also developed the "Healthy Fish Guide," designed to increase public awareness of many commercial and recreational fish choices that exhibit low contaminant concentrations in fish tissue. The guide also identifies fish that should be avoided due to high mercury or PCB levels, communicates the benefits of eating fish, and reminds consumers that eating fish at least two times a week is important for maintaining good health.[151]

DOH provides support documentation for all fish advisories issued throughout Washington. For example, the "Lake Whatcom Fish Advisory" issued by DOH in May 2001 has a companion support document, *Lake Whatcom Residential and Angler Fish Consumption Survey*.[152,153]

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[151] Washington State Department of Health Healthy Fish Guide. http://www.doh.wa.gov/ehp/oehas/fish/fishchart.htm

[152] Washington State Department of Health. Data Report: Lake Whatcom Residential and Angler Fish Consumption Survey. April 2001.

[153] Washington Department of Health. Lake Whatcom Fish Advisory. May 2001

Washington fish consumption advisories and companion support documents provide information on finfish and/or shellfish species, finfish and/or shellfish tissue contaminant levels, and fish consumption for anglers associated with the specific water body being evaluated. In addition, most DOH documents provide fish consumption information gathered from residents who live on or near the water body, from residential developments with access to the water body, or from shore or boat anglers.

Because information collected by DOH is specific to a particular water body and is based on creel surveys, most consumption data is not suitable or designed for the quantitative assessments that provide percentile distributions.

In addition, surface water and sediment cleanup standards developed by Ecology are designed to be protective for unrestricted harvest of fish/shellfish and unrestricted consumption of fish/shellfish. DOH health advisories provide fish consumers with advice on the number of fish meals that can be safely eaten on a weekly or monthly basis and/or fish to be avoided.

Despite these programmatic differences, Ecology acknowledges that DOH fish advisories provide important information on fish/shellfish species and consumption for different water bodies throughout Washington. (Information from selected DOH advisories is provided below.)

Examples of fish consumption rates used in various regulatory contexts

A wide range of fish consumption rates have been used in a regulatory context both for establishing cleanup standards and for developing tribal water quality standards. The lists included here are intended to demonstrate the wide range used in Washington regulatory decisions. This variability has contributed to Ecology proposing a default value for use in regulatory decision making.

Although site-specific data may be available and appropriate for certain situations, Ecology believes that many cleanup decisions can be based on a default fish consumption rate and will result in health-protective cleanup standards.

Table 24. Examples of Fish Consumption Rates and Regulatory Context

Rate (grams/day)	Context
6.5	Rate used for the 1992 National Toxics Rule, ambient water quality criteria, from national nontribal food surveys.
17.5	Rate used for current EPA-recommended water quality criteria (recreational anglers and the general population).
54	MTCA default fish consumption rate based on recreational exposure. Note: MTCA specifies a fish diet fraction = 0.5.
57	API, fish diet fraction 1.0, body weight 63 kilograms, lower Duwamish.
~80	Rates used by Colville Tribe to develop water quality standards.
142	EPA-proposed average for tribal subsistence fishers—freshwater & estuarine, not marine waters. Value used by Oregon DEQ in their bioaccumulation guidance.
140-148	Rates used by Puyallup and Port Gamble Tribes to develop water quality standards.
173	Bellingham Bay – Whatcom Waterway Cleanup Action Plan, 90th percentile value from Tulalip and Squaxin Tribes for crab, bottomfish, clams, and mussels (70 g/day) + additional consumption of salmonid, pelagic, and freshwater fish.
175	Oregon DEQ fish consumption rate based on CRITFC data (approximates the 95th percentile) to establish human health water quality criteria.
194	Tulalip tribal rate applied to lower Duwamish without salmon; effective rate is 97.5, body weight 79 kilograms, fish diet fraction 1.0
389	99th percentile from CRITFC survey & used by Umatilla Tribes for tribal water quality standards.
540	Average for traditional Umatilla tribal fishing families.
583	Port Angeles cleanup, Lower Elwha Klallam rate based on Suquamish data, body weight 79 kilograms, fish diet fraction 1.0
620	Hanford Nuclear Reservation, applied within 20 miles of a major fishing river, 1.0 fish diet fraction, 70 kilograms body weight. This is equal to the Boldt decision historical rate for Columbia River mainstem.
650	Yakama tribal members using Columbia River for resident & anadromous fish.
1,000	Pre-dam rate for Columbia River Plateau Tribes.

Table 25. EPA Region 10 Tribal Fish Consumption Rates Related to Water Quality Standards[154]

Fish Consumption Rate (grams/day)	Tribe	Status of WQS
EPA-Promulgated Water Quality Standards (WQS)		
Narrative Criterion	Colville Tribe	No fish consumption rate revisions by EPA at this time, tribally adopted WQS (no toxics criteria) (6.5 grams/day--EPA AWQC 1989 (per e-mail from EPA, S.Brough to Ecology,C. Niemi, 2/25/08).
Tribes with EPA-Approved "Treated As State" (TAS) and EPA-Approved WQS		
6.5	Chehalis	TAS approved – 2/03/1997. No revisions to the FCR at this time (EPA's National Toxics Rule, 57 Federal Register 60848 [1992])
17.5	Kalispel	TAS approved – 6/24/2004. No revisions to the FCR at this time (EPA's National Toxics Rule & 2002 AWQC Update).
142.4	Makah	TAS approved – 9/29/2006. No revisions to the FCR at this time *(EPA default subsistence rate).*
142.4	Lummi	TAS approved – 9/30/2008. No revisions to the FCR at this time *(EPA default subsistence rate).*
142.4	Port Gamble S'Klallam	TAS approved – 9/27/2005. No revisions to the FCR at this time *(EPA default subsistence rate).*
6.5	Puyallup	TAS approved – 10/31/1994. Tribe conducted public review – proposed 142.4 grams/day (EPA's National Toxics Rule, 57 Federal Register 60848 [1992])
86.3	Spokane	TAS approved – 4/22/2003. Tribe adopted 865 g/day. Submitted to EPA April 2010 (63 Federal Register 43756 [1998][155]).
389	Umatilla	TAS approved – 2/11/2010. No revisions to the rate at this time (*Columbia Basin Fish & Wildlife News Bulletin*[156]).
170	Warm Springs	TAS approved – 7/20/2006 No revisions to the FCR at this time *(CRITFC Survey).*
Tribes with EPA-Approved "Treated As State" (TAS) and Tribally Adopted WQS		
66	Tulalip	WQS are tribally adopted but have not been submitted to EPA.
Tribes with EPA-Approved "Treated As State" (TAS) and in the Process of Developing WQS		
17.5	Coeur d' Alene	Submitted to EPA June 2010 (EPA's National Toxics Rule & 2002 AWQC Update).
Considering 214	Swinomish	Tribe preparing for public review.
Considering 17.5	Shoshone-Bannock	Tribe preparing for public review summer 2010 (EPA's National Toxics Rule & 2002 AWQC Update).
Tribes Developing WQS and "Treated As State" (TAS)		
142.4	Lower Elwha	WQS are tribally adopted; tribe is developing TAS application *(EPA default subsistence rate).*
Considering 17.5	Skokomish	Tribe is developing TAS application.
142.4	Yakama	WQS are tribally adopted (EPA Default Subsistence Rate).

[154] Information Provided at the EPA / Washington Tribes Annual Workshop. "Fish Consumption Rates: Effects on Tribes and Their Traditional Food." Held June 16, 2010 at the Suquamish Community House Co-Sponsored by the Northwest Indian Fisheries Commission and EPA Region 10.

[155] 63 Fed. Register 43768-43769(1998): The AWQC default fish consumption value of 17.80 grams/day is for the general adult population, which represents the 90th percentile consumption rate for the entire adult population and approximates the average consumption rate for sport anglers nationally. The 86.3 grams/day default value for subsistence fishers/minority anglers, represents the 99th percentile consumption rate for the general populations and falls within the range of averages for subsistence/minority anglers.

[156] The Columbia Basin Fish & Wildlife News Bulletin Posted March 12, 2010 on http://www.cbbulletin.com/379763.aspx

Table 26. EPA Region 10 State Fish Consumption Rates Related to Water Quality Standards

Fish Consumption Rate	State	Status of WQS
6.5	Alaska	Promulgated by EPA for carcinogens
6.5		Promulgated by EPA for noncarcinogens
6.5	Idaho	Adopted by Idaho and approved by EPA
17.5		Adopted and submitted by Idaho; no action by EPA
6.5	Oregon	Approved by EPA
17.5		Adopted and submitted by Oregon Disapproved by EPA, June 01, 2010
Considering 175		Will propose new rate January 2011
6.5	Washington	Promulgated by EPA
Considering new rate		Washington to initiate Triennial Review public meetings, fall 2010 (rate likely to be raised).

Summary and conclusions

This chapter provided a survey of fish consumption rates used in the Washington, including mention of EPA Region 10 framework for decisions at federal cleanup sites and DOH health considerations.

Washington's MTCA Cleanup Regulation, Sediment Management Standards, and Water Quality Standards for Surface Waters all use fish consumption rates as a parameter for developing standards protective of human health.

Cleanup standards developed under the MTCA Cleanup Regulation and Sediment Management Standards are based on exposure estimates defined as the RME. The RME is based on the most beneficial, unrestricted use of surface waters and currently assumes, for an adult, a fish consumption rate of 54 g/day.

Washington's numeric water quality standards for the protection of human health are established based on a 6.5-g/day fish consumption rate from the National Toxics Rule.

As shown in this chapter, a large range of fish consumption rates have been used in a regulatory context both for establishing cleanup standards and for developing tribal water quality standards. Recent revisions in various regulatory standards have generally resulted in adoption of higher fish consumption rates.

The remainder of this report focuses on a proposal for:

- A methodology for evaluating or setting site-specific fish consumption rates (Chapter 6).
- Identifying for consideration and discussion a range within which to develop one or more default fish consumption rates protective of Washington fish consumers (Chapter 7).

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Chapter 6: Site-Specific Fish Consumption Rates

Introduction

Cleanup decisions are largely based on preventing health risks associated with the consumption of contaminated fish and shellfish. For site-specific cleanup decisions, default parameters may have to be adjusted to account for specific needs related to the site.

Consistent with EPA guidance and policy and precedence established by Ecology for the cleanup of contaminated sites (Port Angeles-ITT Rayonier), the fish and shellfish habitat quality and abundance must be evaluated and considered when establishing a site-specific fish consumption rate for cleanup purposes.[157,158,159,160] Additional factors, such as how much fish consumed is attributable to the site (the fish diet fraction) and whether to include salmon in a fish consumption rate, may need consideration.[161,162]

Under the MTCA Cleanup Regulation, cleanup levels are based on estimates of the RME. [163]

- The RME is designed to represent a high end (but not worst case) estimate of individual exposures. It provides a conservative estimate that falls within a realistic range of exposures.[164]
- The RME is defined as reasonable because it is a product of several factors that are an appropriate mix of average and upper-bound estimates. RME estimates typically fall between the 90th and 99.9th percentile of the exposure distribution.[165]

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[157] EPA Region 10, *Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates,* 2007.

[158] EPA, *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health,* 2000.

[159] Washington State Department of Ecology, *Site-Specific Proposal for Modifying the Default MTCA Fish Consumption Exposure Parameters, Questions and Background Information*, prepared for the MTCA Science Advisory Board, March 2008, http://www.ecy.wa.gov/programs/tcp/SAB/SAB_mtg_info/mtg_info.htm.

[160] Washington State Department of Ecology, *Continuation of Site-Specific Proposal for Modifying the Default MTCA Fish Consumption Exposure Parameters, Factors to Consider for Inclusion/Exclusion of Salmon for Tribal Fish Consumption,* prepared for the MTCA Science Advisory Board, June 02, 2008, http://www.ecy.wa.gov/programs/tcp/SAB/SAB_mtg_info/mtg_info.htm.

[161] Washington State Department of Ecology, *Site-Specific Proposal for Modifying the Default MTCA Fish Consumption Exposure Parameters,* 2008.

[162] Washington State Department of Ecology, *Continuation of Site-Specific Proposal for Modifying the Default MTCA Fish Consumption Exposure Parameters*, 2008.

[163] MTCA defines the RME as the "…the highest exposure that can be reasonably expected to occur for a human or other living organisms at a site under current and potential future site use." CERCLA provides a similar definition "…the highest exposure that is reasonably expected to occur at a Superfund site…"

[164] EPA, *An Examination of EPA Risk Assessment Principles and Practices*, 2004.

[165] EPA, *An Examination of EPA Risk Assessment Principles and Practices*, 2004.

- The RME takes into account both current and reasonably foreseeable future conditions.

Under MTCA, the default fish consumption rate and fish diet fraction are based on a recreational angler exposure scenario. However, the rule provides the flexibility to establish more stringent cleanup levels when Ecology determines that such levels are "...necessary to protect other beneficial uses or otherwise protect human health and the environment..." (WAC 173-340-730(1)(e)).

This chapter identifies elements to consider in deriving a site-specific fish consumption rate protective of human health. It is organized around three questions:

- When is it appropriate to use a site-specific fish consumption rate?
- What factors must be considered in deriving site-specific fish consumption rate?
- What additional exposure parameters (i.e., fish diet fraction, exposure duration, body weight) should be considered when deriving a site-specific fish consumption rate?

When to use a site-specific fish consumption rate

A site-specific fish consumption rate may be needed when default exposure parameters do not adequately protect the fish-consuming population in question. This allows for consideration of exposure parameters tailored to a specific fish-consuming population within a particular watershed or water body. The goal is for regulatory decisions to be health protective and based on up-to-date information on contamination, exposure, fish dietary and habitats and patterns.

The EPA's Ambient Water Quality Criteria Methodology provides a useful hierarchy of fish consumption data for use in developing a site-specific fish consumption rate. [166] In order of preference:

- Consumption surveys representative of the population and watershed being addressed at the site
- Consumption surveys representative of similar populations and watersheds to those being evaluated
- National consumption data
- MTCA default values

[166] EPA, *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health,* 2000.

Ecology further believes that surveys used should adhere to the standards identified in previous chapters of this report. Using this hierarchy of fish consumption information in conjunction with an assessment of fish/shellfish habitat quality and quantity, the EPA Region 10 framework provides a method to determine a fish consumption rate in the absence of a fish/shellfish dietary survey for specific fish-consuming populations.[167]

The EPA Region 10 framework uses two well conducted fish/shellfish dietary surveys conducted in the Puget Sound area as surrogates for other fish-consuming populations based on consideration of fish/shellfish habitat quality and quantity. Using tribal fish consumption as an example of a fish-consuming population, Figure 2 below provides a brief over view of the decision logic of the Region 10 framework.

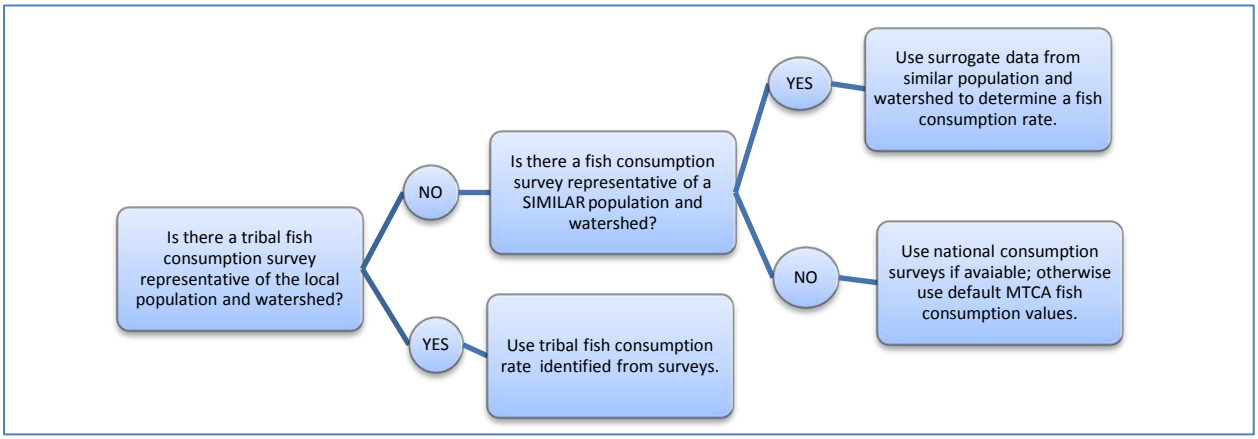

Figure 2. Decision Logic Overview

Ecology recognizes that in developing a site-specific rate it is important to consider the unique characteristics of the fish-consuming population. For example, for a site-specific fish consumption rate evaluation to support the cleanup of Port Angeles harbor area, exposure factors were evaluated for a fish-consuming population for the Port Angeles area, the Lower Elwha Klallam Tribe (LEKT). For the LEKT, the MTCA Science Advisory Board between March 2007 and June 2008 considered modifying different fish consumption-related MTCA exposure factors.[168]

Factors to consider

A variety of elements related to fish/shellfish habitat quality and abundance are important considerations to support fish/shellfish harvests for fish-consuming populations in Washington.

[167] EPA Region 10, *Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates,* 2007.

[168] MTCA Science Advisory Board Meeting Information, http://www.ecy.wa.gov/programs/tcp/SAB/SAB_hp.html.

Environmental considerations

Healthy fish and shellfish habitats are critical to support and sustain harvests relied on by Washington fish-consuming populations. Various environmental factors to consider when deriving a site-specific fish/shellfish consumption rate include the following[169,170,171,172]:

- Historical information on habitat quality, abundance, and density estimates that can provide a baseline for site-specific evaluations
- Population growth and urban impacts on fish/shellfish habitat and abundance (habitat alterations)
- Toxic contamination of habitat and resultant fish tissue concentrations
- The extent and quality of habitat for supporting fish and shellfish harvests in and adjacent to areas of the site – including:
    - Inter-tidal habitat characteristics needed by finfish
    - Intertidal vegetation (eel grass) that provides feeding and forage opportunities
    - Identification of the nature and extent of contamination
- Inter-tidal habitat characteristics required for shellfish beds (i.e., sand, light to heavy gravel, sedimentation influences, wood waste (if applicable)
- Inter tidal and river water temperature variation and oxygen levels
- Tidal influences
- River flow rates
- Fish species and life history
- Residency times for fish/shellfish populations in estuary or inter-tidal zones
- Any relevant closures, warnings, or conditional closures or advisories

Available resources and habitat

The Watershed Planning Act (WPA) (Revised Code of Washington 90-82), passed by the Washington State Legislature in 1998, provides for locally-based watershed planning and management for different watersheds throughout Washington. A watershed is an area draining

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[169] Lamb, Andy, and Bernard Hanby, *Marine Life of the Pacific Northwest: A Photographic Encyclopedia of Invertebrates, Seaweeds and Selected Fishes* (Harbour Publishing, 2005).

[170] Quayle, D.B., *The Intertidal Bivalves of British Columbia,* British Columbia Provincial Museum Handbook No. 17, Victoria, Canada, 1960.

[171] Kozloff, Eugene N., with Linda H. Price, *Marine Invertebrates of the Pacific Northwest* (University of Washington Press, 1999).

[172] Quinn, Thomas P., *The Behavior and Ecology of Pacific Salmon & Trout* (University of Washington Press, 2005).

into a river, lake or other water body, such as the Puget Sound. The watershed management plan is developed in collaboration with citizens, local governments, and tribal governments to develop solutions to water issues in their own watershed. Chapter 173-500 WAC established the Water Resource Inventory Areas planning units.[173] Final decisions regarding the watershed management plan for the planning units must be made by the unanimous consensus of the initiating governments (county, city, and tribal) and the Department of Ecology.[174]

Working in collaboration with other natural resource agencies, the Department of Ecology has divided Washington into 62 Water Resource Inventory Areas to delineate the state's major watersheds.[175] Depending on the WRIA of interest information, accessing the watershed planning and management information may provide a range of information on water quantity and quality, fish and shellfish habitat quality and abundance, in-stream flow patterns, intertidal habitat, and corrective management plans. An example of this type of information available is the Water Resource Inventory Area 20, Watershed Management Plan.[176]

Shellfish growing areas

The National Shellfish Sanitation Program provides the regulatory framework for coastal states to identify, survey and classify shellfish growing waters. The classification status of shellfish is based on sanitary surveys of water quality and shoreline surveys of pollution sources.

Shellfish growing areas are classified either as approved for harvest or as one of four harvest limited categories: 1. conditionally approved, 2. restricted, 3. conditionally restricted, 4. prohibited

All identified shellfish growing and harvest areas must be classified as prohibited unless sanitary surveys indicate that water quality meets regulatory standard for the other categories.[177]

For 1995, Washington had 308,000 classified shellfish acreage with 36 percent harvest limited.[178] In 2009, DOH managed the classification of 356,253 commercial shellfish harvesting acres.[179] In 2009, for Washington, there were 287,741 acres with approved classifications, 6,208

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[173] RCW 90.82.040.

[174] Chapter 90.82 RCW, Watershed Planning, RCW Sections 90.82.005 to 90.82.902.

[175] Washington State Department of Ecology, *Watershed Updates by Water Resource Inventory Areas (WRIA),* http://www.ecy.wa.gov/apps/watersheds/wriapages/index.html.

[176] Washington State Department of Ecology, *Water Resource Inventory Area 20, WRIA 20 Planning Unit, Watershed Management Plan*, June 2009, http://www.ecy.wa.gov/services/gis/maps/wria/number/wria20.htm.

[177] National Oceanic and Atmospheric Administration (NOAA), "Classified Shellfish Growing Waters" by C.E. Alexander, *NOAA's State of the Coast Report* (Silver Spring, MD: NOAA, 1998), http://state_of_coast.noaa.gov/bulletings/html/sgw_04/sgw.html.

[178] Ibid., Table 1.

[179] DOH, Office of Shellfish and Water Protection, *2009 Annual Report: Commercial and Recreational Shellfish Areas in Washington State,* July 2010, www.doh.wa.gov/ehp/sf.

acres with conditionally approved classifications, 981 acres with restricted classifications, and 61,323 acres with prohibited classifications.

Suppression effects

Current Native American fish consumption is lower than historical fish consumption and fewer Native Americans practice subsistence fishing. [180,181,182] Possible reasons for suppressed fish consumption rates are:[183,184]

- Habitat degradation.
- Reduced or inaccessible areas to harvest fish due to increased urbanization or contamination.
- Fewer numbers of Native American are practicing subsistence or traditional lifestyles.
- Reduced numbers of fish/shellfish populations available to harvest.
- Knowledge of fish/shellfish contamination may reduce harvests and consumption.
- Methodological issues and data interpretation related Native American dietary surveys that may not fully account for their high fish consumption habits and patterns.

Suppression effects are of particular concern for subsistence fishers consuming fish or shellfish at rates greater than high fish consumers.[185] Although acknowledging variation across different Pacific Northwest tribal populations, researchers have suggested a tribal fish consumption rate above 454 g/day for subsistence fishers, and 540 g/day has been established as a subsistence fish consumption rate for the Umatilla Tribe.[186,187]

Exposure parameters

On a site-specific basis, it may be necessary to adjust default exposure assumptions in order to establish sediment or surface water cleanup standard based on a reasonable maximum exposure to the fish-consuming population impacted by the site. (The exposure assumption and equations

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[180] Subsistence Native American fish consumers are a subset of the Native American tribal population (Donatuto and Harper, 2008).

[181] Harper and Harris, *Environmental Research,* 2008.

[182] Donatuto and Harper, *Risk Analysis*, 2008.

[183] Harper and Harris, *Environmental Research,* 2008.

[184] EPA, *Fish Consumption and Environmental Justice* (report developed from the National Environmental Justice Advisory Council Meeting of December 3-6, 2001), November 2002, http://www.epa.gov/complinace/resources/publications/ ej/fish_consump_report_1102.pdf.

[185] Harper, Barbara L., et al., *Traditional Tribal Subsistence Exposure Scenario and Risk Assessment Guidance Manual*, Oregon State University Department of Public Health, Confederated Tribes of the Umatilla Indian Reservation; Oregon State University Departments of Public Health and Nutrition and Exercise Sciences, August 2007.

[186] Harper and Harris, *Environmental Research,* 2008.

[187] Harris and Harper, *Risk Analysis*, 1997.

for establishing water quality standards vary slightly and are not addressed in this report; interested readers are referred to EPA guidance.)

In addition to a fish consumption rate, body weight, fish diet fraction, and exposure duration parameters are used to set surface water and sediment cleanup standards protective of human health.

Body weight

Based on exposure assumptions of the MTCA Cleanup Regulation RME, surface water cleanup standards protective of human health are computed based on a default adult male body weight of 70 kilograms (kg). Body weight, along with an estimate of fish consumption, duration, and frequency of exposure is used to derive media specific protective risk-based concentrations.

Regarding differences between children and adult body weights, Oregon's Human Health Focus Group noted the following:

"In the case of adult males (18 to 74 years of age), mean body weight is 78 kg (172 lbs), with the 5th and 95th percentile weights of 59 kg (130 lbs) to 103 kg (227 lbs), respectively. Mean adult female body weight for the same age range is 65 kg (143 lbs), with 5th and 95th percentiles of 48 kg (106 lbs) and 93 kg (205 lbs), respectively.[188]

The variation of weight between children and adults is significant, considering that newborns typically weigh 4 kg (8 lbs) while adults can reach weights of 113 kg (250 lbs). Thus, risk estimates for children versus adults can vary considerably. In the current water quality criteria guidance EPA recommends using an average adult body weight of 70 kg (154 lbs) as a default body weight value in water quality criteria calculations. While use of water quality criteria based on the adult default weight provides adequate protection for adults, it may not provide adequate protection for children."[189]

Similar to the body weight variation between adults and children in computing ambient water quality criterion, surface water cleanup standards are based on an adult male body weight. EPA directs tribes and state agencies to use alternative body weight estimates for populations other than the general populations when these estimates are more protective for the populations of concern. For example, EPA recommends using a default body weight of 30 kg (66 lbs) to be protective of children when exposure to environmental contaminants may have early-life effects. Recognizing the hierarchy of information used to establish site-specific water quality standards,

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[188] Oregon Department of Environmental Quality, *Oregon Fish and Shellfish Consumption Rate Project Report*, 2008. Page 36 noted the reference for body weights as EPA, 1997, *Exposure Factors Handbook,* Chapter 7, Body Weight Studies, http://www.epa.gov/ncea/efh/ (retrieved May 27, 2008).

[189] Ibid.

EPA directs states and tribes to use local or regional data when available to compute health protective water quality criteria.[190]

Fish diet fraction

The fish diet fraction (FDF) is defined as "….the percentage of the total fish and/or shellfish in an individual's diet that is obtained or has the potential to be obtained from the site.[191][192]." (The MTCA rule establishes a default fish diet fraction (50 percent). However, the rule provides the flexibility to modify the fish diet fraction when necessary to establish a more stringent cleanup level to protect human health."[193] Ecology believes that the following factors should be considered when selecting a fish diet fraction on a site-specific basis in consideration of a fish/shellfish-consuming population:

- The range of fish-diet fraction values used to make site-specific decisions. The EPA Region 10 framework recommends the use of a relative source contribution equal to 100 percent. [194] Ecology and EPA have used this value when evaluating health risks for tribes at several cleanup sites in Washington (e.g., Bellingham Bay and the Lower Duwamish Waterway). Ecology has also used or is considering using a fish diet fraction less than 50 percent in other areas.
- Practical risk management decisions. From a practical standpoint, risk-based concentrations for sediments or surface waters calculated using higher fish consumption rates will, for many contaminants, fall below background concentrations. In these situations, cleanup standards will likely be based on considerations other than fish consumption or fish diet fraction.
- Estimates of the reasonable maximum exposure. [195] The RME is designed to represent a high end (but not worst case) estimate of individual exposures. It provides a conservative estimate

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[190] Ibid.

[191] WAC 173-340-200.

[192] Site is defined in WAC 173-340-200 to mean the same as "facility," which is defined to mean the following (emphasis added):

"Any building, structure, installation, equipment, pipe or pipeline (including any pipe into a sewer or publicly owned treatment works), well, pit, pond, lagoon, impoundment, ditch, landfill, storage container, motor vehicle, rolling stock, vessel, or aircraft; or any site or area where a hazardous substance, other than a consumer product in consumer use, has been deposited, stored, disposed of, or placed, or otherwise come to be located."

[193] WAC 173-340-708(10)(b).

[194] EPA Region 10 Framework (2007) states "Although the degree to which site-related risks could be overestimated by the use of any of the fish and shellfish consumption rates presented in this Framework cannot be known precisely, these methods are preferable to alternatives that would be likely to underestimate site-related risks, such as basing a consumption rate (or site-related estimates of risk) on the size of the cleanup site, or reducing the site's estimated contribution to fish and shellfish contamination because nearby sites or sources are associated with similar contaminants." This Framework includes the assumption that the selected Tribal fish and shellfish consumption rates and their associated risk estimates will not be reduced based on consideration of the size of the cleanup site or the presence of additional sources of contamination. (Page 23)

[195] MTCA defines the RME as the "…the highest exposure that can be reasonably expected to occur for a human or other living organisms at a site under current and potential future site use." CERCLA provides a similar definition "…the highest exposure that is reasonably expected to occur at a Superfund site…"

that falls within a realistic range of exposures.[196] The RME is defined as reasonable because it is a product of several factors that are an appropriate mix of average and upper-bound estimates. RME estimates typically fall between the 90th and 99.9 percentile of the exposure distribution.[197]

- Current fish and shellfish harvesting and consumption habits and patterns. In the absence of a well designed and conducted fish dietary survey Ecology recommends the EPA Region 10 framework on a site-specific basis. However, modifications to the default fish diet fraction need to consider whether using a surrogate fish/shellfish rate would lead to exposure estimates above the 95th percentile value generally used by Ecology when establishing cleanup levels and standards.
- Reasonably anticipated future fish and shellfish harvesting and consumption habits and patterns, including reasonably anticipated future habitat conditions.

Exposure duration

Groundwater and surface water cleanup standards for carcinogens are based on an exposure duration of 30 years.[198] This 30-year exposure duration was based on the estimated household residency time for U.S. populations.[199] It is consistent with EPA Mid-Atlantic Risk Assessment Equations in their fish ingestion and tap water equations for carcinogens.[200] The EPA 2009 Exposure Factors Handbook provides descriptive statistics for residency times:[201]

- Mean is 13 years.
- 90th percentile is 32 years.
- 95th percentile is 46 years.
- 99th percentile is 62 years.

The 30-year exposure duration specified in the MTCA rule approximates the 90th percentile residence time in the same household (in other words, 90 percent of the U.S. population reside in the same household for 30 years or less). On a site-specific basis, the exposure duration may vary depending on the population's mobility. Factors to consider when changing the exposure duration are:

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196 EPA, *An Examination of EPA Risk Assessment Principles and Practices*, 2004.

197 Ibid.

198 WAC 173-340-200.

199 EPA, *Exposure Factors Handbook,* 2009.

200 EPA, *Mid-Atlantic Risk Assessment,* Regional Screening Table, http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm.

201 EPA, *Exposure Factors Handbook,* 2009, Table 16-5, page 16-9.

- *Demographic and population-specific census information* related to residency times and potential period of exposure to a hazardous substance. For example, some tribal populations may live on or near their reservation for periods longer than 30 years. Tribal elders may reside on or near reservations for a significant portion of their lives, 50 years or longer.[202]
- *Consistency with EPA regional and federal guidance and policies* for site-specific evaluations. The EPA Region 10 framework and the EPA methodology for deriving surface water cleanup standards and criteria protective of human health established an information hierarchy of preferred exposure data. The highest preference is given to exposure information (fish dietary information) from local watersheds representative of the people being addressed for the particular water body.[203,204,205,206]
- *Consistency with exposure assumptions used at other cleanup sites* that evaluate population-specific exposures from contaminants. For example, exposure duration was considered for site-specific evaluations and cleanup decisions at the ITT Rayonier Port Angeles site and the Lower Duwamish Waterway.[207,208]

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[202] Charles, Frances, and Larry Dunn, *Lower Elwha Klallam Tribe Fish Consumption and the EPA Region 10 Framework*, submitted by F. Charles, Lower Elwha Tribal Chairperson, and L. Dunn, LEKT, Rayonier Project Coordinator. to Ecology in consideration of site-specific cleanup for Port Angeles harbor area, October 15, 2007.

[203] EPA, *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health,* 2000.

[204] EPA, *Estimated Per Capita Fish Consumption,* 2002.

[205] EPA Region 10, *Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates,* 2007.

[206] EPA, *Fish Consumption and Environmental Justice,* 2002.

[207] Washington State Department of Ecology, *Port Angeles Harbor-Marine Environment*, *Baseline Human Health and Ecological Risk Assessment*, public review draft, March 2011.

[208] EPA Region 10 and Washington State Department of Ecology, *Lower Duwamish Waterway Remedial Investigation*, 2007.

Chapter 7: Recommendations

Introduction

Ecology is considering revisions to the SMS rule (WAC 173-204) and, over the next several years, will consider updates to the Water Quality Standards for Surface Waters (WAC 173-201A) and the MTCA Cleanup Regulation (WAC 173-340).

This chapter is organized into four sections:

- Regulatory dilemma
- Preliminary recommendations
- Key issues
- Summary and conclusions

Regulatory dilemma

Ecology has been struggling to determine an approach for recommendations related to fish and shellfish consumption rates. There is inherent tension between a desire for regulatory simplicity, where rules are straightforward, and complexity of issues. The agency recognizes that determining a fish consumption rate, or rates, for use in regulatory programs is a complex issue with many significant considerations. These include multiple regulatory contexts, implementation concerns, technical details, variability, and scientific uncertainty. Furthermore, in Washington fish and shellfish are associated with deeply held cultural values.

Regulatory decisions include:

- Cleanup goals for sites with contaminated sediments.
- Surface water cleanup standards.
- State water quality standards (marine and freshwater).

Because of the differing regulatory contexts it may not be possible or desirable to establish a single default fish consumption rate for statewide use. Ecology is looking for feedback on this issue. We believe that the body of data used to establish the decisions should be consistent across state regulations, and that the differences in the regulatory contexts should be acknowledged.

In this chapter, Ecology proposes a technically defensible preliminary range for a default fish consumption rate (or rates) for use in regulatory decisions. Ecology believes that the range

should be based on surveys of Pacific Northwest populations. Policy considerations, including the approach for recognizing the transient nature of anadromous salmonids, are recognized.

Statement of the regulatory question

Over the last 20 years, numerous scientific and regulatory developments have been made regarding statewide default fish consumption rates. Further developments are expected. Ecology is evaluating this information to answer the questions:

- What is a technically defensible range within which to establish a default fish consumption rate (or rates) appropriate for use in regulatory decision making?
- What is a technically defensible default fish consumption rate (or rates) appropriate for use in regulatory decision making?

Key considerations are:

- Recent scientific data on fish and shellfish consumption rates for different population groups.
- Approaches used by other state and federal agencies.
- Uncertainty and variability in fish and shellfish consumption rates for different population groups and individuals within those groups.
- State laws and policies, including MTCA and the Water Pollution Control Act.

Current rulemaking efforts

Revisions to the SMS rule are being developed that will include one or more default fish consumption rates within a technically defensible range, for use in establishing cleanup goals protective of Washington fish consumers but maintaining the option for site-specific flexibility. Specific rule revision proposals will be evaluated according to regulatory analyses required under the Washington Administrative Procedures Act and the State Environmental Protection Act.

Ecology is approaching this issue with the goal of recommending a fish consumption rate appropriate for use in making sediment cleanup decisions, understanding that for some chemicals, risk-based concentrations based on high fish consumption rates fall below background concentrations. In this case, decisions about where cleanup occurs are made by identifying areas where contaminants are above background levels; the numerical value used for the fish consumption rate may not directly influence cleanup decisions.

Fish consumption rates do have enormous importance, however, in identifying long-term environmental goals. Regulatory decisions should ultimately lead toward eliminating—or minimizing—risk to human health.

Given this goal, Ecology is looking to develop, through the rulemaking process, a default fish consumption rate for use with the Sediment Management Standards. The range identified in this report may be applicable to other rulemaking efforts, although various policy considerations may influence the specific rate.

Questions remain

Ecology acknowledges that there are multiple ways to go about developing a range for further consideration. The statistical method used by Ecology in this report was developed in response to feedback that the initial approach of averaging upper percentile values was invalid. We believe the resulting methodology (presented in Appendix C) is robust. However, it is not the only way to combine information from the surveys. Indeed, Ecology acknowledges that it is also appropriate to ask whether the data can or should be combined.

Ecology thinks that combining information from the four surveys to identify a range is useful. It is intended to assist in focusing the discussion around what is an appropriate default fish consumption rate for use in regulatory decisions.

The range identified takes into account current scientific information, recognizes regional differences, and allows for variability, and uncertainty. Ecology views this preliminary recommendation as a starting point for further discussions. We are asking for input regarding identifying one or more default fish consumption rates for use in the various regulatory contexts.

Preliminary recommendations

A default fish consumption rate for use in cleanup decisions should be protective of Washington fish consumers. Based on the evaluations in this report, Ecology is preliminarily recommending a default fish consumption rate (or rates) in the range of 157 to 267 g/day.

The range above includes salmon consumption, which, as discussed in this report, is still an issue for further discussion in determining a fish consumption rate. (Additional statistical analysis and data review would be needed to develop an equivalent range reflective of fish consumption that does not include salmon.)

Ecology recommends that one or more default fish consumption rates in this range should be used to establish sediment cleanup standards under the SMS rule. In addition, future rulemaking would apply a default rate in this range to surface water cleanup standards under the MTCA rule and water quality standards for surface waters.

Reasons for the proposed preliminary recommendation

The Washington general population consumes fish and shellfish at rates above current regulatory defaults. Furthermore, sediment cleanup standards are set on a site-by-site basis using site-specific fish consumption rates, a process that can contribute to cleanup delay.

In addition, MTCA surface water cleanup standards are currently based on a recreational angler exposure scenario that assumes a fish consumption rate of 54 g/day. Based on data reviewed by Ecology, this scenario does not represent the reasonable maximum exposure (RME) to Washington residents who consume larger amounts of fish and shellfish. These include Native Americans, Asian and Pacific Islanders, and other Washington residents.

Also, Washington water quality standards are based on an outdated fish consumption rate of 6.5 g/day.

Rationale and basis for the preliminary recommendation

Ecology developed this preliminary proposal by considering the following questions:

(1) What exposure scenarios should be considered?

(2) Is there an appropriate range within which to develop a statewide default fish consumption rate given current exposure scenarios?

(3) What other exposure parameters should Ecology be considering and how do they relate to a statewide default fish consumption rate?

(4) What factors should Ecology consider when reviewing the proposed statewide default fish consumption rate during future regulatory reviews?

Each question is considered separately below.

Question #1: What exposure scenarios should be considered?

Ecology recommends that a statewide default fish consumption rate should take into account the quantity and types of fish and shellfish available in Washington, as well as consumption habits and patterns of Native Americans, Asian and Pacific Islanders, recreational fishers, and the general population.

The four surveys identified in this report provide a basis for selecting a range of values that Ecology considers protective of both high fish consumers in the general Washington population and in high fish consuming populations. The range suggested is not based on subsistence-level consumption rates. Rather it is intended to assist in indentifying a reasonable maximum exposure for people who as part of their regular diet eat a lot of fish.

The rationale for this approach includes both science and policy considerations:

- Washington has plentiful commercial and recreational fisheries, and significant numbers of high fish consumers, including Native Americans and Asian and Pacific Islanders.
- Fish and shellfish are harvested from waters throughout the state.
- Defensible dietary information is available from Pacific Northwest fish consumption surveys.
- The fish consumption survey information indicates that a default fish consumption rate in the proposed range would be protective of fish consumers.
- The approach is consistent with current Ecology risk-based policy decisions.

Question #2: What is an appropriate range within which to develop one or more default fish consumption rates given current exposure scenarios?

The proposed range is based on a number of factors:

- It considers current scientific information on fish consumption rates for different population groups in the Pacific Northwest. Ecology has reviewed available fish consumption surveys relevant to the Pacific Northwest (see Chapter 4). We concluded that information from these surveys provides a solid technical basis for regulatory decisions.
- The Oregon DEQ Human Health Focus Group reached similar conclusions. Ecology's focus on these studies is also consistent with EPA's hierarchy of information and preferences for local data. The results and findings from these studies are consistent with scientific information on fish consumption rates from other parts of the United States.
- The preliminary recommendation is consistent with Ecology's policy decision to base cleanup standards on an RME. It considers several exposure scenarios, including the general population and population groups known to consume higher amounts of fish and shellfish. It takes into account the variability in fish consumption rates among population groups and individuals.
- The preliminary recommendation falls with the range of fish consumption rates identified in EPA Superfund policies and guidance.[209]
- The preliminary recommendation is consistent with recommendations in EPA's *Exposure Factor Handbook* (1997), where EPA recommends an average ingestion rate of 70 g/day and a 95th percentile ingestion rate of 170 g/day. [210]

[209] EPA Region 10, *Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates,* 2007, page 6.

[210] EPA, *Exposure Factors Handbook,* 2009.

- The preliminary recommendation was developed using methods and policies similar to those used by the Oregon DEQ in proposing revisions to the Oregon water quality standards.[211]
- The preliminary recommendation falls within the range of fish consumption rates in federally approved water quality standards established by Washington tribes. Several Washington tribes have developed tribal surface water standards based on Native American fish consumption rates.
- EPA and Ecology have established cleanup standards at several sites based on tribal fish consumption scenarios. Ecology and EPA currently establish site-specific sediment cleanup standards and/or screening levels based on tribal fish consumption rates in areas designated as usual and accustomed fishing areas for one or more tribes.[212] In general, fish consumption rates used at these sites range from around 50 to 300 g/day (Malcolm Pirnie, 2008).[213]

Question #3: What other exposure parameters should Ecology be considering and how do they relate to a statewide default fish consumption rate?

Fish and shellfish consumption is a major exposure pathway considered when evaluating risk from bioaccumulative chemicals in Washington waters. As discussed in Chapter 5, the rate of consumption is one of several exposure parameters used to establish risk-based standards for this exposure pathway. The regulatory choices for other parameters can significantly impact the resulting standards.

Other key exposure parameters include:

- Body weight.
- Exposure duration.
- Relative source contribution, site use factor, or fish diet fraction.

At this time Ecology is not considering regulatory changes to the default body weight. Differences do exist between the default averaging times used in different regulatory exposure scenarios, which is why a single default fish consumption rate may not be applicable for multiple

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[211] Oregon DEQ is proposing a default fish consumption rate of 175 g/day, which represents the approximate 95th percentile from the Columbia River Inter-Tribal Fish Consumption Survey. To support efforts to revise the Oregon water quality standards, ODEQ organized a Human Health Focus Group to evaluate fish consumption information and recommend a fish consumption rate for fish-consuming populations in Oregon. The group consisted of regional experts with experience in areas of toxicology, risk assessment, public health, biostatistics, and/or epidemiology. They concluded that (1) there are relevant studies available for recommending fish consumption rates, (2) Pacific salmon should be included in the fish consumption rate, and (3) fish-consuming populations who eat more than 17.5 g/day of fish and shellfish are at an increased risk of cancer and noncancer adverse health effects. (Oregon Department of Environmental Quality, *Oregon Fish and Shellfish Consumption Rate Project Report*, 2008)

[212] Naval Facilities Engineering Command, *Technical Memorandum: Human Health Risk Evaluation of Mercury in Sinclair Inlet Seafood, OU B Marine*, *Bremerton Naval Complex,* 2010.

[213] Pirnie, Malcolm, *Scientific Considerations for Identifying Subsistence User Ingestion Rates in Port Angeles, Washington*, 2008. Figure 1 summarizes fish consumption rates used at nine cleanup sites. One value (KPC) appears to be 6.5 g/day.

regulations. Similarly, the question of salmon and the different regulatory uses of relative source contribution, site use factors, and fish diet fraction may suggest the need for multiple default fish consumption rates. (Refer to Chapter 5.)

Note also that average body weight, exposure duration, and fish diet fraction are appropriately considered when establishing site-specific fish consumption rates under MTCA, as described in Chapter 6.

Question # 4: What factors should Ecology consider when reviewing the proposed statewide default fish consumption rate during future regulatory reviews?

Ecology considered a variety of factors that affect fish- and shellfish-consuming populations and fish consumption rates for Washington fish consumers. Future regulatory reviews and/or rulemaking regarding fish consumption and the fish-consuming habits and patterns of fish consumers may consider:

- Technical quality of information.
- Federal and state regulatory policies and procedures.
- Federal directives, such as presidential executive orders.
- Native American customs and practices.
- Environmental justice.
- Other relevant issues.

Key policy issues associated with developing a default fish consumption rate

A number of policy issues were considered in developing a preliminary recommendation for a default fish consumption rate. Ecology considered the RME, how to account for consumption of Pacific salmon caught in Washington waters, and uncertainty regarding the estimates for consumption.

Suppression effects

Studies indicate that tribal fish consumption rates are suppressed compared with historical rates and presumable rates that would exist given historical fishing stocks. The recommendations in this report, however, were developed using existing data from published studies.

For Native American populations in Washington, evaluating fish consumption rates using common survey methodology may be problematic.[214] Surveys and the exposure models they develop provide information only about current consumption patterns. The number of tribal members practicing traditional lifestyles is below known historical levels. Survey data does not provide information on historical fish consumption rates and resource use, which may be more indicative of consumption rates.

Researchers suggest that suppression happens for various reasons. [215] Two reasons are contamination and lower abundance. When the fish are contaminated or absent, tribal members may eat less fish and/or substitute other types of fish. While, historically, fish provided the main dietary source of protein, this is true today for only a small subset of the tribal population. [216,217, 218] Tribal health experts suggest that current tribal fish consumption rates are suppressed due to diminished access to historical quantities of fish and shellfish, and some researchers believe that historical rates represent the appropriate baseline level of consumption. Ecology notes that suppression effects may be important when evaluating risk at contaminated sites and when setting site-specific cleanup standards that consider historical site characteristics.

The question of whether to include salmon

There are multiple factors to consider when assessing the risk from consuming salmon. Most Washington salmon spend the largest part of their lives in the open ocean, where exposure to contaminants originating from Washington sources is minimal. Salmon life cycles are complex, and the various species have different survival strategies.

A significant part of salmon contamination occurs in waters and from sources outside of individual MTCA sites or the waters of the state that are regulated under the CWA-based criteria.

- MTCA cleanups are focused on addressing risks that originate from the cleanup site, (for example, contamination from a site that bioaccumulates in biota).
- CWA-based water quality criteria address contamination of freshwater and estuarine fish (for example, sources that can in general be regulated by states in waters of the state), and do not address offshore marine pollution sources that are beyond the control of individual states.

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[214] Donatuto and Harper, *Risk Analysis*, 2008.

[215] Ibid.

[216] Harper and Harris, *Environmental Research,* 2008.

[217] Harper, et al., *Traditional Tribal Subsistence Exposure Scenario and Risk Assessment Guidance Manual,* 2007.

[218] Harris and Harper, *Environmental Research,* 2001.

Ecology has reviewed information related to Washington salmon fisheries and salmonid life cycles. (See Appendix E for a broader discussion of issues related to considering salmon in fish consumption rates.) The available Pacific Northwest consumption surveys, with a focus on Puget Sound fish consumption, document salmon as a primary fish species consumed by Washington fish consumers. A discussion of developing default fish consumption rates for regulatory use should include how to appropriately address the question of salmon.

- There are significant numbers of salmon harvested throughout Washington.
- Salmonids are harvested for recreational, tribal, and commercial purposes.
- Salmonids may contribute to the contaminant body burden of fish-consuming populations.

Ecology believes that the issue of salmon is a question without a single answer. Considerable uncertainty exists around risk associated with consuming salmon, and differing regulatory schemes provide different tools:

- Under MTCA, the fish diet fraction provides flexibility to allow for the transient nature of certain fish species.
- The Clean Water Act-based surface water quality criteria in some cases include a relative source contribution when evaluating the noncancer risks associated with specific chemicals. EPA's human health-based water quality criteria are developed to protect people from effects of exposure to contaminants in freshwater and estuarine fish (not to marine species). EPA's current guidance categorizes salmon as a marine fish and EPA's recommended criteria do not include salmon in the fish consumption rate.

In recommending a range within which to develop one or more default fish consumption rate, Ecology acknowledges these various regulatory paradigms. The approach identified in this report is to identify a technically defensible range, within which the various regulatory paradigms can operate to identify appropriate default fish consumption rates. This approach provides statewide consistency by establishing a common set of data used and identifies explicitly the differences due to regulatory context.

Choice of the reasonable maximum exposure

Exposure to hazardous substances is influenced by multiple factors and may vary widely within a given population. Agencies may have some information on the variability for a particular parameter. However, agencies must also decide which value within the range to use to characterize the range of values (that is, whether to use either an average or the high end of the exposure distribution).

Choosing a summary measure to characterize population exposure reflects an explicit (or implicit) policy choice on the appropriate balance between over- or underestimating exposure

levels for particular individuals within the population group. The RME under MTCA, considering all exposure parameters, is typically set at 90 – 95 percent of the exposure distribution.

Options for the preliminary recommendation

Ecology used the state surveys identified in Chapter 4 to identify the recommended range for establishing a default fish consumption rate or rates. Although a single statewide default rate may be preferable for the sake of simplicity, different regulatory goals and even regional differences may suggest multiple options.

Regulations should provide consistency and predictability for the people of the state. So while multiple options provide flexibility they also add regulatory complexity. Given the uncertainty around fish consumption rates, it is not certain that the added complexity would in fact increase health protection.

Cleanup decisions around bioaccumulative chemicals are increasingly based on background concentrations. In these cases, regional differences in fish consumption rates would not affect cleanup standards. Water quality criteria based on human health provide long-term water-body based goals, and even current values are difficult to achieve.

Data analysis

Ecology considered multiple ways of approaching the data from the Pacific Northwest regional-specific fish consumption rate surveys:

1. Visual analysis of the data
2. Simple averaging of the upper percentiles
3. Averaging and developing confidence intervals[219]
4. Fitting to lognormal probability distributions, combining the distributions, and suggesting a range based on the combined data

The first three approaches were rejected as inadequate or inappropriate. The fourth approach is described in Appendix C. Ecology continues exploring statistical methods for evaluating the Pacific Northwest fish dietary information. Additional approaches are being considered, including Monte Carlo simulations to approximate each dataset.[220]

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[219] The Wilcoxon confidence interval provides information about the median of a distribution. To evaluate the possible ranges of data for the upper percentiles of fish and shellfish consumption for the different populations, Ecology calculated the median of the 95th percentiles and corresponding Wilcoxon signed-rank confidence intervals using the WINTERVAL procedure in Minitab. [219] [219] [219] A similar evaluation was conducted using 90 percent confidence intervals around the median.

[220] At this time Ecology does not have access to the survey data. The analyses are based on published summary statistics.

Acceptable risk

In most cases, environmental agencies consider risk policies only implicitly.[221] MTCA cleanup standards and Washington's ambient water quality criteria are both based on an acceptable cancer risk of 1 in 1 million.

Selection of an RME approximately between the 80th and 95th percentile is consistent with Ecology's policy choices on target or acceptable risk. A higher percentile (for example, the 99th percentile) might be preferable if Ecology was basing regulatory decisions on a higher acceptable risk range (such as 1 in 10,000). However, this analysis has not considered changes to the acceptable cancer risk level.

Summary and conclusions

Ecology's recommendations are intended to assist in producing health-protective and technically defensible default fish consumption rates for use in regulatory decision making. In recommending a range, Ecology acknowledges outstanding questions related to the rulemaking efforts.

Ecology believes that a range can be developed within which default fish consumption rates should be established. This report identifies a technically defensible range within which the various regulatory paradigms can operate to identify appropriate default fish consumption rates. Ecology recommends that default fish consumption rates be established in the range of 150 to 275 g/day. This approach provides statewide consistency and recognizes inherent differences due to regulatory context.

In conclusion:

- Washington has the resources to support a variety of large fish/shellfish populations.
- Washington has a significant number of fish consumers as well as high fish-consuming populations.
- Washington has fish dietary survey information that quantifies the fish-consuming habits and patterns.
- Fish dietary survey information for state consumers is technically defensible and sufficiently quantifies amounts and types of fish consumed.

[221] The one exception is the Oregon DEQ guidance document on probabilistic risk assessment (DEQ, 1999). In that document, Oregon DEQ explicitly established a policy that used different statistical metrics (percentiles) for different target risk levels. For example, DEQ states "…[f]or individual carcinogens, a lifetime excess cancer risk for each carcinogen of less than or equal to one per one million at the 90th percentile, and less than or equal to one per one hundred thousand at the 95th percentile, each based upon the same distribution of lifetime excess cancer risks for an exposed individual…" (OAR 340-122-115(2)(b)).

- Fish dietary survey information for Washington fish consumers provides a sound technical basis to make informed risk-management decisions protective of human health.
- Washington has a large fish-consuming population that consumes fish in larger amounts than the current default fish consumption rates.
- This range is consistent with state and federal regulatory policies and procedures.

Appendices

Appendix A
Data Used to Develop Proposed Default FCR

Information used by Ecology for developing a proposed default fish consumption rate appropriate for regulatory use in Washington is provided below.

Table A-1. Summary of Fish Consumption Rate Data

	Population Surveyed	Type of Fish Included in Survey	Number of Adults Surveyed	Descriptive Statistics (g/day)					
				Mean	Median	Percentiles			
						75th	90th	95th	99th
Data from dietary recall surveys	Tulalip Tribe	Finfish (anadromous & estuarine) Shellfish	73	72	45	85	186	244	312
	Suquamish Tribe	Finfish (anadromous & estuarine) Shellfish	284	214	132	-[a]	489	-	-
	Squaxin Island Tribe	Finfish (anadromous & estuarine) Shellfish	117	73	43	-	193	247	-
	Columbia River Tribes	Finfish (anadromous & freshwater)	512	63	40	60	113	176	389
	Asian & Pacific Islanders	Finfish (anadromous & estuarine) Shellfish	202	117	78	139	236	306	-

Source: Adapted from Table 3, page 28, Human Health Focus Group Report, Oregon Fish and Shellfish Consumption Rate Project, Oregon Department of Environmental Quality, June 2008. Use above footnote at June 2008.[222]

a. Blank cells indicate data not available.

[222] See Appendix C, Table C-1, for descriptive statistics used in statistical analysis of Pacific Northwest fish dietary information.

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Appendix B
Additional Supporting Information

Children's fish consumption rates

The *Child-Specific Exposure Factors Handbook* and the *Highlights of the Child-Specific Exposure Factors Handbook* summarize children's fish consumption rates for different age groups (U.S. Environmental Protection Agency [EPA], 2008 and 2009). The mean and 95th percentile consumer-only total fish (marine, estuarine, freshwater) consumption rate for 16 to less than18 years of age for the general population is 2.1 grams per kilogram per day (g/kg-day) (136 grams per day [g/day]) and 6.6 g/kg-day (357 g/day), respectively.[223,224] The mean and 95th percentile consumer-only total fish (fish and shellfish) consumption rate for 3 to under 6 years old for the general population is 4.2 g/kg-day (78 g/day) and 10 g/kg-day (186 g/day), respectively.[225] The *Interim Report Child-Specific Exposure Factors Handbook* summarizes the fish consumption rates among Native American children (consumers only, 5 or 6 years old or younger) using Pacific Northwest fish consumption survey information (EPA, 2002).

Table B-1. Fish Consumption Rates of Native American Children 5 or 6 Years of Age or Less

Survey (Native Populations)	Mean (g/day)	90th Percentile (unless otherwise noted, g/day)	95th Percentile (g/day)
CRITFC, 1994 (Umatilla, Yakama, Nez Perce, Warm Springs)	25	63	73
Toy et al., 1996 (Tulalip and Squaxin Island Tribes)[a]	11	21 (86th percentile)	
Suquamish Tribal Survey, 2000[b]	21	48	103

a. Consumption rate calculated using the average body weight of 15.2 kilograms reported in Toy et al., 1996.
b. Consumption rate calculated using the average body weight of 14.1 kilograms from the general population.

Although the age groups and body weights may differ across the general and Native American children population groups, the fish consumption rates for the children begin to approximate one another at the upper percentiles (78 to 186 g/day and 63 to 103 g/day). EPA has noted that there

[223] U.S. Environmental Protection Agency. Child-Specific Exposure Factors Handbook. (Final Report) EPA/600/R-06/096F. September 2008 [http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=199243]

[224] U.S. Environmental Protection Agency. Highlights of the Child-Specific Exposure Factors Handbook. EPA/600/R-08/135. August 2009

[225] U.S. Environmental Protection Agency. Highlights of the Child-Specific Exposure Factors Handbook. EPA/600/R-08/135. August 2009. Table 1, using a body weight of 18.6 kilograms for children 3 to <6 years of age.

is a high degree of variability in fish consumption rates across the Pacific Northwest tribes.[226] The 2008 Oregon DEQ Human Health Focus Group Report referenced EPA's *Per Capita Fish Consumption in the U.S.* (2002) as supporting documentation for the children's fish consumption rate (consumers only) of 191 g/day.[227,228] The same documentation and children's fish consumption rate (190 g/day) is used in to recognize the variability expressed by different fish consumption rates for different fish-consuming populations.

The following tables, excerpted from Moya, 2004, summarize analysis of fish consumption rate data for surveys identified by Ecology as meeting measures of technical defensibility. These tables are included here to show age group data.

[226] EPA, *Exposure Factors Handbook: 2009 Update*, EPA/600/R-09/052A, July 2009.

[227] State of Oregon Department of Environmental Quality (Oregon DEQ). Human Health Focus Group Report Oregon Fish and Shellfish Consumption Rate Project. June 2008

[228] U.S. Environmental Protection Agency. Estimated per Capita Fish Consumption in the United States. EPA-821-C-02-003. [Table 4, Section 5.2.1.1]

Table B-2. Tribal Fish Consumption Rates [229]

Fish Consumption Rate by Age Group From Selected Pacific Northwest Tribes				
Age Group	Mean	50th Percentile	90th Percentile	95th Percentile
Tulalip Tribe, g/kg -day				
0-5	0.2	0.08	0.7	
18-34		0.06	2.0	2.6
35-49		1.0	3.7	4.2
50-64		0.5	1.6	1.6
65 and over		0.2	0.6	0.6
Adults	0.9	0.6	2.9	
Squaxin Tribe, g/kg -day				
0-5	0.8	0.5	2.1	
18-34		0.5	2.3	3.1
35-49		0.5	2.6	3.0
50-64		1.1	3.6	3.6
65 and over		0.8	2.2	2.2
Adults	0.9	0.5	3.0	
Suquamish Tribe, g/kg -day				
0-6	1.5		3.4	
Adult Males				
16-42	3.3	2.3	8.6	13.0
43-54	5.2	4.6	10.3	
55 and over	1.6	1.4	4.8	
Adult Females				
16-42	1.9	1.0	4.9	10.1
43-54	1.2	0.8		
55 and over	3.7	2.1		
Columbia River Basin Tribes, g/day				
Adults	58.7			
18-39	57.6			
40-59	55.8			
60 and over	74.4			

Table B-3. Fish Consumption Rate Data for Asian and Pacific Islanders[230]

Asian and Pacific Islanders in King County, by Age Group (g/kg-day)	Mean	50th Percentile	90th Percentile	95th Percentile
All respondents	1.9	0.8	2.4	3.9
18-29	1.8		2.1	3.9
30-54	1.6		2.3	3.8
55 and over	2.1		3.2	5.2

[229] Moya, *Human and Ecological Risk Assessment,* 2004, adapted from Table 5, page 1204.

[230] Moya, *Human and Ecological Risk Assessment,* 2004, adapted from Table 4, page 1203.

Table B-4. EPA Data on Children's Fish and Shellfish Consumption Rates for the U.S. General Population[231]

Fish Population Description	Fish Consumption by Age Group, g/kg-day			
	3 to < 6 years	6 to < 11 years	11 to < 16 years	16 to < 18 years
Total fish				
Mean per capita	0.43	0.28	0.23	0.16
95th percentile per capita	3.0	1.9	1.5	1.3
Mean consumer only	4.2	3.2	2.2	2.1
95th percentile consumer	10	8.7	6.2	6.6
Marine fish				
Mean per capita	0.31	0.20	0.15	0.10
95th percentile per capita	2.3	1.5	1.3	0.46
Mean consumer only	3.7	2.8	2.0	2.0
95th percentile consumer	9.3	8.0	5.2	6.5
Freshwater fish				
Mean per capita	0.12	0.08	0.08	0.07
95th percentile per capita	0.71	0.35	0.48	0.29
Mean consumer only	2.3	1.8	1.3	1.4
95th percentile consumer	7.2	6.2	4.4	3.3

Data on fish species consumed

The EPA Region 10 framework for establishing site-specific fish consumption rates for use at CERCLA sites provides the following information related to types of seafood consumed.

Table B-5. Seafood Consumed by Adult Members of the Tulalip Tribe

Seafood Category	Examples	Central Tendency Estimate (g/day)	95th Percentile (g/day)	Percent of Fish Diet
Anadromous fish	Salmon/steelhead	14.9	96.4	49.7
Pelagic fish	Smelt, mackerel, cod, perch	1.3	8.1	4.2
Benthic/demersal fish	Halibut, sole, rockfish, snappers	1.2	7.5	3.9
Shellfish	Crabs, clams, mussels, bivalves	12.5	81.9	42.2
	Total ingestion rate	30	194	100

For adult members of the Tulalip Tribe, a 95th percentile total consumption rate of 194 g/day is obtained after adjusting the total consumption rate of 243 g/day to include only fish and shellfish harvested from Puget Sound. This is based on information from the EPA Region 10

[231] U.S. Environmental Protection Agency. Highlights of the Child-Specific Exposure Factors Handbook. EPA/600/R-08/135. August 2009. Adapted from Table 1, page 20. [www.epa.gov/ncea]

framework[232] as cited in the Lower Duwamish Waterway Group Remedial Investigation Report Appendix B: Baseline Human Health Risk Assessment, Final, November 12, 2007.

Table B-6. Seafood Consumed by Adult Members of the Suquamish Tribe

Seafood Category	Examples	95th Percentile (g/day)	Percent of Fish Diet
Anadromous fish	Salmon/steelhead	183.5	23.9
Pelagic fish	Smelt, mackerel, cod, perch	56.0	7.3
Benthic/ demersal fish	Halibut, sole, rockfish, snappers	29.1	3.8
Shellfish	Crabs, clams, mussels, bivalves	498.4	65
	Total ingestion rate	766.8	100

For adult members of the Suquamish Tribe, a 95th percentile total consumption rate of 766.8 g/d is obtained after adjusting the total consumption rate of 796 g/day to include only fish and shellfish harvested from Puget Sound. This is based on information from U.S. EPA Region 10 framework[233] as cited in the *Lower Duwamish Waterway Group Remedial Investigation Report* (EPA, 2007).

Table B-7. Seafood Consumed by Adult Asian-Pacific Islanders (API)

Seafood Category	Central Tendency Estimate (g/day)	95th Percentile (g/day)	Percent of fish diet
Anadromous fish	0.56	5.5	9.6
Pelagic fish	0.5	4.9	8.6
Benthic fish	0.24	2.4	4.2
Shellfish	4.6	44.2	77.5
Total	5.9	57	99.9

Freshwater fish make up 8.3 percent of the API seafood consumption, based on information from the API fish consumption survey from King County, Washington, as cited in the *Lower Duwamish Waterway Group Remedial Investigation Report* (EPA, 2007).

[232] EPA Region 10, Office of Environmental Assessment, *Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia*, August 2007.

[233] EPA Region 10, *Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates,* 2007.

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Appendix C
Statistical Analysis

Background information

Fish dietary information is available for selected Pacific Northwest fish-consuming populations. Descriptive statistics for the Pacific Northwest fish-consuming populations and the U.S. general population of fish consumers are provided in the table below.[234] [235] A graphical display of the information is provided to pictorially represent the descriptive statistics of selected fish consumption rates relevant to consideration for Washington State fish-consuming populations (Graph 1).

Table C-1. Published Descriptive Statistics of Fish Consumption Rate for Selected Pacific Northwest Fish-Consuming Populations, grams/day

Survey Population		Adult Sample Size Population (n)	Mean	Median	90th Percentile	95th Percentile
Regional-Specific Fish Dietary Information	Tulalip Tribe	73	72	45	186	244
	Suquamish Tribe	284	214	132	489	796
	Squaxin Island Tribe	117	73	42	193	247
	Columbia River Tribes	512	63	40	113	176
	Asian-Pacific Islander	202	117	78	236	306

[234] Oregon Department of Environmental Quality. Human Health Focus Group Report, Oregon Fish and Shellfish Consumption Rate Project, June 2008. Adapted from Table 3, page 28 of fish consumption rates and fish dietary survey information considered relevant for the Pacific NW fish consuming populations.

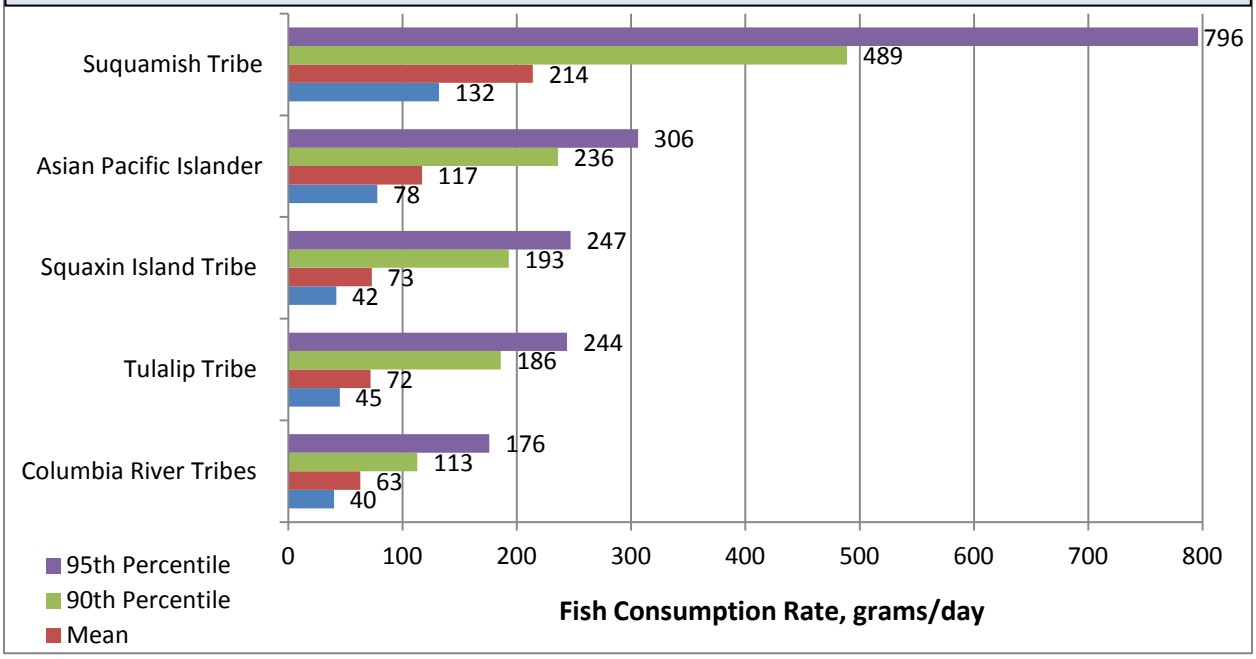
[235] EPA recommends comparing regional specific fish consumption information with national data to ensure that rates derived from regional specific dietary information are protective of general fish consuming populations.

EPA recommends default fish intake rates for recreational and subsistence fishers of 17.5 grams/day and 142.4 grams/day, respectively. However, because the level of fish intake varies by geographical location, EPA suggests a four preference hierarchy for States and authorized Tribes to follow when deriving consumption rates. The hierarchy encourages use of the best local, state, or regional data available and is intended for use in evaluating fish intake from fresh and estuarine species. For marine species the RBC for dietary intake should consider another source of exposure. EPA's first preference is for results from fish intake surveys of a local watershed within the State or Tribal jurisdiction to establish rates representative of local populations.

States and authorized tribes may use either high-end (90th or 95th percentile) or average fish consumption rate values for an identified population that they plan to protect. EPA recommends that arithmetic mean values be the lowest value considered by States or tribes when choosing intake rates for use in water quality criteria. States and Tribes need to ensure that the distribution of fish consumption rates is based on survey respondent who reported consuming fish because surveys based on both consumers and non-consumer can results in median values of zero. EPA notes that if a State or Tribe chooses values from studies that target high-end consumers, then these values should be compared to high-end intake rates for the general population to make sure that the high-end consumers within the general population would be protected by the chosen rates.

U.S. EPA, 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000) U.S. Environmental Protection Agency. Office of Water and Office of Science and Technology. EPA-822-B-00-004.

Graph C-1 Graphical Display of Descriptive Statistics for Pacific NW Fish Dietary



Fitting summary statistics from regional fish consumption rate surveys to lognormal distributions

Given the limited descriptive statistics for Pacific Northwest (regional-specific) fish dietary information, the objective of this analysis is to provide an analytical method to more comprehensively evaluate available fish dietary information to derive a fish consumption rate range and default fish consumption rate. The methodology and analysis is modeled after similar work conducted by the Oregon Department of Environmental Quality.[236] [237]

Method

The fish consumption rates of the Pacific Northwest populations were assumed to follow lognormal distributions.[238,239] Using the descriptive statistics (sample mean, median, and upper percentiles) from each of the regional-specific fish dietary surveys, the parameters *mu* (μ) and

[236] Fish & Shellfish Consumption Rate Values for Public Review & Comment. Public Workshop, April 02, 2008, Pendleton, Oregon. Web location: http://www.deq.state.or.us/wq/standards/fish.htm

[237] Statistical methodological design, execution, and analysis is the product of collaboration with the University of Washington, Department of Biostatistics and Statistics, Nayak Polissar (Statistical Consultant), and Environmental Assessment Program (Valerie Partridge).

[238] Ruffle et al., 1994. Ruffle, Betsy; Burmaster, David E.; Anderson, Paul D.; Gordon, Henry D. Lognormal distributions for fish Consumption by the General U.S. Population. Risk Analysis, Vol 14, No. 4, 1994,pages 395 to 404.

[239] Limpert et al., 2001. Limpert, Eckhard; Stahel, Werner A.; Abbt, Markus. Log-normal distributions Across the Sciences: Keys and Clues. BioScience Vol. 51, No. 5, May 2001, pages 341-352.

sigma (σ) were derived for each population. Lognormal probability density (probability density function, PDF) and cumulative probability (cumulative density functions, CDF) distributions for each sample population were generated with the μ and σ derived for that population. Seven weighting schemes were developed, described further below, to generate composite cumulative density functions (lognormal distributions). Weighted composite cumulative density functions (lognormal distributions) were generated, from which median and upper percentile fish consumption rates can be estimated.

Census-based weighting of fish dietary survey populations

Regional-specific fish dietary survey information was reviewed and cross-checked with census information to confirm the number of adult fish consumers in the populations.

Weighting schemes

Weighting of the regional-specific adult fish consuming populations surveyed was based on 2010 Census data.[240] Specific 2010 Census population estimates were used for weighting the different Asian and Pacific Islander (API) ethnic groups identified in the API survey. Similarly, 2010 Census population estimates were used for weighting the different tribal populations surveyed throughout the Puget Sound area and Columbia River basin. Table C-2 summarizes the population estimates used in the various weighting options to fit lognormal distributions to the fish dietary information.

Seven weighting schemes were developed to account for differences between the surveyed population sizes and Washington State populations, ethnic and tribal populations, and finally, the U.S. general population. These weighting schemes are intended to recognize and account for the variability in population size across the different fish consuming populations surveyed. The seven weighting schemes were evaluated to determine the weighting scheme that best represents the upper percentile fish consumption rates across the populations surveyed in the Pacific Northwest.

The seven weighting schemes used to derive the lognormal distributions are described below.

1. *Weight by sample size*: Each population surveyed was adjusted to account for the size of the sample used in that survey.
2. *Weight by 2010 Census population estimates*: Each sample population surveyed was adjusted to account for tribal adults living on or near the reservations and for adult Asians and Pacific Islanders living in King County.

[240] U.S. Census Bureau: http://factfinder2.census.gov/

3. *Tribes only, equal weighting*: The four tribal populations surveyed were equally weighted. No API populations were included in this weighting scheme.
4. *Tribes only, weighted by population*: Tribal populations surveyed were weighted based on tribal adult population estimates on or near their respective reservation.
5. *Weight API along with tribes weighted equally*: The four tribal populations surveyed were weighted equally, and then all the Pacific Northwest tribes surveyed were weighted equally with the API.
6. *Equal weighting of surveyed populations, including U.S. general population*: Equal weighting was given to all surveyed populations including the U.S. general population surveyed.
7. *Equal weighting*: Equal weighting was applied to all surveyed populations in the Pacific Northwest only.

Individual probability and cumulative density functions were generated for each of the surveyed populations using different combinations of the descriptive statistics from the Pacific Northwest adult surveyed populations. The best fit of the survey data was determined using the following combinations of sample summary statistics: (1) the median and mean, (2) the median and 75th percentile, (3) the median and 90th percentile, (4) the median and 95th percentile, and (5) the mean and standard deviation. The median and 95th percentile was determined to provide the best fit of the fish consumption data and was used to generate individual and composite cumulative distributions using the seven different weighting schemes.

Table C-2. Weighting Factors Used to Generate Probability and Cumulative Density Functions

Weighting Scheme	Squaxin Island Tribe	Tulalip Tribe	Suquamish Tribe	Columbia River Tribes	Asian-Pacific Islander (API)	U.S. General Population
Equal weighting for Pacific Northwest surveyed population only	0.2	0.2	0.2	0.2	0.2	- - - - -
Weight by 2010 Census pop. estimates	0.0011	0.0098	0.0034	0.0561	0.9297	- - - - -
Tribe only, equal weighting	0.25	0.25	0.25	0.25	- - - - -	- - - - -
Equally weighted tribes (individual) and API	0.1250	0.1250	0.1250	0.1250	0.5000	- - - - -
Equal weighting of surveyed populations, including U.S. general population	0.1667	0.1667	0.1667	0.1667	0.1667	0.1667
Tribes only, weighted by population	0.0153	0.1387	0.0479	0.7980	- - - - -	- - - - -
Weight by sample size	0.1175	0.0733	0.0924	0.5141	0.2028	- - - - -

Table C-3: Information Used to Derive Weighting Factors

Parameters for Weighting	Squaxin Island Tribe	Tulalip Tribe	Suquamish Tribe	Columbia River Tribes	Asian-Pacific Islander (API)	U.S. General Population
Surveyed population sample size	117	73	92	512	202	2585
Estimated adults in Washington and on or near tribal reservation, 2010 estimates	198	1,792	619	10,308	298,391	5,143,186

Statistical methods applied to regional-specific fish dietary information to generate lognormal distributions

Let the random variable X_i represent population i, $i = 1, 2, ..., k$.

For each population i, the only information available is sample summary statistics, specifically:

- Sample size, n_i .
- Sample mean, $\bar{x}_i$.
- Sample standard deviation, s_i , or sample standard error, $\frac{s_i}{\sqrt{n_i}}$.
- Sample percentiles x_{pi} , where $p = 50, 75, 90, 95$, or 99.
- Sample median, $m_i = x_{50i}$.

Assume X_i is lognormally distributed with parameters μ_i and σ_i , i.e., $X_i \sim \ln N(\mu_i , \sigma_i)$, and that the X_i are independent but not identically distributed.

For each population i, estimate the parameters μ_i and σ_i by substituting the distribution mean, median, standard deviation, and upper percentiles with the available sample statistics and solving for μ_i and σ_i.

- Population median: $M_i = e^{\mu_i}$. Use $\widehat{M}_i = m_i$.
- Population mean: $E(X_i) = e^{(\mu_i + \sigma_i{}^2/2)}$. Use $\hat{E}(X_i) = \bar{x}_i$.
- Population variance: $V(X_i) = e^{(2\mu_i + \sigma_i^2)} \cdot \left(e^{\sigma_i^2} - 1\right)$. Use $\hat{V}(X_i) = s_i^2$.
- Population percentiles: $X_{pi} = e^{\mu_i + Z_p \cdot \sigma_i}$, where Z_p is the pth percentile of the standard normal distribution, i.e., $Z \sim N(0,1)$. Use $\hat{X}_{pi} = x_{pi}$.
- To estimate the parameters μ_i and σ_i by using the sample mean and median:
- $\hat{E}(X_i) = \bar{x}_i \; and \; \widehat{M}_i = m_i \;\Rightarrow\; \hat{\mu}_i = \ln m_i \; and \; \hat{\sigma}_i = \sqrt{2ln(\bar{x}_i/m_i)}$.
- To estimate the parameters μ_i and σ_i by using the sample median and p^{th} percentile:

  $$\hat{X}_{pi} = x_{pi} \; and \; \widehat{M}_i = m_i \;\Rightarrow\; \hat{\mu}_i = \ln m_i \; and \; \hat{\sigma}_i = \frac{1}{Z_p} \ln\left(\frac{x_{pi}}{m_i}\right),$$

  where Z_p is the pth percentile of the standard normal distribution.
- To estimate the parameters μ_i and σ_i by using the sample mean and standard deviation: $\hat{E}(X_i) = \bar{x}_i \; and \; \hat{V}(X_i) = s_i^2 \Rightarrow$

$$\hat{\mu}_i = ln(\bar{x}_i) - \frac{1}{2}\, ln\left[\left(\frac{s_i}{\bar{x}_i}\right)^2 + 1\right] \; and \; \hat{\sigma}_i = \sqrt{ln\left[\left(\frac{s_i}{\bar{x}_i}\right)^2 + 1\right]}\,.$$

Estimate the parameters μ_i and σ_i for each population i by using two sample statistics at a time as indicated above, and determine which set results in the best fit. Use as the determination of fit the root mean squared deviation of the estimators, i.e., the square root of the average squared differences between the theoretical and sample summary statistics.

Calculate and plot lognormal density and cumulative density functions for each population i with the chosen best-fit μ_i and σ_i .

Generate a composite lognormal distribution from a weighted sum of the individual random variables X_i using the Fenton-Wilkinson approximation[241]:

Given that $X \sim ln\mathrm{N}(\mu, \sigma) \Rightarrow aX \sim ln\mathrm{N}(\mu+\ln a, \sigma)$ and $X_i \sim ln\mathrm{N}(\mu_i, \sigma_i) \Rightarrow \mathrm{Y}=\Sigma X_i$ is not lognormal but may be approximated[1] by a lognormal with parameters μ_Y and σ_Y, where

$$\sigma_Y^2 = ln\left[1 + \frac{\sum e^{2\mu_i+\sigma_i^2}\left(e^{\sigma_i^2}-1\right)}{\left(\sum e^{\mu_i+\sigma_i^2/2}\right)^2}\right] \text{ and } \mu_Y = ln\left[\sum e^{\mu_i+\sigma_i^2/2}\right] - \frac{\sigma_Y^2}{2}\,,$$

then it follows that $\mathrm{Y} = \Sigma w_i X_i \sim$ approx. $ln\mathrm{N}(\mu_Y, \sigma_Y)$, where $\Sigma w_i = 1$,

$$\sigma_Y^2 = ln\left[1 + \frac{\sum e^{2(\mu_i+lnw_i)+\sigma_i^2}\left(e^{\sigma_i^2}-1\right)}{\left(\sum e^{(\mu_i+lnw_i)+\sigma_i^2/2}\right)^2}\right], \text{ and } \mu_Y = ln\left[\sum e^{(\mu_i+lnw_i)+\sigma_i^2/2}\right] - \frac{\sigma_Y^2}{2}\,.$$

Options for the weights w_i include:

- $w_i = \frac{1}{k}$, where k is the number of random variables being composited, i.e., equal weighting.
- $w_i = \frac{n_i}{n}$, where $n = \Sigma n_i$ and n_i is the sample size for random variable X_i .
  (The rationale for this weighting would be to give greater weight to surveys with larger sample sizes, since they would have greater precision, all other things being equal.)
- $w_i = \frac{N_i}{N}$, where $N = \Sigma N_i$ and N_i is the population size for random variable X_i .
- Other, more complex weighting schemes.

Calculate and plot the [approximate] lognormal density and cumulative density functions.

Calculate the pth percentiles from the composite distribution for p = 50, 75, 90, 95, or 99:

[241] Fenton, L.F. 1960. The sum of log-normal probability distibutions in scattered transmission systems. IRE Transactions on Communication Systems 8:57-67.

$Y_p = e^{\mu_Y + Z_p \cdot \sigma_Y}$, where Z_p is the pth percentile of the standard normal distribution.

Assumptions

Certain assumptions were made regarding the characteristics of the datasets describing the Pacific Northwest fish dietary information, the populations surveyed in the Pacific Northwest, and the relationship between these surveyed populations and 2010 Census population estimates for Washington State. Some of these assumptions include:

- Lognormality. Assumed lognormality is consistent with exposure to environmental contaminants from consuming contaminated fish.[242,243,244,245]
- Independence. The Pacific Northwest fish-consuming populations are assumed to be independent of one another.
- For pulling census data:
  - Tribal population on reservation = American Indian and Alaska Native[246], alone or in combination[247], on reservations and off-reservation trust lands[248]:
    - WA: Port Madison, Squaxin Island, Tulalip, Yakama.
    - OR: Umatilla, Warm Springs.
    - ID: Nez Perce.
  - Asians and Pacific Islanders (API) = Native Hawaiian and Other Pacific Islander[1] Samoan category[249] and Asian[1] categories[4]: Cambodian, Chinese (excluding Taiwanese), Filipino, Hmong, Japanese, Korean, Laotian, Taiwanese, and Vietnamese; alone[2] (not in combination). The rationale is to approximate the 1st- and 2nd-generation API population surveyed in the API study (Sechena et al., 2003).
  - Adult = 18 years and older, except for Suquamish; 16 years and older for Suquamish, for consistency with the age group surveyed in the original study (Suquamish, 2000).

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242 Ruffle et al., 1994. Ruffle, Betsy; Burmaster, David E.; Anderson, Paul D.; Gordon, Henry D. Lognormal Distributions for Fish Consumption by the General U.S. Population. Risk Analysis, Vol 14, No. 4, 1994, pages 395-404.

243 Limpert et al., 2001. Limpert, Eckhard; Stahel, Werner A.; Abbt, Markus. Log-Normal Distributions across the Sciences: Keys and Clues. BioScience, Vol. 51, No. 5, May 2001, pages 341-352.

244 Suquamish Tribe, 2000. Fish Consumption Survey of the Suquamish Indian Tribe of The Port Madixon Indian Reservation, Puget Sound Region. The Suquamish Tribe, Port Madison Indian Reservation, Suquamish, Washington. August 2000

245 Polissar et al., 2006. Polissar, Nayak L.; Stanford, Derek; Liao, Shiquan; Neradilek, Glazej; Mittelstaedt, Gillian D.; Toy, Kelly A. A fish Consumption Survey Of The Tulalip and Squaxin Island Tribes of the Puget Sound Region—Consumption Rates For Fish Consumers Only. Report by The Mountain-Whisper-Light Statistical Consulting and Department of Environment, Tulalip Tribes. 2006.

246 Race as defined by U.S. Census Bureau.

247 Race combinations and permutations as defined by U.S. Census Bureau.

248 American Indian Area/Alaska Native Area/Hawaiian Home Land as defined by U.S. Census Bureau.

249 Race groups or categories as defined by U.S. Census Bureau.

- For estimating populations from census data where complete delineation was not available:
  - To estimate population 16 years and older for Suquamish: Multiply Port Madison tribal population (see above definition) 18 years and older (known) by ratio of Port Madison total population age 16+ (known) to Port Madison total population age 18+ (known).
  - To estimate adult population for API 2010: Multiply each subgroup population in 2010 (known) by ratio of 2000 subgroup population age 18+ (known) to 2000 subgroup total population (known).

Results

Ecology reviewed the surveys and, in consultation with one of the primary authors for the Pacific Northwest fish dietary surveys, fitted lognormal distributions based upon the descriptive statistics for adult fish consuming populations from the regional-specific fish.

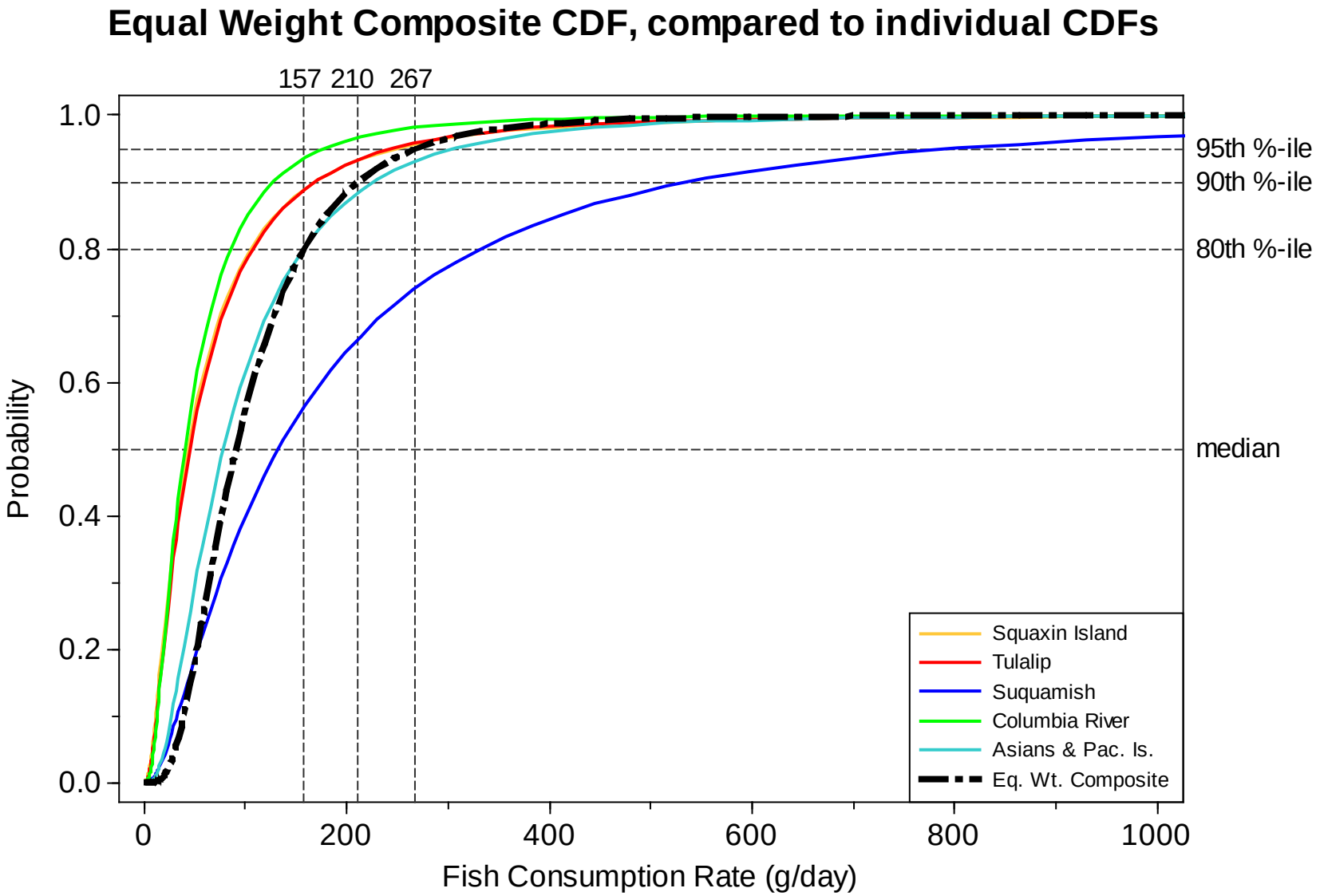
The composite cumulative distributions were quite similar for five of the seven weighting schemes, resulting in similar values for the estimated upper percentiles. The equal-weight composite cumulative distribution was in the middle of those five composites. This scheme is independent of the population sizes and is the simplest to implement. Therefore, the equal-weight composite was judged to be the best representation of the fish consumption rates of the majority of Pacific Northwest fish-consuming populations.

Observations

The following rates are based on the weighted (equal weighting for the Pacific Northwest surveyed populations) cumulative density function for the combined regional specific fish dietary survey information.

- 80 percent of the surveyed populations consume less than approximately 157 grams/day
- 20 percent of the surveyed populations consume more than approximately 157 grams/day
- 90 percent of the surveyed populations consume less than approximately 210 grams/day
- 10 percent of the surveyed populations consume more than approximately 210 grams/day
- 95 percent of the surveyed populations consume less than approximately 267 grams/day
- 5 percent of the surveyed populations consume more than approximately 267 grams/day
- 99 percent of the surveyed populations consume less than approximately 418 grams/day
- 1 percent of the surveyed populations consume more than approximately 418 grams/day

Composite Equal Weighted Cumulative Density Function and Individual Cumulative Density Functions for Pacific Northwest Fish Dietary Surveyed Populations Only Show 80th, 90th and 95th Percentile Intercepts



Truncated Scale: Composite Equal Weighted Cumulative Density Function and Individual Cumulative Density Functions for Pacific Northwest Fish Dietary Surveyed Populations Only Show 80th, 90th and 95th Percentile Intercepts

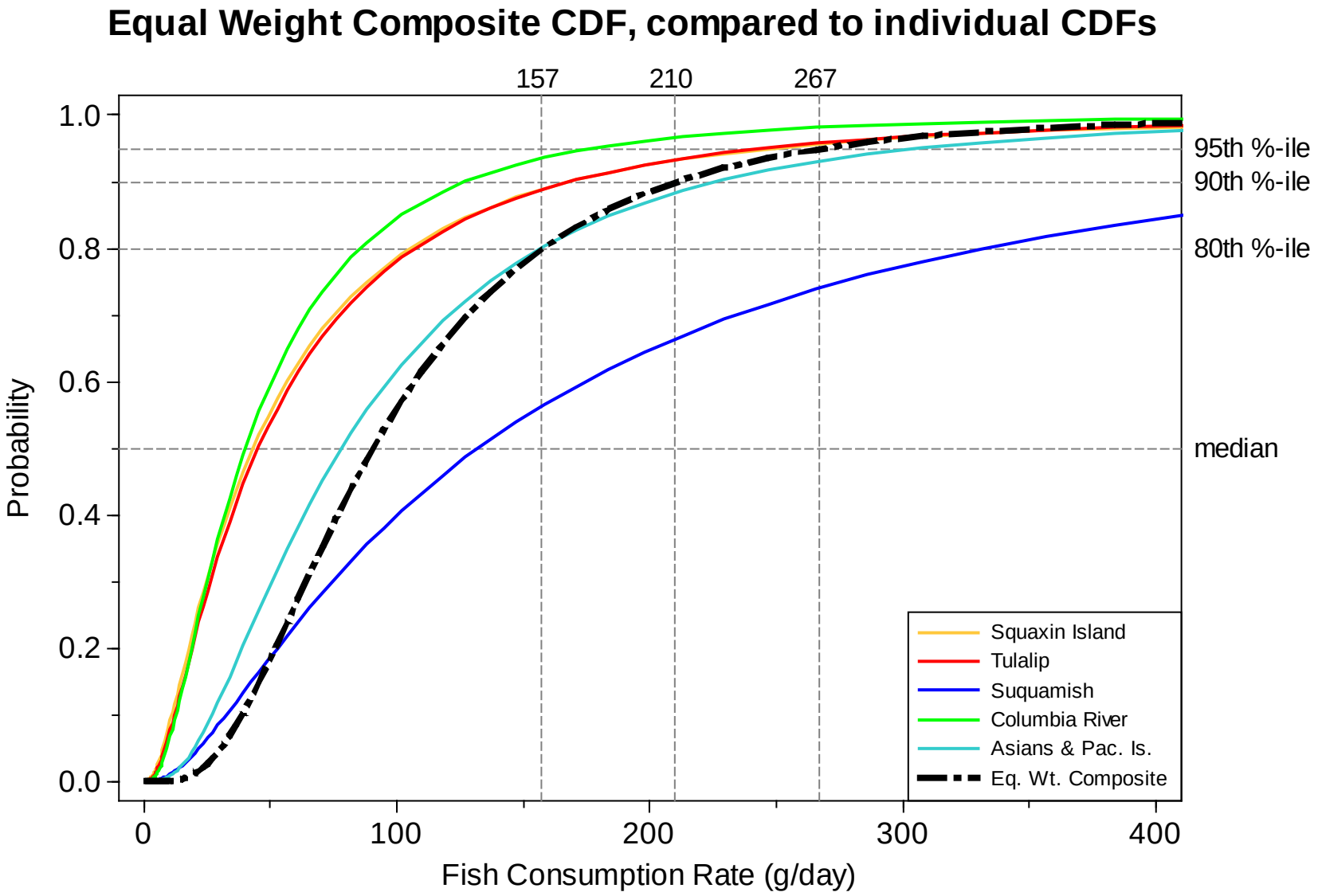


Table C-4. Results: Derived Descriptive Statistics for various Weighting Schemes

Descriptive Statistics, estimated	Weighting Scheme						
	(1) Equal weighting for Pacific Northwest Surveyed Pop.'s only	(2) Weight by 2010 Census Adult Pop. Estimates On/Near Res or API in King County	(3) Tribes only, equal weighting, no API Pop. Accounted For	(4) Equally weighted tribes (individual) and API	(5) Equal Weighting of surveyed populations, including U.S. Gen'l Population	(6) Tribes only, weighted by population, no API Pop. Accounted For	(7) Weight by Sample Size
mu	4.5048	4.3543	4.4379	4.5311	4.5853	4.0083	4.3379
sigma	0.6588	0.8031	0.7599	0.6055	0.5700	0.7158	0.5653
mean	112.37	107.42	112.92	111.54	115.33	71.12	89.81
median	90.45	77.81	84.60	92.86	98.03	55.05	76.55
75th percentiles	141.05	133.75	141.24	139.70	143.99	89.22	112.08
80th percentiles	157.47	152.96	160.37	154.58	158.39	100.55	123.19
90th percentiles	210.41	217.78	224.04	201.76	203.53	137.77	157.98
95th percentiles	267.30	291.56	295.27	251.40	250.37	178.69	194.00
99th percentiles	418.77	503.97	495.61	379.82	369.22	291.03	285.18
Standard deviation	82.83	102.24	99.83	74.23	71.46	58.18	55.12

Appendix D
EPA Region 10 Framework

The U.S. Environmental Protection Agency (EPA), Region 10, published in 2007 a decision-making framework for use in deriving fish/shellfish consumption rates to help support the cleanup of contaminated sites in Puget Sound and the Strait of Georgia up to the Canadian border. [250] The framework recognizes the limited seafood consumption information available. It supports site-specific regulatory cleanup decisions at the many hazardous waste sites located on tribal lands or within tribal fishing areas. The framework provides a consistent and protective approach to establishing fish consumption rates by identifying a tiered information hierarchy of preferred data:

1. Fish/shellfish consumption surveys from local watershed representative of the population being addressed for a water body.
2. Fish/shellfish consumption surveys that reflect geography or population groups similar to those under evaluation.
3. National food consumption survey information.
4. Default values.

The EPA Region 10 framework uses the seafood consumption information from the Suquamish and the Tulalip Tribes to support the development of fish consumption rates for other tribal fish-consuming populations.[251] The selection of the Suquamish or the Tulalip consumption information to be used as a surrogate for other tribal or fish-consuming populations is dependent on consideration of the following:

- Fish/shellfish abundance
- Fish/shelf habitat quality
- Fish/shellfish habitat quantity
- Careful consultation with fish/shellfish tribal biologists to make an informed decision regarding the selection of the dataset
- Historical patterns of fish/shellfish abundance and habitat quality

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[250] EPA Region 10, Office of Environmental Assessment, *Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia*, August 2007.

[251] Toy, K.A., et al., *A Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region*, Tulalip Tribes, Department of Environment, Marysville, Washington, 1996.

Selection of the Suquamish Tribe's dataset is most applicable to cleanup sites with the extensive intertidal habitat needed to sustain shellfish harvests. Selection of the Tulalip Tribe's dataset is most applicable where there is less shellfish habitat to sustain shellfish harvests.

Fish species

The EPA Region 10 framework assumes all of the fish and shellfish harvested from the Puget Sound may be affected by site contaminants. Hence, unless there is site-specific information attributing salmon contaminant body burdens to site contaminants, salmon are included in the overall fish consumption rate. Consistent with EPA regulatory policies, procedures, and guidance, the fish consumption rates used in framework were based on the 95th percentile from the Suquamish or Tulalip consumption dataset (uncooked weight, harvested from Puget Sound). The fish consumption rates are categorized for various species: salmon, pelagic fish, bottom fish, and shellfish. The total fish/shellfish ingestion rates for the two tribes are adjusted to include only fish and shellfish harvested from Puget Sound.

The table below provides the Tulalip Tribe's fish consumption rate and percent of diet assumed by the species tabulated in the EPA Region 10 framework. The total unadjusted fish/shellfish consumption rate for the Tulalip Tribe is 243 grams/day. The average Tulalip adult body weight used to derive the grams/day fish consumption rate was 81.8 kilograms.

Table D-1. Tulalip Tribe's Fish Consumption Rate (grams/day)

Species Category	Fish Consumption Rate	Percent of diet
Salmon	96.4	49.7
Pelagic fish	8.1	4.2
Bottom	7.5	3.9
Shellfish	81.9	42.2
Total ingestion rate with salmon	194	100
Total Ingestion rate without salmon	98	

Source: U.S. Environmental Protection Agency. 2007. *Region 10 Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia.*" August. Adapted from Table B-1.

The table below provides the Suquamish Tribe's fish consumption rate and percent of diet assumed by the species tabulated in the EPA Region 10 framework. The total unadjusted fish/shellfish consumption rate for the Suquamish Tribe is 796 grams/day. The average Suquamish adult body weight used to derive the grams/day fish consumption rate was 79 kilograms.

Table D-2. Suquamish Tribe's Fish Consumption Rate (grams/day)

Species Category	Fish Consumption Rate	Percent of diet
Salmon	183.5	23.9
Pelagic fish	56.0	7.3
Bottom	29.1	3.8
Shellfish	498.4	65
Total Ingestion rate with salmon	766	100
Total Ingestion rate without salmon	583	

Source: U.S. Environmental Protection Agency. 2007. *Region 10 Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia.*" August. Adapted from Table B-1.

The EPA Region 10 framework has been applied to support cleanups of the following Washington sites:

- Lower Duwamish Waterway and associated sites along the waterway
- Port Angeles ITT Rayonier
- Puget Sound Naval Shipyard

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Appendix E
The Question of Salmon

Ecology is considering several factors related to risk management when deciding how to include salmon when assessing the risks from the consumption of fish. Some of these factors are discussed in this appendix:

- The abundance of salmon
- Salmon lifecycles
- Chemical contaminants in ambient waters and sediments
- The unique quality of Puget Sound and other Washington waters

Considerations of the complex life cycle and survival strategies of anadromous fish species like salmonids complicate and influence many risk management decisions. For example, risk management cleanup decisions in Port Angeles harbor and the Lower Duwamish Waterway are influenced by the presence/absences of salmonids in the harbor or waterway, migratory patterns, and contaminant body burdens attributable to site contaminants.[252,253] The complication arises because it is difficult to attribute salmon contaminant body burdens to site-specific contaminants.

This appendix describes the life cycle and survival strategies of salmonids. This information is related to policy and technical considerations regarding how to appropriately address the question of salmon when developing fish consumption rates for regulatory purposes.

Background

Salmon is consumed in abundance. On a global scale, over the last two decades, advances in farmed-salmon production have tripled the world's supply of salmon. In 1985, 6 percent of all salmon consumed around the world was farmed.[254] In 1988, farmed salmon production surpassed wild fisheries.[255] In 2000, 58 percent of all salmon consumed around the world was farmed, almost a tenfold increase. In the U.S., between 1987 and 1999, salmon consumption

[252] Washington State Department of Ecology. Port Angeles Harbor Marine Environment. Human Health and Ecological Risk Assessment. Public Review DRAFT. March 2011.

[253] U.S. Environmental Protection Agency, Region 10, and Washington State Department of Ecology, Northwest Regional Office. Lower Duwamish Waterway Remedial Investigation. Appendix B: Human Health Risk Assessment. Final. November 12, 2007.

[254] Institute for Health and the Environment. University at Albany. General Information about World Salmon Production and Consumption. Web location: http://www.albany.edu/ihe/salmonstudy/background.html

[255] IBID

increased nine times.[256] During that time period, salmon consumption increased annually at a rate of 14 percent in the European Union and 23 percent in the United States.[257]

Over half the salmon sold globally is farm-raised in Northern Europe, Chile, Canada, and the United States. The annual global production of farmed salmon (Atlantic salmon, *Salmo salar*) has increased from approximately 24,000 to over 1 million metric tons during the past two decades.[258,259] Contaminant body burdens in farm-raised salmon have been well documented and compared to wild salmon. European farm-raised salmon have significantly greater organochlorine (dioxin, dioxin-like polychlorinated biphenyls [PCBs], and selected pesticides) contaminant body burdens than those salmon raised in North and South America.[260]

Factors influencing the health risk from consuming salmon

There are multiple factors to consider when assessing the risk from consuming salmon. Most Washington salmon spend the largest part of their lives in the open ocean, where exposure to contaminants originating from Washington sources is minimal. Salmon life cycles are complex, and the many species have different survival strategies.

Ecology recognizes that:

- Salmon are an available Washington State resource.
- Salmon are an available Washington State resource for harvest and consumption.

It is appropriate to consider:

- Washington State estimates of recreational and commercial salmon harvests.
- Estimates of Washington State fish consuming populations.
- Cultural and religious significance of salmon to different Native American fish-consuming populations in Washington State.

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[256] IBID

[257] Hites et al., 2004. Hites, Ronald A., Foran, Feffery A.; Carpenter, David O.; Hamilton, Coreen M.; Knuth, Barbara A.; Schwager, Steve J. Global Assessment of Organic Contaminants in Farmed Salmon.Science 09 January 2004, Vol 303, pages 226-229

[258] Institute for Health and the Environment. University at Albany. General Information about World Salmon Production and Consumption. Web location: http://www.albany.edu/ihe/salmonstudy/background.html

[259] From B. Charron, An IntraFish.com Industry Report on Salmon Product Development-The Fish of the Future and Fisheries Global Information System of the Food and Agriculture Organization of the United Nations as cited from Hites et al., 2004.

[260] Hites et al., 2004. Hites, Ronald A., Foran, Feffery A.; Carpenter, David O.; Hamilton, Coreen M.; Knuth, Barbara A.; Schwager, Steve J. Global Assessment of Organic Contaminants in Farmed Salmon. Science 09 January 2004, Vol 303, pages 226-229

- The complexity of the salmon life cycle and survival strategies, local and global salmon contaminant body burdens, and Puget Sound resident and nonresident salmon populations.
- Federal and state regulatory policies and procedures.

Ecology notes that similarities between bioaccumulative and persistent contaminant (organochlorines) salmon body burdens from local and global distributions would preclude the ability to define a chemical fingerprint to attribute salmon body burdens to site-specific bioaccumulative and persistent contaminants

Information about salmon consumption in Washington

For Ecology to determine how to appropriately address salmon when developing one or more default fish consumption rates, Ecology examined the regional fish dietary survey information regarding salmon-related consumption. These surveys show that salmon is consumed frequently and in large amounts.

Based on Pacific Northwest regional specific fish dietary surveys, salmon and selected types of shellfish are the most frequently consumed and consumed in the largest amounts of all seafood. Salmon is the most frequently consumed finfish (more than 90 percent) for all adult respondents from all of the regional-specific fish dietary surveys. (This observation follows the national trend where U.S. salmon consumption grew from 9.5 percent to 15 percent from 1996 to 2005 as a share [percentage] of fish and shellfish consumption.[261])

For the API populations surveyed, 96 percent of the survey respondents consume anadromous fish comprising greater than 10 percent of all seafood consumed.[262] Also, 99 percent of the survey participants consume shellfish comprising more than 45 percent of all seafood consumed. The API survey participants consume a large variety of fish and shellfish.

For the Tulalip Tribes and the Squaxin Island Tribe, 72 to 80 percent of anadromous fish and 62 to 72 percent of shellfish were harvested in the Puget Sound area.[263] When fish harvests are accounted for outside of the Puget Sound area, greater than 90 percent of the seafood harvested were anadromous. Of both the Tulalip Tribes and the Squaxin Island Tribe surveyed, greater than 90 percent of the survey respondents consume anadromous, fish which comprises almost 50 percent of all seafood consumed. The Tulalip dataset was adjusted for the harvest and consumption of fish and shellfish from Puget Sound in the EPA Region 10 framework. With the adjusted rates used in the EPA Region 10 framework, salmon and shellfish assume about 50 percent each of the Tulalip tribal seafood diet, with salmon consumed in slightly greater amounts

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[261] Fish and Shellfish Consumption data from National Marine Fisheries Service, Salmon Consumption data from National Fisheries Institute. Web location: http://www.fas.usda.gov/ffpd/Newsroom/Salmon.pdf

[262] Sechena et al., 2003. Sechena, Ruth; Liao, Shiquan; Lorenzana, Roseanne; Nakano, Connie; Polissar, Nayak; Fenske, Richard. Asian American and Pacific Islander Seafood Consumption – a community-based study in King County, Washington. Journal of Exposure Analysis and Environmental Epidemiology. (2003) 13, pages 256-266. Tables 2 and 5.

[263] Toy, K.A, Polissar, N.L., Liao, S., and Mittelstaedt, G.D., 1996. A fish consumption survey of the Tulalip and Squaxin Island tribes of the Puget Sound region. Tulalip Tribes, Department of Environemtn 7615 Totem Beach Road, Marysville, WA 98271.

than shellfish. Hence, if the total fish ingestion rate did not account for salmon consumption, then the fish consumption rate would be reduced by about 50 percent, from 194 grams/day to 97.6 grams/day.[264]

The Suquamish fish dietary survey identified the largest variety, most frequently consumed, and consumed in the largest amounts of fish and shellfish for all of the Pacific Northwest tribal fish-consuming populations surveyed.[265] Fifty percent or more of the respondents consumed various types of anadromous fish and about 10 different types of shellfish. The Suquamish dataset was adjusted for the harvest and consumption of fish and shellfish from Puget Sound in the EPA Region 10 framework. With the adjusted rates used in the EPA Region 10 framework, salmon and shellfish assume about 25 percent and 65 percent, respectively, of the Suquamish tribal seafood diet. Hence, if the total fish ingestion rate did not account for salmon consumption, then the fish consumption rate would be reduced by about 25 percent, from 766.8 grams/day to about 583 grams/day.[266]

The fish dietary survey for the Columbia River tribal populations identified a variety of fish harvested and consumed in large amounts.[267] The fish dietary survey conducted for the Columbia River tribal populations did not include any questions regarding shellfish consumption. Salmon is consumed by the largest number of adult respondents (92 percent), followed by trout (70 percent), lamprey (54 percent), and smelt (52 percent). Using the weighted mean fish consumption rate for adult fish consuming CRITFC tribal populations, salmon would contribute about 50 percent of the tribal seafood diet (≈25/63 grams/day). Hence, if the total fish ingestion rate did not account for salmon consumption, then the fish consumption rate would be reduced by more than about 50 percent, from a weighted mean of 63 to about 40 grams/day.

Pacific salmon life cycle and survival strategies

Salmonids have a complex life cycle and survival strategies, with large variations across and among different species.[268] The geographic distribution of Pacific salmonids extends from San Francisco Bay northward along the Canadian and Alaskan coasts to rivers draining into the Arctic Ocean, and southward down the Asian coastal areas of Russia, Japan, and Korea.

Although variation exists, generally, chinook, coho, and steelhead have migratory patterns along the Pacific continental shelf and remain in a freshwater and estuarine environments for longer periods of time than other Pacific salmonid species.

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[264] U.S. EPA Region-10. Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia. August 2007. Table B-1, Appendix B-1.

[265] The Suquamish Tribe. 2000. Fish Consumption Survey of the Suquamish Indian Tribe Of The Port Madison Indian Reservation, Puget Sound Region. The Suquamish Tribe. 15838 Sandy Hook Road, Post Office Box 498, Suquamish, WA 98392.

[266] U.S. EPA Region-10. Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia. August 2007. Table B-2, Appendix B-2.

[267] CRITFC (Columbia River Inter-Tribal Fish Commission). 1994. A fish consumption survey of the Umatilla, Nez Perce, Yakama and Warms Springs Tribes of the Columbia River Basin. CRITFC Technical Report No. 94-3. Portland, Oregon.

[268] Quinn, Thomas P. 2005. *The Behavior and Ecology of Pacific Salmon & Trout*. American Fisheries Society. University of Washington Press. 2005

After pink, chum, and sockeye salmon enter the ocean environment, they rapidly migrate northward and westward through coastal waters of North America and are found in the open waters of the North Pacific, Gulf of Alaska, and the Bering Sea by the end of their first year at sea.

Table E-1. Pacific Salmon Life Cycle

Salmonid Life-cycle Environment	← Salmon Species →						
	Chinook	Coho	Sockeye	Chum	Pink	Steelhead	Cutthroat
Riverine rearing	X	X	X			X	X
Estuarine rearing	X	X	X			X	X
Lacustrine rearing			X				X
Nearshore migration	X	X	X	X	X	X	X
Continental shelf migration	X	X				X	
Mid-oceanic migration			X	X	X		

Salmonid contaminant body burden

All seven Pacific salmon species are biotranporters of pollutants to and from the Pacific Ocean and their spawning sites in freshwater.[269] During river ascent, salmonids use their muscle lipid and triacyglycerol deposits for energy and gonadal development. Particularly in female salmonids, the organic pollutant body burden redistributes and accumulates in the lipid-rich gonads and salmon roe. Furthermore, the lipid depletions and redistribution during the river ascent is not coupled with a simultaneous elimination of the organic pollutant body burden in the salmonids.

The pollutants in the salmonids are readily available for bioaccumulation, because the migrating salmonids, salmon roe, and salmon carcasses are a direct food source for predators (birds, mammals, and other fish). Hence, salmonids redistribute their pollutant body burdens back to their spawning grounds, to the open ocean predators, or bioaccumulate in the food web.

The redistribution, biotransportation, and bioaccumulation of the salmonid pollutant body burden helps contribute to food web contamination.

Persistent bioaccumulative toxics

Because of their chemical and physical properties, persistent bioaccumulative toxics (PBTs) are a group of chemicals that exist within the environment for long periods of time, are lipophilic and bioaccumulate in fish tissue and animal fat, and are highly toxic to animals and humans.[270] The unique geologic and hydrogeologic nature of the Puget Sound, in combination with the bioaccumulative, persistent, and toxicity of the PBT-type contaminants, creates additional risks

[269] Ewald, GÖran, Per Larsson, Henric Linge, Lennart Okla, and Nicole Szarzi. Biotransport of Organic Pollutants to an Inland Alaska Lake by Migrating Sockeye Salmon (Oncorhynchus nerka) Arctic, Volume 51, No. 1, pages 40-47. March 1998.

[270] 2007 Puget Sound Update. Ninth Report of the Puget Sound Assessment and Monitoring Program. Puget Sound Action Team. Publication No. PSAT 07-02.

to the Puget Sound ecosystem. Some of the PBTs that continue to contaminate, threaten, or harm the Puget Sound ecosystem include polychlorinated biphenyls (PCBs); polycyclic aromatic hydrocarbons (PAHs); dioxins and furans; polybrominated diphenyl ethers (PBDEs); and hormone-disrupting chemicals (e.g., bisphenol A). PBTs are contaminants throughout the entire pelagic food web in the Puget Sound.[271]

Of the different PBTs that permeate the Puget Sound food web, PCBs are well-documented contaminants in coho and chinook Pacific salmon.[272] Pacific salmon exposure to PBTs, and PCBs in particular are, in part, contingent on migratory patterns, residency time in Puget Sound, proximity of the salmon to contaminated sediments, waste sites, and different behavior and dietary patterns as the fish mature. [273] PCBs were detected in composite samples of adult chinook and coho salmon collected from various in-river and marine locations in Puget Sound. Chinook salmon PCB tissue concentrations were greater than coho salmon PCB concentrations collected from in-river and marine locations.

Table E-2. Average PCB Concentrations For Coho & Chinook Salmon From In-River & Marine Locations, Puget Sound (µg/kg)

Salmon Species	Location		Mean Concentration
	Marine	In-River	
Chinook	74.2	49.1	53.9
Coho	35.1	26.5	28.3
Mean	55.3	38.6	41.85

Source: O'Neill, Sandra M., James E. West, James C. Hoeman. 1998. "Spatial Trends in the Concentration of Polychlorinated Biphenyls (PCBs) in Chinook (Oncorhynchus tshawytscha) and Coho Salmon (O. kisutch) in Puget Sound and Factors Affecting PCB Accumulation: Results from the Puget Sound Ambient Monitoring Program." *Puget Sound Research '98 Proceedings, Seattle, Washington, Volume 1, pages 312-328*. Adapted from page 316, Table 1.

After investigating different factors and correlates associated with PCBs in muscle tissue of chinook and coho salmon from marine and in-river locations in Puget Sound, O'Neill et al., 1998, page 323, observed "…that chinook salmon had significantly higher PCB concentrations than coho salmon and within each species, PCB concentrations were higher in fish caught in marine areas than in-river areas." Taking into account differences in their anadromous life cycles, age, and information from other studies evaluating contaminant exposures of salmon in the Puget Sound estuaries, O'Neill et al., 1998, suggested "…that chinook and coho salmon accumulate most of their PCB body-burden in the marine waters of Puget Sound and the ocean, and because chinook salmon live longer and stay at sea longer than coho salmon they accumulate

[271] 2007 Puget Sound Update. Ninth Report of the Puget Sound Assessment and Monitoring Program. Puget Sound Action Team. Publication No. PSAT 07-02.

[272] O'Neill, Sandra M., James E. West, James C. Hoeman. Spatial Trends in the Concentration of Polychlorianted Biphenyls (PCBs) in Chinook (Oncorhynchus tshawytscha) and Coho Salmon (O. kisutch) in Puget Sound and Factors Affecting PCB Accumulation: Results from the Puget Sound Ambient Monitoring Program. Published in Puget Sound Research '98 Proceedings, Seattle, Washington, Volume 1, pages 312-328, 1998.

[273] 2007 Puget Sound Update. Ninth Report of the Puget Sound Assessment and Monitoring Program. Puget Sound Action Team. Publication No. PSAT 07-02. and O'Neill et al., 1998.

higher PCB concentrations in their muscle tissues."[274] The authors further noted that the salmon contaminant body burden attributable to freshwater and estuarine environments was negligible compared with residency time, growth patterns, and feeding habits of the salmon at sea. T. Quinn, 2005, noted that salmon have high metabolic rates, feed heavily and grow fast in the ocean.[275]

Salmon can double their body length and increase their body weight tenfold during their first summer at sea. More than 98 percent of the final body weight of most salmon is attained at sea. For example, pink salmon entering the ocean may have a body weight of 0.2 grams but return from the sea weighing 2 kilograms, a ten thousand-fold increase. Further study by O'Neill et al., 2006, also associates the percent contaminant body burden with fish biology.[276] Coho and chinook salmon populations that have more coastal migratory distributions have higher tissue concentrations of PCBs compared with those salmonids with more oceanic migratory distributions (chum, pink, and sockeye). Variations in the contaminant body burdens were noted and attributed to the marine distribution of the species.

> *…Chinook salmon returning to Puget Sound had significantly higher concentrations of PCBs and PBDEs compared to other Pacific coast salmon populations we sampled. Furthermore, Chinook salmon that resided in Puget Sound in the winter rather than migrate to the Pacific Ocean ("residents") had the highest concentrations of POPs, followed by Puget Sound fish populations believed to be more ocean-reared. Fall Chinook from Puget Sound have a more localized marine distribution in Puget Sound and the Georgia Basin than other populations of Chinook from the west coast of North American and are more contaminated with PCBs (2 to 6 times) and PBDEs (5 to 17 times).*[277]

Residence time in Puget Sound

Ecology evaluated a variety of information related to the residence time of salmon in Puget Sound and different river systems of Puget Sound. Several factors have a bearing on the salmon residence time:

- Biological variability exists across and within salmon species regarding migratory habits and behavior patterns.
- The location of rivers or streams within Puget Sound. Locations deep within the sound lengthen the time the salmon reside in the sound.

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[274] Chinook and coho salmon occupy three distinct habitat types during their lifecycle: a. Freshwater habitats (eggs hatch & fry develop); b. Puget Sound (smolts enter marine waters to feed & reside during migration); c. Ocean habitat (O'Neill et al., 1998)

[275] Quinn, Thomas P. 2005. *The Behavior and Ecology of Pacific Salmon & Trout*. By Thomas P. Quinn, American Fisheries Society in Association with University of Washington Press. 2005.

[276] O'Neill et al., 2006. Regional patterns of persistent organic pollutants in five Pacific salmon species (Oncorhynchus spp) and their contributions to contaminant levels in northern and sourthern resident killer whales (Orcinus orca). Extended Abstract in 2006 Southern Resident Killer Whale Symposium. April 3-5, 2006.

[277] O'Neill et al., 2006. Regional patterns of persistent organic pollutants in five Pacific salmon species (Oncorhynchus spp) and their contributions to contaminant levels in northern and sourthern resident killer whales (Orcinus orca). Extended Abstract in 2006 Southern Resident Killer Whale Symposium. April 3-5, 2006, pages 3 to 4.

- Selected salmonid species do not die after spawning, and may spawn more than once migrating to and from the same river/stream in the Puget Sound.
- With considerable species variability, selected salmonid populations do not migrate to the open ocean and, instead, remain in Puget Sound.

Different residency times of salmon within Puget Sound will result in more or less exposure to chemicals that contaminate the sound and, therefore, contribute to the contaminant body burden of salmon. Some salmon (resident "blackmouth" or chinook salmon populations) may spend significant portions of their lives in Puget Sound.

Salmon abundance

Interpreting salmon abundance records and historical records on salmon counts is complicated. Salmon are difficult to count because salmon populations are variable due to continual changes in freshwater and marine environments or to the cyclic nature of salmonid behaviors. Very long time-series records (a decade or longer) of catch or escapement are required for detecting large changes (50 percent or greater) in population abundance. Also, long-term changes in abundance may not occur as a continuous linear series of events and, therefore, are not accounted for with standard statistical evaluations. Therefore, records of abundance for short periods of time may suggest an increase or decrease in salmonid populations when, in fact, long-term trends are the reverse. The inherent biological variability of salmonids confers a level of uncertainty about the abundance counts and records associated with the different salmonid species.[278]

Puget Sound salmon

The Puget Sound Basin includes the river systems in Puget Sound, Hood Canal, and the Strait of Juan de Fuca. As shown in the tables below (which provide the status of Washington and Puget Sound Salmon Stocks), there is a wide range of salmon population conditions in the Puget Sound ranging from critical to healthy.[279] Generally, for the Puget Sound, the Washington Department of Fisheries, now referred to as Washington Department of Fish and Wildlife, in 1993 classified about 44 percent of the salmon stocks as healthy, about 21 percent as depressed, about 5 percent as critical, and about 30 percent unknown. Puget Sound is considered to have more depressed salmon stocks compared to the Washington coastal regions but fewer depressed stocks than the Columbia River Basin.[280] Many wild salmon, steelhead and bull trout stocks have been listed under the Endangered Species Act by the National Marine Fisheries Services or the U.S. Fish and Wildlife Service. As of 1998, less than 50 percent of Washington's salmon stocks are

[278] Upstream. Salmon and Society in the Pacific Northwest. National Research Council, National Academy of Sciences. Pages 77-79. 1996

[279] Stock is defined by Governor's Salmon Recovery Office (http://www.governor.wa.gov/gsr0/glossary/default.asp) as "fish spawning in a particular lake or stream(s) at a particular season which to a substantial degree do not interbreed with any group spawning in a different place at the same time, or in the same place at a different time." The National Research Council, Upstream. Salmon and Society In The Pacific Northwest, pages 12 to 13, notes that salmon stocks refers to a geographic aggregate of salmon populations that includes many local breeding populations of varied size and productivity.

[280] Upstream. Salmon and Society in the Pacific Northwest. National Research Council, National Academy of Sciences. pages 86 to 90, 1996.

considered to be healthy.[281] The tables below summarize the status of salmon stocks for Puget Sound and Pacific Coastal areas and percentages associated with the different regional salmon stocks.

Table E-3. Status of Washington Salmon Stocks

Status[282]	Puget Sound		Washington Coasts		Columbia River		All Of Washington	
	Number of Stocks	%	Number of Stocks	%	Number of Stocks	%	Number of Stocks	%
Healthy	93	44.7	65	56.5	29	26.1	187	43.1
Depressed	44	21.2	8	7.0	70	63.1	122	28.1
Critical	11	5.3	0	0	1	0.9	12	2.8
Unknown	60	28.8	42	36.5	11	9.9	113	26.0
Total	208	100	115	100	111	100	434	100

Source: National Research Council. 1996. *Upstream. Salmon and Society in the Pacific Northwest*. National Academy of Sciences. Adapted from Table 4-4.

Table E-4. Status of Puget Sound Salmon Stock

Status	Chinook	Chum	Coho	Pink	Sockeye	Steelhead	Total
Healthy	10	38	20	9	0	16	93
Depressed	8	1	16	2	3	14	44
Critical	4	2	1	2	1	1	11
Unknown	7	13	9	2	0	29	60

Source: National Research Council. 1996. *Upstream. Salmon and Society in the Pacific Northwest*. National Academy of Sciences. Adapted from Table 4-3.

When the geographic scale changes from the Puget Sound to broader geographic areas of Pacific salmon habitat for the Northwest, the picture of abundance changes but still reflects declining populations. There is a drop in Pacific adult salmon returning to rivers to spawn. Historically, 56 to 65 percent of the Pacific salmon returned to Alaska's streams, 19 to 26 percent returned to streams in British Columbia, and 15 to 16 percent returned to streams in Oregon, Washington, Idaho, and California. Currently in the Pacific Northwest only one percent are returning.[283]

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[281] Summary Statewide Strategy to Recovery Salmon. Extinction Is Not An Option. Governor's Salmon Recovery Office. September 1999, Pages II.9 to II.10

[282] Status descriptors defined by Washington Department of Fisheries (status criteria descriptors may change depending on regulatory agency or publication); as used by National Research Council in Upstream. Salmon and Society in the Pacific Northwest follows:

Healthy: Stock of fish experiencing production levels consistent with its available habitat and within the natural variations in survival for the stock.

Depressed: Stock of fish whose productions is below expected levels based on available habitat and natural variations in survival rates but above the level where permanent damage to the stock is likely.

Critical: A stock of fish experiencing production levels that are so low that permanent damage to the stock is likely or has already occurred.

Unknown: There is insufficient information to rate stock status.

[283] Salmon Without Rivers, A History of the Pacific Salmon Crisis by Jim Lichatowich, Island Press, 1999. Pages 206 to 207.

WDFW hatchery release estimates to the Puget Sound:

The Washington Department of Fish and Wildlife provided Ecology with hatchery releases of yearling Chinook salmon into the Puget Sound from 1993 to 2005. Chinook salmon released as yearlings tend to remain in the Sound for their entire life-cycle. Although the Chinook salmon release estimates may be subject to revision, the queried data by WDFW provide the most current estimates for chinook salmon releases in the Puget Sound area and from the Dungeness and Elwha River hatcheries. Total hatchery releases of yearling Chinook salmon into the Puget Sound (the Straits and North and South Puget Sound) ranged from a low of 1,835,320 in 2005 to a high of 3, 367,106 in 1994.[284]

Chemical contaminants in Puget Sound

Chemical contamination of Puget Sound has occurred over a long period of time (150 years by some estimates) with various chemicals posing risks to the environment, aquatic life, and humans.

Ecology noted at the March 2008 SAB meeting, that Persistent Bioaccumulative Toxics (PBTs) pose a significant threat to the Puget Sound ecosystem. This section provides information about the presence, transport, and fate of chemical contaminants in and throughout Puget Sound. These chemicals may be factors to consider when evaluating the chemical contaminant body burdens of salmon acquired on a site-specific basis.

Some of the chemical contaminants of concern for Puget Sound are:[285,286,287]

Metals (Inorganic Contaminants)	Organic Contaminants
* Lead	* Polychlorinated biphenyls (PCBs)
* Cadmium	* Polycyclic aromatic hydrocarbons (PAHs)
* Tributyl tins	* Dioxins and Furans
* Copper	* Selected pesticides
* Mercury	* Phthalate esters
* Arsenic	* Polybrominated diphenyl ethers (PBDEs)
* Others	* Hormone disrupting chemicals (Bisphenol A)
	* Petroleum & Petroleum by-products
	* Pharmaceuticals

[284] Washington Department of Fish and Wildlife Hatchery Releases of Yearling Chinook into Puget Sound Brood Years 1993-2005, WDFW spreadsheet and raw data query provided to S. Duncan by Jeffrey Haymes, WDFW in e-mail correspondence dated 4/22/08

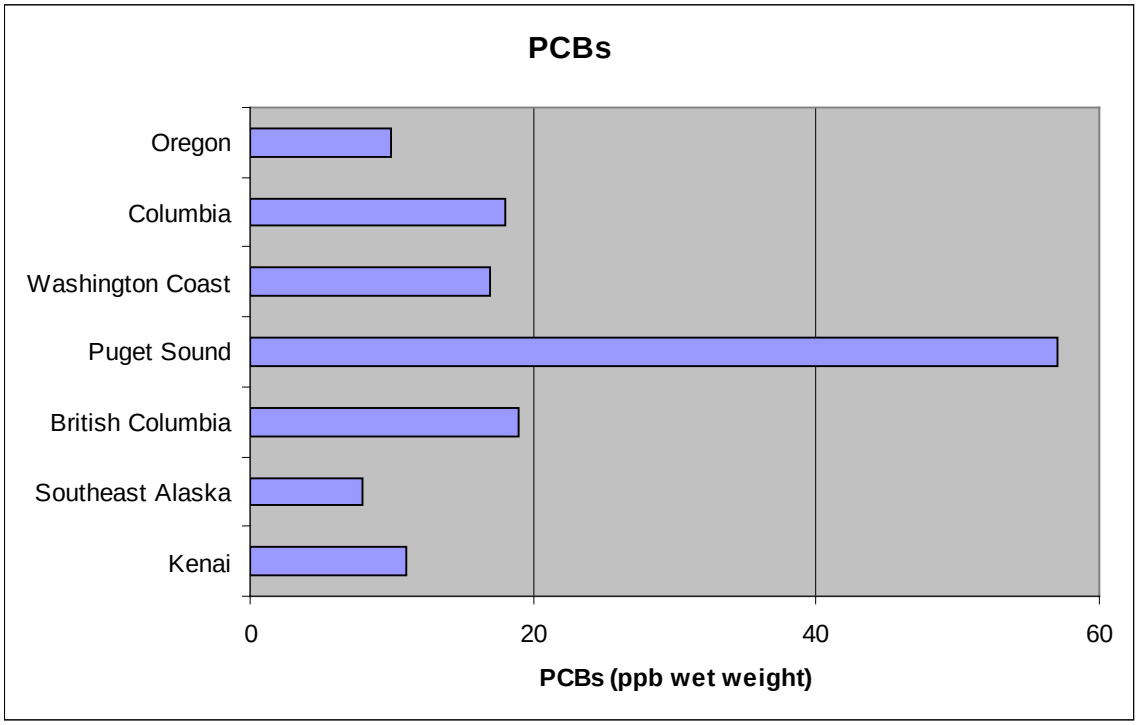
[285] 2007 Puget Sound Update. Ninth Report of the Puget Sound Assessment and Monitoring Program, Puget Sound Action Team, February 2007 (Publication No.l PSAT 07-02); Table 4-1.

[286] West et al., 2011. West, J.E., Lanksbury, J., O'Neill, Sandra M. Persistent Organic Pollutants in Marine Plankton from Puget Sound. Washington Department of Ecology. Publication number 11-10-002. March, 2011. Web location: http://www.ecy.wa.gov/biblio/1110003.html

[287] West et al., 2011. West, J.E., Lanksbury, J., O'Neill, S., Marshall, A. Persistent Bioaccumulative and Toxic Contaminants in Pelagic Marine Fish Species from Puget Sound. Washington Department of Ecology. Publication number 11-10-003. March, 2011. Web location: http://www.ecy.wa.gov/biblio/1110002.html

Polychlorinated biphenyls

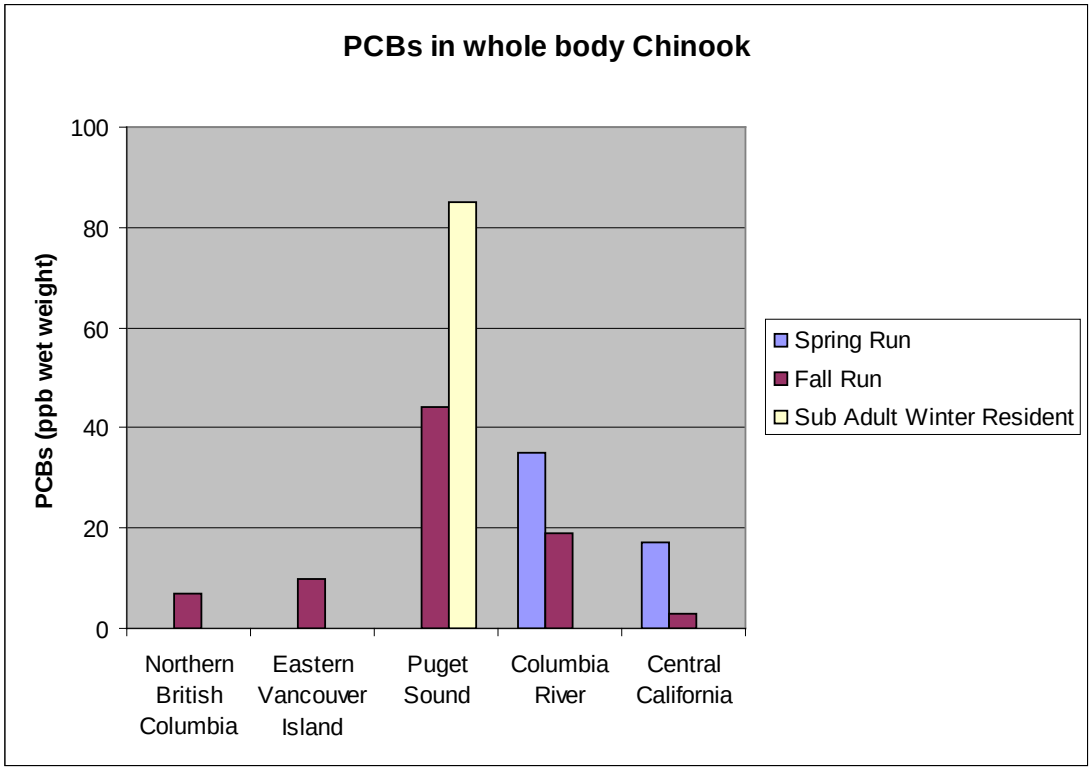
Polychlorinated biphenyls (PCBs) are persistent, bioaccumulative, and toxic chemicals found throughout Puget Sound. The bar chart below compares PCBs sampled in Chinook salmon filets from Puget Sound and Chinook salmon filets sampled for PCBs from other Pacific West Coast areas. Puget Sound Chinook salmon fillets are almost three times more contaminated than fillets of Chinook salmon from other Pacific West Coast areas.[288]

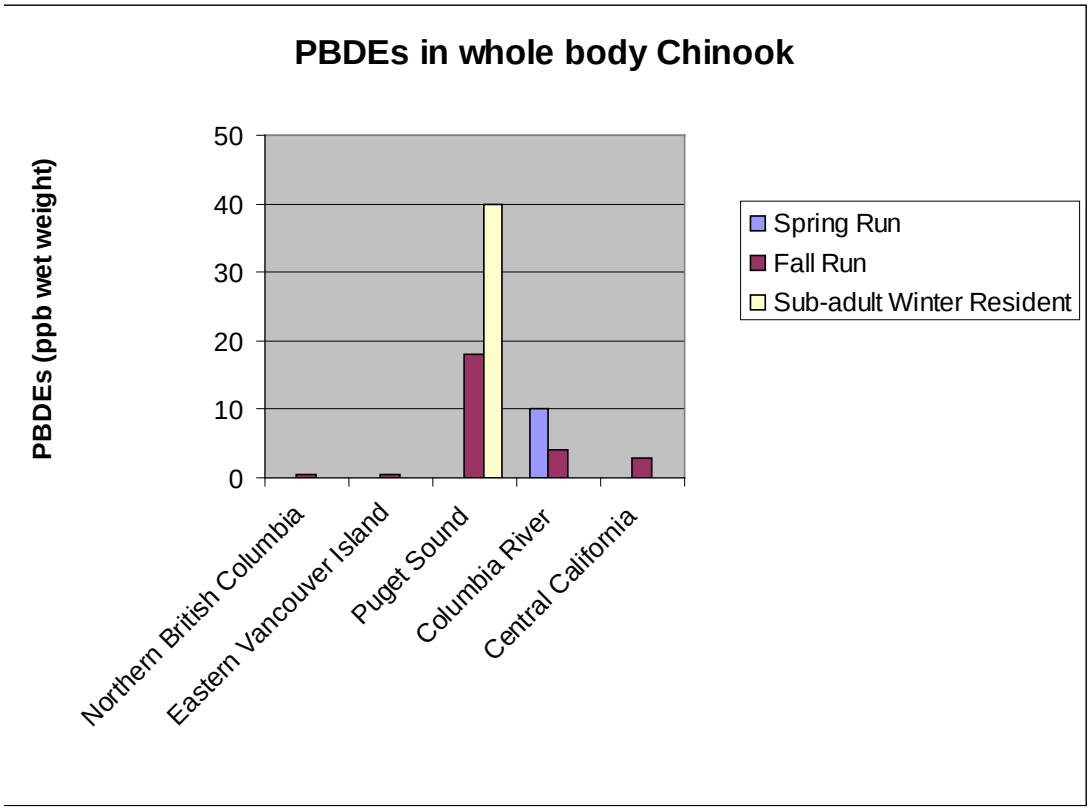


The bar charts below illustrate differences in contaminant body burdens for salmon from Pacific West Coastal areas. The bar charts illustrate that Puget Sound resident Chinook salmon had the highest contaminant body burden of PCBs and PBDEs compared to other Pacific West Coastal areas. PCBs and polybrominated diphenyl ethers (PBDEs) in whole body samples of individual summer/fall Chinook salmon from Puget Sound were 2 to 6 times more contaminated with PCBs and 5 to 17 times more contaminated with PBDEs than other populations of Chinook salmon from the Pacific West coastal areas.[289]

[288] 2007 Puget Sound Update. Ninth Report of the Puget Sound Assessment and Monitoring Program, Puget Sound Action Team, February 2007 (Publication No.l PSAT 07-02); adapted from Figure 4-18, page 156

[289] Ibid, page 157, figure 4-19; and O'Neill et al., 2006. O'Neill, S., Ylitalo, G., West, J., Bolton, J., Sloan, C., and Krahn, M. 2006. "Regional patterns of persistent organic pollutants in five Pacific salmon species (Oncorhynchus spp) and their contributions to contaminant levels in northern and southern resident killer whales (Orcinus orca)." 2006 Southern Resident Killer Whale Symposium. NOAA Fisheries Service Northwest Regional Office, Seattle. Extended Abstract


PCBs in whole body Chinook
PCBs (ppb wet weight)
100
80
60
40
20
0
Northern British Columbia
Eastern Vancouver Island
Puget Sound
Columbia River
Central California
Spring Run
Fall Run
Sub Adult Winter Resident


PBDEs in whole body Chinook
PBDEs (ppb wet weight)
50
40
30
20
10
0
Northern British Columbia
Eastern Vancouver Island
Puget Sound
Columbia River
Central California
Spring Run
Fall Run
Sub-adult Winter Resident

Chemical contaminant transport in and around Puget Sound

The Puget Sound has unique geologic qualities among North American estuaries. These unique features confer a greater residence time for contaminants and trap them within the Sound, thereby increasing the potential for exposure.

The transport and fate of site-specific contaminants

Site-specific chemical contaminants in sediments may be relocated throughout the Puget Sound by mechanical or biological transport mechanisms. Based on their life-cycle, salmon play a unique role in the biological transport of contaminants in and through Puget Sound and contribute to the chemical contamination of the food web.

Hydrodynamic conditions of the Puget Sound

Unlike other North American estuaries, the flushing of chemical contaminants in the sound is minimized by shallow sills, such as Admiralty Inlet. The circular pattern of currents combined with reduced current velocity at the sills results in the contaminants being circulated for longer periods of time.

Contaminant residence times

The residence times for contaminants in Puget Sound are extended because the circulation conditions of the Sound, including the shallow sills associated with different inlets, freshwater/marine water gradients, and highly variable flow velocities in different areas of the Sound, all facilitate the trapping and mixing of toxic chemical contaminants. Chemical contaminants spend longer in the Sound increasing exposures to aquatic organisms, humans, and the environment.

Mechanical transport

Plastic debris may be transporting hydrophobic contaminants to sediments and sediment-dwelling (benthic infaunal communities) organisms. [290] Representative plastics (polyethylene, polypropylene, and PVC) were used to evaluate the preferential sorption of PAHs in plastics compared sediments in marine environments. The addition of small amounts of PAH contaminated plastics to sediments significantly increased the bioaccumulation of PAHs (phenanthrene) sediment dwelling organisms. In addition, sorption of hydrophobic chemicals to plastics facilitates the transport of the contaminants to other areas in marine environments and to marine aquatic life.

[290] Teuten et al., 2007. Emma L. Teuten, Steven J. Rowland, Tamara S. Galloway, and Richard C. Thomposon. Potential for Plastics to Transport Hydrophobic Contaminants. Environmental Science and Technology, 2007, 41 (22) pages 7759-7764.

Contaminant dispersal, resuspension, and transport

Chemical contaminants can be transported and dispersed throughout the Puget Sound by a variety of processes. Chemical contaminants within different estuaries and marine water bodies can be transported and dispersed through different watersheds, bay and harbor areas, and inlets. The implications for the transport and dispersion of chemical contaminants throughout these water bodies is an increased potential for exposure to these contaminants by aquatic life and humans, regardless of where the contaminants originated from.

Dispersal

Sediment reservoirs of historically discharged contaminants (metals, PAHs, PCBs, selected pesticides) may be disturbed and distributed by dioadvection, biodiffusion, and physical processes. The sediment-bound contaminants may be moved from the subsurface to upper sediments where the contaminants may undergo further resuspension and redistribution. Benthic infaunal communities (annelids, mollusks, crustaceans), storm events, and tidal influences contribute to the redistribution and dispersion of contaminated sediments. [291]

Resuspension and transport

Historically deposited chemical contaminants buried in sediments may be resuspended in the water column and then transported and redeposited into coastal areas distant from the bay areas where the contaminants originated. Hydrodynamic processes include diffusion, tidal dispersion and transport of chemicals, sediment-water interactions, and adsorption-desorption of chemicals to and from suspended particulate matter. Models evaluate the transport and fate of chemical contaminants from tidal estuaries and bay areas to other proximate marine environments. Empirical data supports modeled outputs related to the remobilization of sediment contaminants, resuspension of the contaminants into the water column, and the subsequent redeposition of the contaminants to distant areas.[292]

Biological transport

All seven Pacific salmon species are biotranporters of pollutants to and from the Pacific Ocean and their spawning sites in freshwater.[293] During river ascent, salmonids use their muscle lipid and triacyglycerol deposits for energy and gonadal development. Particularly in female

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[291] (1) Stull et al., 1996. Janet K. Stull, Donald J.P. Swift, Alan W. Niedoroda. Contaminant dispersal on the Palos Verdes continental margin: I. Sediments and biota near a major California wastewater discharge. The Science of the Total Environment 179 (1996) pages 73-90. (2) Swift et al., 1996. Donald J.P. Swift, Janet K. Stull, Alan W. Niedoroda, Christopher W. Reed, George T.F. Wong. Contaminant dispersal on the Palos Verdes continental margin: II. Estimates of the biodiffusion coefficient, D_B, from composition of the benthic infaunal community. The Science of the Total Environment 179 (1996) pages 91-107. (3) Niedoroda et al., 1996. Alan W. Niedoroda, Donald J.P. Swift, Christopher W. Reed, Janet K. Stull. Contaminant dispersal on the Palos Verdes continental margin: III. Processes controlling transport, accumulation and re-emergence of DDT-contaminated sediment particles. The Science of the Total Environment 179 (1996) pages 109-133.

[292] (1) Zeng and Venkatesan, 1999. Eddy Y. Zeng and M. I. Venkatesan. Dispersion of sediment DDTs in the Coastal Ocean off Southern California. The Science of the Total Environment, Volume 229, Issue 3, 19 May 1999, pages 195 -208. (2) Zeng et al., 2005. Eddy Y. Zeng, David Tsukada, Dario W. Diehl, Jian Peng, Kenneth Schiff, James A Noblet, and Keith A. Maruya. Distribution and Mass Invenotry of Total Dichlorodiphenyldicloroethylene in the Water Column of the Southern California Bight. Environmental Science & Technology, 2005, Volume 39, No. 21, pages 8170-8176.

[293] Ewald, GÖran, Per Larsson, Henric Linge, Lennart Okla, and Nicole Szarzi. Biotransport of Organic Pollutants to an Inland Alaska Lake by Migrating Sockeye Salmon (Oncorhynchus nerka) Arctic, Volume 51, No. 1, pages 40-47. March 1998.

salmonids, the organic pollutant body burden redistributes and accumulates in the lipid rich gonads and salmon roe. Furthermore, the lipid depletions and redistribution during the river ascent is not coupled with a simultaneous elimination of the organic pollutant body burden in the salmonids. The pollutants in the salmonids are readily available for bioaccumulation because the migrating salmonids, the salmon roe, and salmon carcasses are a direct food source for predators (birds, mammals and other fish). Hence, salmonids redistribute their pollutant body burdens back to their spawning grounds, to the open ocean predators, or bioaccumulate in the food web. The redistribution, biotransportation, and bioaccumulation of the salmonid pollutant body burden helps contribute to food web contamination.

Chemical contaminants are exhibited through the salmon lifecycle which contributes to the transport and distribution of contaminants in Puget Sound:

- Depletion of lipid reserves in salmon during upstream migration can cause significant biomagnifications of contaminant body burdens in eggs and gonadal tissues.[294]
- Post spawning decay of Chinook salmon carcasses are sources of persistent organic pollutants (POPs-PCBs & DDTs) where body burden contaminants are released into river sediments and, furthermore, are released into the water column of tributary streams. [295]
- Areas in the Pacific Northwest where Chinook salmon are harvested may account for the variations in their PCB body burden concentrations. Although some contamination of the Chinook salmon occurs in the Pacific Ocean, a larger source of the salmon body burden occurs within Puget Sound or along the migratory route within Puget Sound for Chinook salmon. [296]
- Chemical contaminants (selected pesticides and POPs) have been documented in outmigrant juvenile Chinook salmon.[297]

[294] Kelly et. al., 2007. Barry C. Kelly, Samantha L. Gray, Machael G Ikonomou, et. al. Lipid Reserve Dynamics and Magnification of Persistent Organic Pollutants in Spawning Sockeye Salmon (Oncorhynchus nerka) from the Fraser River, British Columbia. Environmental Science and Technology, Vol. 41, No 9, 2007, pages 3083 – 3089.

[295] O'Toole et. al., 2006. Shaun O'Toole, Chris Metcalfe, Ian Craine, Mart Gross. Release of persistent organic contaminants from carcasses of Lake Ontario Chinook salmon (Oncorhynchus tshawytscha). Environmental Pollution 140 (2006) pages 102 to 113.

[296] Missildine et. al., 2005. Polychlorinated Biphenyl Concentrations in Adult Chinook Salmon (Oncorhynchus tshawytscha) Returning to Coastal and Puget Sound Hatcheries of Washington State. Environmental Science & Technology, Vol. 39, No. 18, 2005, pages 6944 to 6951.

[297] Johnson et. al., 2007. Persistent organic pollutants in outmigrant juvenile Chinook salmon from the Lower Columbia Estuary, USA. Science of the Total Environment 374 (2007) pages 342-366.

Life histories and biological variability in life histories of pacific coast salmonids

Table E-5. Life Histories of Pacific Coast Salmonids

Species	Spawning Migration	Spawning Period	Spawning Area	Life History	Most Common Age At Maturity (Years)
Anadromous Salmon					
Chum salmon	Summer to Winter	Summer to Winter	Usually near tidewater	Fry go directly to sea; 2-5 years ocean	4
Pink salmon	Late summer to early Fall	Late summer to early Fall	Usually near tidewater	Fry go directly to sea; 2 years ocean	2
Sockeye salmon	Spring to fall	Late summer to fall	Tributaries of lakes	1-3 years lake 2-3 years ocean	4-5
Coho salmon	Summer to fall	Fall to early winter	Small headwater streams	1-3 years freshwater 6 months Jack ocean 18 month adult ocean	3
Chinook salmon	Spring to fall	Summer to early winter	Large rivers	3 months – 2 years freshwater 2-5 years ocean	4 -5
Anadromous Trout and Char					
Steelhead trout	Summer to winter	Late winter to spring	Small headwater streams	2-3 years freshwater 1-3 years ocean *Repeat spawners*	4-5
Searun cutthroat trout	Fall to winter	Late winter to early spring	Small headwater streams	2-4 years freshwater 2-5 months ocean *Repeat spawners*	3-4
Dolly Varden[298]	Late summer to fall	Fall	Main channels on rivers	2-4 years freshwater 2-4 years ocean *Repeat spawners*	Mature 5-6 Die 6-7
Resident Species					
Kokanee salmon	Late summer to fall	Late summer to fall	Tributaries of lakes, lakeshores	Juveniles migrate to lakes to reside	3-4
Rainbow trout	Spring	Spring	Small headwater streams	Variable residence in natal, streams, rivers, & lakes	2-3
Cutthroat trout	Spring	Spring to early summer	Small headwater streams	Variable residence in natal, streams, rivers, & lakes	3-4
Bull trout (see footnote 30, page 32)	Fall	Fall	Large streams with groundwater infiltration	Juveniles migrate from tributaries to lakes or large streams at about 2 years, highly variable	4-9
Mountain white fish	Fall	Fall	Mid-sized streams, lakes	Reside in streams and lakes	3-4

Source: National Marine Fisheries Service. 1996. *An Ecosystem Approach to Salmonid Conservation, Part I*. December. Adapted from Table 4-1, page 64.

[298] On occasion WDFW lumps bull trout and Dolly Varden together because both are listed under the Endangered Species Act and are hard to differential the two species in the field; genetic studies have found bull trout throughout Puget Sound and the Strait. (S. Duncan, personal communication with CR McCormack, May 16, 2008).

Table E-6. Biological Variability In Life Histories Of Pacific Salmonids

Species Of Salmon	Life History	Spawns In			Rears In			
		Lakes	Streams	Intertidal	Lakes	Streams	Estuaries	Ocean
Pink salmon	Anadromous		X			X	X	X
	Anadromous		X					X
	Anadromous			X			X	X
Chum salmon	Anadromous		X			X	X	X
	Anadromous		X			X		X
	Anadromous		X					X
	Anadromous			X			X	X
Coho salmon	Anadromous		X			X	X	X
	Anadromous		X			X		X
Sockeye salmon	Anadromous		X		X			X
	Anadromous	X			X			X
Chinook salmon (spring)	Anadromous		X			X	X	X
	Anadromous		X			X		X
Chinook salmon (fall)	Anadromous		X				X	
	Anadromous		X			X		X
Steelhead Trout	Anadromous		X			X		X
Dolly Varden	Anadromous		X			X	X	X
Kokanee salmon	Resident		X		X			
	Resident	X			X			
Cutthroat trout	Resident		X			X		
	Resident		X		X			
Cutthroat trout (searun)	Anadromous		X			X	X	X
	Anadromous		X			X		X
Rainbow trout	Resident		X		X			
	Resident		X		X			
	Resident	X						
Bull trout (see footnote 30, page 32	Resident		X			X		
	Resident		X		X			
Mountain whitefish	Resident		X			X		
	Resident	X			X			

Source: National Marine Fisheries Service. 1996. *An Ecosystem Approach to Salmonid Conservation, Part I*. December. Adapted from Table 4-2, page 66.

Table E-7. 2001-2002 Freshwater Salmon Sport Catch For Puget Sound River Systems

Catch Area	Species	2001									2002			Total
		April	May	June	July	August	Sept	Oct	Nov	Dec	Jan	Feb	Mar	
Dungeness River	Coho							5,949	597		12			6,558
	Steelhead					9		43	22	107	58	9	4	252
Elwha River	Coho							816	127					943
	Steelhead			5	46	5	5	36						97
Morse Creek	Steelhead							4						4
Total Salmon Sport Catch														7,854

Source: Manning, T., and S. Smith. *Washington State Sport Catch Report 2001.* 2005. Washington Department of Fish And Wildlife, Fish Program Science Division, May. Adapted From Table 26, Page 42; Table 35, Page 92; Table 35, Page 90.

Table E-8. 2001-2002 Sport Salmon Catch For East Juan de Fuca (Port Angeles Areas)

Species	2001								2002		Total
	April	May	June	July	August	Sept	Oct	Nov	Feb	Mar	
Chinook	136				18	17	132	171	172	115	761
Coho			10	239	1,492	1,806	199	8			3,754
Pink			21	840	5,742	951					7,554
Sockeye					2						2
Chum						3	3	4			10
Steelhead			6			6					12
Total Salmon Sport Catch For Area											12,093

Source: Manning, T., and S. Smith. *Washington State Sport Catch Report 2001.* 2005. Washington Department of Fish And Wildlife, Fish Program Science Division, May. Adapted from Table16, page 25 & Table 35, page 101.

Table E-9. 2002-2003 Freshwater Salmon Sport Catch for Puget Sound River Systems

Catch Area	Species	2002									2003			Total
		April	May	June	July	August	Sept	Oct	Nov	Dec	Jan	Feb	Mar	
Dungeness River	Coho							398	711	25				1134
	Steelhead							4	3	5	15	15	3	45
Elwha River	Coho							948	175					1123
	Steelhead				2	1	1	9	59	92	17	9	2	192
Morse Creek	Steelhead								3	15	5	10		33
Total Salmon Sport Catch														2527

Source: Kraig, E., and S. Smith. 2008. *Washington State Sport Catch Report 2002.* Washington Department of Fish and Wildlife, Fish Program Science Division, April. Adapted from Table 25, page 41; Table 34, page 87; Table 34, page 88.

Table E-10. 2002-2003 Sport Salmon Catch For East Juan de Fuca (Port Angeles Areas)

Species	2002								2003		Total
	April	May	June	July	August	Sept	Oct	Nov	Feb	Mar	
Chinook	55					3	12	59	103	81	313
Coho				43	281	713	35				1072
Pink				21							21
Sockeye											0
Chum							12				12
Steelhead				3			3	3(Dec)	3(Jan)		12
Total Salmon Sport Catch For Area											1430

Source: Kraig, E., and S. Smith. 2008. *Washington State Sport Catch Report 2002.* Washington Department of Fish and Wildlife, Fish Program Science Division, April. Adapted from Table 16, page 25; Table 34, page 97.

Table E-11. Salmonid Stock Inventory For The Port Angeles Harbor & Adjacent Areas

Anadromous Fish		Total Escapement Estimates		WDFW Designated Status		Comments
Species	Stock	From Year: Est. #	To Year: Est. #	1992	2002	
Chinook	Dungeness Chinook	1986: 238	2003: 640	Critical	Critical	Critical due to chronically low escapements below goal of 925 adults; increased escapement #'s due to continuing hatchery supplementation; spawning mainstream Dungeness River
	Elwha Chinook	1986: 3,127	2003: 1,045	Healthy	Depressed	Depressed due to long-term negative trend and chronically low escapements since 1992; Spawning lower 4.9 mile of river below Elwha Dam.
Chum	Dungeness Summer Chum	1992: Unknown	2002: Unknown	Not Rated	Unknown	No abundance trend data available; Numbers so low that may not represent a self-sustaining stock; Summer timed limited #'s observed in Dungeness River
	Dungeness Fall Chum	1992: Unknown	2002: Unknown	Unknown	Unknown	Live + dead counts in one day, one mile section of (Lower Dungeness tributary) Beebe Creek 1997: 303, 1998: 1,025; 2001: 1,062.
	Elwha Fall Chum	1992: Unknown	2002: Unknown	Unknown	Unknown	No abundance trend data available;

Source: Washington Department of Fish and Wildlife. Salmon stock Inventory. Water Resource Inventory Area (WRIA) 18 – Elwha-Dungeness, http://wdfw.wa.gov/cgi-bin/database/sasi_search_new_db.cgi?keyword=18&field=4&search_sort=sort&srchtype=within&job=search&wria=wria.

Table E-12. Salmonid Stock Inventory For The Port Angeles Harbor & Adjacent Areas

Anadromous Fish		Total Escapement Estimates		WDFW Designated Status		Comments
Species	Stock	From Year: Est. #	To Year: Est. #	1992	2002	
Coho	Dungeness Coho	1992: Depressed	2002: Unknown	Unknown	Unknown	No abundance trend data available; Limited recent-year estimates of smolt production suggest significant natural production Dungeness R. watershed.
	Morse Creek Coho	1998: 488 adults and 511 smolts	2002: 676 adults and 2, 966 smolts	Depressed	Depressed	Spawning distribution: McDonald, Siebert, Morse, Ennis, Valley and Tumwater Creeks; Depressed because of chronically low "redd" counts; mixture of wild & farm raised stock
	Elwha Coho	Unknown	Unknown	Healthy	Unknown	No abundance trend data available; Healthy rating based on escapement estimates from Strait of Juan de Fuca tributaries
Pink	Lower Dungeness Pink	1985: 966	2001: 11, 072; 2003: 3,540	Critical	Critical	Estimates based on counts from mainstem of Dungeness R., Gold Creek, & Gray Wolf river; Critical designation due to chronically low escapements
	Upper Dungeness Pink	1985: 3,764 1989: 10,579	2001: 69,272 2003: 11,576	Depressed	Depressed	Prior to 1981 escapements usually in excess of 20,000; stock status depressed because of chronically low escapements
	Elwha Pink	1985: 30 1991: 0	2001: 605 2003: 32	Critical	Critical	In early '70s instantaneous counts over a thousand pinks were made; since 1981 not more than 30 pinks have been seen on any one day; stock status depressed because of chronically low escapements

Table E-13. Salmonid Stock Inventory For The Port Angeles Harbor & Adjacent Areas

Anadromous Fish		Total Escapement Estimates		WDFW Designated Status		Comments
Species	Stock	From Year: Est. #	To Year: Est. #	1992	2002	
Steelhead	Dungeness Summer Steelhead	Unknown	Unknown	Depressed	Unknown	No abundance trend data available. Due to fisheries closures and low harvest numbers sport harvest is no longer adequate to assess stock status.
	Dungeness Winter Steelhead	1988: 438 1993: 338	2000: 165 2001 183	Depressed	Depressed	Depressed status because of long term negative trends
	Morse Creek Winter Steelhead	1986: 105 1988: 138	1997: 183 2003: 84	Depressed	Depressed	Escapement estimates based on redd counts; depressed due to chronically low escapements
	Elwha Summer Steelhead	Depressed	Unknown	Depressed	Unknown	No abundance trend data available
	Elwha Winter Steelhead	1986: 834 1989: 416	1992: 560 1997: 153	Depressed	Unknown	Access to historic spawning areas blocked by Elwha Dam; Average of 50 redds/year; Lack of systematic abundance trend data;

Source: Washington Department of Fish and Wildlife. Salmon stock Inventory. Water Resource Inventory Area (WRIA) 18 – Elwha-Dungeness, http://wdfw.wa.gov/cgi-bin/database/sasi_search_new_db.cgi?keyword=18&field=4&search_sort=sort&srchtype=within&job=search&wria=wria.

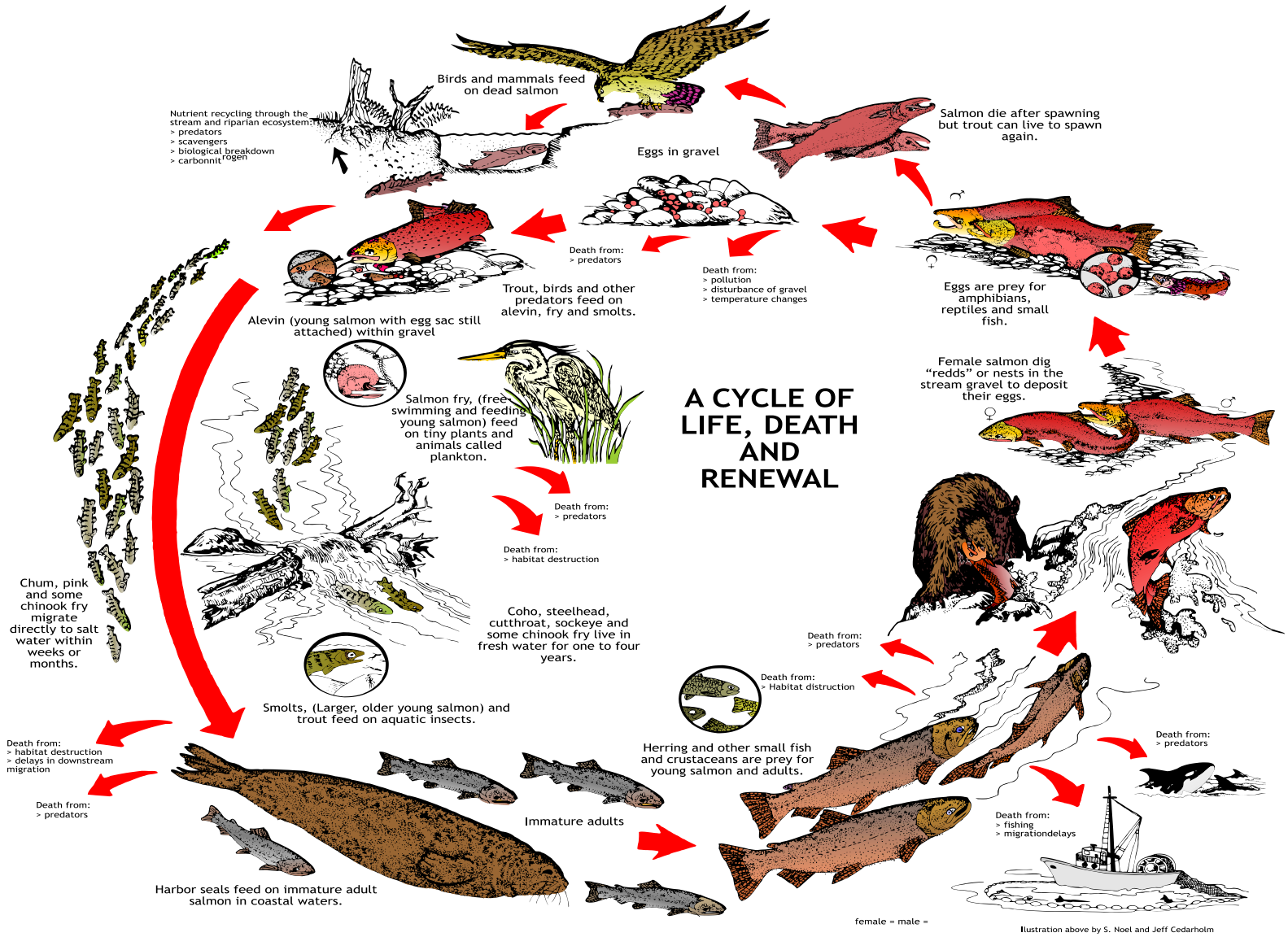
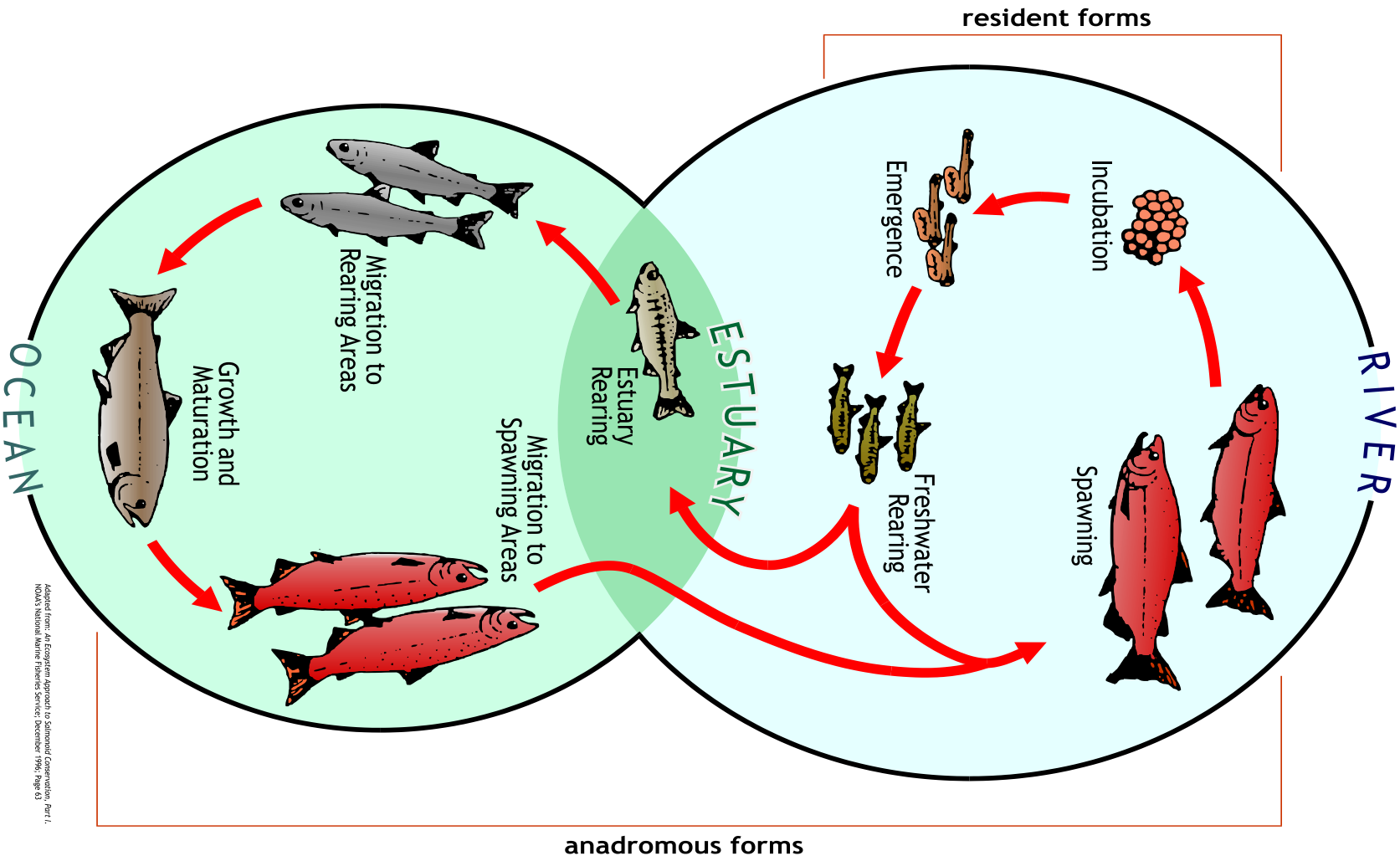


Illustration above by S. Noel and Jeff Cedarholm



Adapted from: *An Ecosystem Approach to Salmonid Conservation, Part I.*, NOAA's National Marine Fisheries Service; December 1996; Page 63

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Appendix F
Washington Tribes

Washington Indian tribes and treaty reserved rights

There are 29 federally recognized tribes in Washington.[299] Through treaties, executive orders and customs, tribes have maintained their use of native fisheries for trade, subsistence, religious and ceremonial use from time immemorial. Because of this, tribal communities represent one of the most sensitive populations for fish consumption rates.

Tribal governments

The principles of tribal sovereignty, federal trust responsibility, and reserved rights are grounded in the United States Constitution, treaties, executive orders, federal statutes, and various court decisions.[300] These sources of federal Indian law provide for the unique sovereign status of federally recognized tribes and distinguish tribes from other ethnic minority populations in the United States.

Under the Clean Water Act, tribes are eligible to receive "treatment as a state" status and to adopt water quality standards with Environmental Protection Agency approval. A number of tribes in Washington have approved water quality standards, including established fish consumption rates for reservation waters (http://water.epa.gov/scitech/swguidance/standards/wqslibrary/tribes.cfm#r10). Tribes are effectively neighboring states for the purposes of the Clean Water Act and cross border flows.

Usual and accustomed fishing rights

Through treaties and executive orders, tribes ceded or relinquished most of what is now Washington to the U.S. in exchange for permanent reservation homelands and certain services. In addition, many tribes retained their right to utilize the fisheries resources throughout their aboriginal areas. Washington Territorial Governor Isaac Stevens, in 1854 and 1855, negotiated treaties with most of the tribes of Washington and concluded treaties with 21 tribes. Under the Stevens' treaties, tribes ceded vast areas of what is now Washington State to the United States

[299] Governor's Office of Indian Affairs, July 2010 access to web link: http://www.goia.wa.gov/Tribal-Information/Map.htm

[300] United States Constitution, Article VI, Section II states that, "…all treaties made, or which shall be made under the authority of the United States, shall be the supreme law of the land; and the judges in every state shall be bound thereby, anything in the Constitution or laws of any State to the contrary notwithstanding."

while reserving certain off-reservation rights including the right to take fish in their "usual and accustomed" places and the right to hunt on "open and unclaimed lands". In addition to 21 tribes in Washington, three tribes located in other states have ceded and usual and accustomed fishing areas in Washington.

The Stevens negotiated treaties included the following provision or some similar type of provision:

"The exclusive right of taking fish in all the streams, where running through or bordering said reservation, is further secured to said confederated tribes and bands of Indians, as also the right of taking fish at all usual and accustomed places, in common with Citizen of the Territory, and of erecting temporary buildings for curing them; together with the privilege of hunting, gathering roots and berries, and pasturing their horses and cattle upon open and unclaimed land."[301] [302]

Federal case law has established that this treaty provision reserved aboriginal rights for tribes to continue their harvest of fish in "usual and accustomed" areas. Shellfish are fish within the meaning of the Indian treaties and treaty reserved rights to harvest fish includes the harvesting of shellfish in "usual and accustomed grounds and stations."[303] Tribal treaty fishing areas may overlap with one another and may have geographical extensions beyond tribal ceded areas.

Most areas of Washington include areas where tribes have traditionally harvested fish and shellfish and continue to do so by custom and under treaty reserved rights. Treaty reserved rights to harvest fish and shellfish is particularly significant throughout the marine waters of Washington.

[301] The Yakima Treaty, June 09, 1855. Treaty between the United States and the Yakama Nation of Indians. Concluded at Camp Stevens, Walla Walla Valley, June 9 1855. ARTICLE III. Web location for treaty: http://www.ccrh.org/comm/moses/primary/yaktreaty.html

[302] Nez Perce Treaty, 1855, ARTICLE 3 found at web location: http://www.ccrh.org/comm/river/treaties/nexperce.htm

[303] United State v. Washington: the Boldt decision reincarnated. Mariel J. Combs. *Environmental Law*. Vol. 29. 1999.

Appendix G
Glossary

Angler: one who fishes with hook and line, sometimes used to denote "fishers."

Aquatic: from or living in a water body, including both marine and freshwater.

Commercial fishers: those individuals who harvest fish and/or shellfish by any method from Washington State waters (marine, estuarine, and freshwaters) for economic gain as a livelihood.

Creel survey: on-site interview with fishers to obtain information such as species caught; number, length, and weight of catch; location; etc.; typically for use by fisheries managers; may or may not include information on consumption.

Estuarine: from an estuary, i.e., a partly enclosed water body, such as an inlet of the ocean or the mouth of a river where it meets the ocean that contains brackish water (a mixture of salty and freshwater) such as Elliott Bay in Seattle, Washington.

Finfish: fish; a term that is usually applied to the consumption of fish as opposed to shellfish.

Fish: any of various aquatic animals (belonging to the subphylum Vertebrata) having gills, commonly fins, and bodies usually but not always covered by scales, including those having bony skeletons (bony fishes) and more primitive forms with cartilaginous skeletons (lampreys; hagfishes; and sharks, skates, and rays).

Fish consumers: those individuals who consume fish and/or shellfish; synonymous with Washington State fish consuming populations.

Fisher: one who fishes for any type of seafood by any method, inclusive of hook and line and other methods of catching seafood.

Fish-In-Hand: fish and/or shellfish that a fisher has caught and which he/she has at the time of being interviewed (in a creel survey)

Freshwater: water bodies including lakes, ponds, rivers, and streams that contain water with relatively low salinity, i.e., less that 0.5 parts per trillion (ppt); species inhabiting freshwater bodies.

Game fish: sport fish that are caught for food.

Indian (Native American) Reservation: land set aside by the federal government for the use, possession, and benefit of a Native American tribe or group of Indians; created by some formal legal directive such as a treaty, statute passed by Congress or an executive Presidential order.

Marine: from, or living in, the ocean; saltwater, with a salinity of approximately 35 ppt.

Native American: a member of the indigenous peoples of the Western Hemisphere. In this technical support document the term "Indian" is used only with reference to the name of a specific Native American tribe.

Noncommercial fisher: one who fishes for recreation and/or home consumption, synonymous with recreational fisher, sport fisher.

Recall bias: Dietary recall surveys may cover specific periods of time or seasons; short term recall surveys may cover a 24-hour food recall to obtain information on the diet of an individual in the prior 24 hours. Dietary surveys that rely on an individual's recall of their diet may undergo some recall errors that introduce an element of bias in the dietary estimates. These recall errors may result in either overestimation or underestimation of fish consumption. Factors that contribute to recall error and bias include how commonly or frequently the food (fish) is consumed, time frames covered by the survey that contribute to seasonal variation if food consumption, survey methods used including provisions to enhance dietary memory or recall (food models), and the desirability or cultural influences on the food consumed. Generally, recall error increases as the length of the recall period increases with recall periods of one year likely to result in the least reliable estimates of consumption. The optimal recall period will be long enough to accurately portray typical dietary (fish consumption) habits and patterns without impairing the ability of respondents to recall their dietary (fish) consumption.[304]

Recreational fisher: one who fishes primarily for recreational purposes; recreational catch is used primarily for home consumption, synonymous with noncommercial fisher, sport fisher.

Seafood: aquatic organisms that are consumed, including mainly fish and shellfish, and less frequently, other invertebrate animals or plants or marine mammals.

Self-caught fish: fish that are caught by a sport fisher as opposed to purchased commercially, synonymous with sport, sport-caught, recreationally caught, and noncommercial fish.

Shellfish: aquatic invertebrate animals having a shell or exoskeleton, the term usually used in the context of food, including species belonging to the following taxa (some of which have evolved such that the shell has become internal and/or reduced, or has disappeared entirely): 1/

[304] Chu A, Eisenhower D, Hay M, Morganstein D, Neter J, Waksberg J (1992). Measuring the recall error in self-reported fishing and hunting activities. *Journal of Official Statistics* 8(1):19-39.

mollusks, including bivalves (e.g., clams, oysters, mussels, scallops), gastropods (e.g., snails, limpets, abalone), and cephalopods (e.g., squid, octopods), 2/ crustaceans (e.g., crabs, shrimps, lobsters); and 3/ echinoderms (e.g., sea urchins, sea cucumbers).

Sport fish: fish that are caught by a sport fisher as opposed to purchased or caught commercially, synonymous with sport-caught, recreationally caught, and noncommercial fish.

Sport fishers: those individuals who harvest fish and/or shellfish by any method from Washington State waters (marine, estuarine, and freshwaters) for recreation; synonymous with recreational fisher or noncommercial fisher.

Subsistence: Although no single universally accepted definition is available to define what is meant by subsistence or subsistence-based populations, several definitions of subsistence fishers may apply to Washington State ethnic groups and/or fish consuming populations. It is difficult to define and to quantify subsistence fishers. Definitions and perceptions of what constitute subsistence fishers and fishing may vary among regions and cultures. The 1994 Presidential Executive Order 12898, Section 4-4. Subsistence Consumption of Fish and Wildlife noted differential patterns of subsistence consumption of fish and wildlife for populations who principally rely on fish and/or wildlife for subsistence.[305] Differential patterns of subsistence consumption of fish and wildlife relates to subsistence and differential patterns of subsistence, and means differences in rates and/or patterns of fish, water, vegetation and/or wildlife consumption among minority populations, low-income populations, or Native American tribes, as compared to the general populations. As a response to Executive Order 12898, the 1999 National Academy of Sciences publication noted the following[306]:

> *… differences in behavior, employment, and lifestyles among subgroups in the population may result in differences in exposure. For example, among the Alutiiq, Yup'ik, and Inupiat Alsakan Native peoples, the yearly intake of wild foods per person is between 171 and 272 kilograms (375 and 600 pounds). Increasing evidence of certain contaminants such as mercury in the wild food supply of these Alaskan Natives has been exhibited by methyl mercury levels that exceed those provisionally established as safe by the World Health Organization.*

Tribal subsistence exposure scenario and fishers: "Subsistence" refers to the hunting, fishing, and gathering activities that are fundamental to the way of life of many indigenous peoples. [307]

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[305] Presidential Executive Order 12898: Federal Actions To Address Environmental Justice In Minority Populations and Low-Income Populations. Signed by President William J. Clinton, February 11, 1994 web location: http://www.epa.gov/region2/ej/exec_order_12898.pdf

[306] Toward Environmental Justice. Research, Education, and Health Policy Needs. Institute of Medicine, National Academy of Sciences, Washington, D.C., 1999. Page17.

[307] Exposure Scenario for CTUIR Traditional Subsistence Lifeways. Confederated Tribes of the Umatilla Indian Reservation. Department of Science & Engineering. Stuart Harris, Director. September 15, 2004. Quoted from page 4. Web location: http://www.hhs.oregonstate.edu/ph/sites/default/files/CTUIR-SCENARIO.pdf

Subsistence utilizes traditional, small-scale technologies for harvesting and preserving foods as well as for distributing the produce through communal networks of sharing and bartering. Because it often misinterpreted, an explanation of "subsistence" is taken from the National Park Service:[308]

> *While non-natives tend to define subsistence in terms of poverty or the minimum amount of food necessary to support life, native people equate subsistence with their culture. Among many tribes, maintaining a subsistence lifestyle has become the symbol of their survival in the face of mounting political and economic pressures. It defines who they are as a people. To Native Americans who continue to depend on natural resources, subsistence is more than eking out a living. While it is important to the economic well-being of their communities, the subsistence lifestyle is also the basis of cultural existence and survival. It is a communal activity. It unifies communities as cohesive functional units through collective production and distribution of the harvest. Some groups have formalized patterns of sharing, while others do so in more informal ways. Entire families participate, including elders, who assist with less physically demanding tasks. Parents teach the young to hunt, fish, and farm. Food and goods are also distributed through native cultural institutions. Most require young hunters to distribute their first catch throughout the community. Subsistence embodies cultural values that recognize both the social obligation to share as well as the special spiritual relationship to the land and resources. This relationship is portrayed in native are and in many ceremonies held throughout the year.*[309]
>
> The average subsistence adult fish consumption rate is 620 grams/day (500 pounds/year) for the Confederated Tribes of the Umatilla Indian Reservation.[310]

Usual and Accustomed Fishing Areas: also referred to as U & A areas or U & A fishing areas. The term refers to the 1854 and 1855 negotiated treaties with the Pacific Northwest Native Americans in Washington state: "The right of taking fish at usual and accustomed grounds and stations is further secured to said Indian in common with all citizens of the Territory,…"

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[308] As quoted from the Exposure Scenario for CTUIR Traditional Subsistence Lifeways. Confederated Tribes of the Umatilla Indian Reservation. Department of Science & Engineering. Stuart Harris, Director. September 15, 2004.

[309] National Park Service. Archeology Program. Preservation On the Reservation [And Beyond] Web location: http://www.nps.gov/archeology/cg/fa_1999/Subsist.htm

[310] Traditional Tribal Subsistence Exposure Scenario and Risk Assessment Guidance Manual. August 2007. Appendix 3: Fish Consumption Rate. Web location: http://www.hhs.oregonstate.edu/ph/tribal-grant-main-page2

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