WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

DRAFT: Analysis and Selection of Fish Consumption Rates for Washington State Risk Assessments and Risk-based Standards

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DRAFT: Analysis and Selection of Fish Consumption Rates for Washington State Risk Assessments and Risk-based Standards

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In conjunction with

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The Risk Assessment Forum (RAF) is a group of agency staff who regularly meet to discuss risk assessment related issues faced by the Washington State Department of Ecology. RAF recommendations and products are typically reached through group consensus. Minority opinions are attached where necessary. The RAF is comprised of representatives from programs within Ecology, the Washington Department of Health (WADOH), and Region X of the U.S. Environmental Protection Agency (USEPA). The RAF consists of the following members:

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EXECUTIVE SUMMARY

The Washington State Department of Ecology's (Ecology) Risk Assessment Forum (RAF) developed this report in response to requests from within and outside the agency for more consistent application of fish consumption rates in Ecology's risk assessments, screening criteria, and risk-based standards. This document provides an evaluation of fish consumption surveys conducted among Washington State residents, a review of applicable policy directives, and recommendations for consumption rates that are to be used in Ecology's risk-based guidelines and risk assessments.

Background

Several Ecology programs, such as Water Quality and Toxics Cleanup, operate under regulations that require protection of human health from water or sediment contamination (e.g., the Model Toxics Control Act [MTCA]). These regulations typically use a fish consumption exposure scenario to develop risk-based cleanup or water quality standards. Programs also conduct risk assessments of larger waterbodies or regions to determine human health risks from consumption of contaminated fish. As several programs require similar technical support and interested groups have urged more consistent approaches, Ecology managers directed the RAF to draft a review paper that 1) provides a consistent technical basis for consumption rates, and 2) adheres to applicable policy directives.

Objectives

In conducting this analysis, the RAF considered five primary objectives. These are to provide recommendations that:

1) are scientifically defensible by considering the best available studies,
2) are legally defensible/sound public policy by considering legislative, executive, and judicial directives,
3) improve inter-program consistency by considering federal guidance,
4) improve intra-agency consistency by providing specific default values, and

5) are flexible in that there is a range of rates that allow consideration of site-specific or unforeseen issues.

Methods

Identification and Evaluation of Washington State Surveys

The RAF reviewed the literature and identified a total of seven consumption surveys in Washington State, including three recent surveys among Native American tribes in Washington, four shore-side angler surveys, and one on-going survey among Washington State Laotians. The RAF reviewed each survey for general design issues (e.g., sample size, interviewer bias, etc.) and discussed strengths and limitations of each survey. For each study, fish consumption rates corresponding to the 50th, 90th, 95th percentiles and the arithmetic mean were presented. This review and a comparison of the various consumption survey results are provided in Section II of this report.

Policy Review

The RAF reviewed relevant statutes, executive orders, and judicial interpretations that serve to guide the selection of populations of concern and therefore key studies and appropriate fish consumption parameters (e.g., mean, upper percentile values, etc.) Of particular relevance were the Model Toxics Control Act, the Executive Order on Environmental Justice (Executive Order 12898, 1994), and treaties with various Washington State tribal nations. These are discussed in Section III.

Selection of Key Studies

Based on the technical merits of the studies and applicable policy directives, the RAF selected two Native American studies (one for freshwater and one for marine) to form the basis for the final recommended fish consumption values.

Results

The RAF found that consumption rates among fish eaters range from less than one meal per month to up to several servings per day for some minority group members.[1] For

[1] One serving or fish meal is assumed to approximately 150 g/day (USEPA. 1989).

example, median and mean estimates for the two Native American studies suggest that tribal populations consume approximately one to two fish meals per week. These values also compare reasonably well with other fish-eating populations such as shore-side anglers and the one Asian American group for which some preliminary data were available (Laotians).

However, the types of fish consumed and the source of fish among various populations were found to be highly variable and may depend upon cultural preferences/behaviors and year-to-year variations in fish runs. For example, tribal members appeared to consume more salmon than shore-side anglers and Laotians. Similarly, even though Laotians expressed a preference for non-anadromous species, they appeared to consume. greater amounts of salmon when it was more readily available, although not as much as some Native American groups. As a result, separate consumption rates for individual fish species (except shellfish) are not recommended at this time.

The RAF found that the source of the fish consumed by fish eating populations also varies. Native American groups obtain much of their fish from state water bodies such as the Puget Sound and Columbia River, but specific locations were difficult to identify. Shore-side anglers obviously obtain their fish from urban and rural bays in Washington waters, but the number of sites an individual angler might use could not be identified. Also, the fishing areas that have been surveyed represent only a small percentage of potential areas throughout the state. Thus, quantitative estimates of the amount of fish obtained from specific sources (e.g., from one local area or store bought versus self-caught) could not be determined.

The RAF found that legislative, executive and judicial considerations direct the agency to provide equal protection to minority groups such as Native Americans and Asian and Pacific Islanders. The RAF also found that studies for these populations, particularly two of the tribal studies, are well designed and provide reasonable consumption estimates. As a result, Native American studies in marine and freshwater areas are recommended as the basis for consumption rates in agency risk assessments and regulations. The values for the tribal populations are listed in Table ES - 1 below:

Table ES - 1

Summary of Fish Consumption Rates in grams/day [wet weight]

Authors (date)	*~50th Percentile g/day*	*~9 th Percentile g/day*	*~95 th Percentile g/clay,*	*~98 th h Percentile g/clay*	*Arithmetic mean g/day*
Freshwater CRITFC (1994)	*42*	*127*	*182*	*317*	*63*
Marine Toy et al (1996)					
Finfish	*17*	*104*	*174*	*313*	*42*
Shellfish	*13*	*67*	*104*	*179*	*19*
Total	*30*	*171*	*278*	*492*	*61*

A typical fish meal is estimated at approximately 150 g/meal (USEPA, 1989). Therefore, these values range from one meal per week to slightly less than two meals per day.

Calculation of Default Consumption Rate

Ecology management requested that the RAF provide a specific consumption rate as a default value for Ecology programs. This request proved to be one of the more challenging tasks of this project because 1) the degree of desired protection had to be determined, and *2)* other assumptions in the risk equation contribute to the overall degree of protection and thus had to be evaluated.

To address the first issue, the RAF assumed that a default consumption rate would be used in a scenario where the *overall* degree of protection should fall somewhere between the *90*th and *98*th percentile of exposure (e.g., as in risk-based screening criteria, water quality standards, or cleanup levels).[2] This is referred to as a reasonable maximum exposure, or RME scenario. In other words, exposure to toxic chemicals is assumed to be as high as at least 90% of the range of potential exposures.

To address the second issue, the RAF identified values for other exposure parameters that would be used with the consumption rate in the RME scenario (e.g., 70 kg [150 lb. bodyweight], 30 year exposure duration - See Table ES-2 below). The overall degree of protection that results from the combination of these assumptions was evaluated using distributional analyses (see Section IV and Appendix B).

Table ES - 2
Exposure Assumptions Used with Default n

Variable	**Value (units)**
Exposure Duration	30 years
Exposure Frequency	365 days/year
Body-weight	70 kg
Averaging Time/lifespan	70 years

When combined with other exposure parameters listed in Table ES-2, consumption rates of approximately 178 grams per day (for both finfish and shellfish in coastal/marine water tribes) and 175 grams per day (freshwater tribes) should cover at least 90% o, f potential exposures. These values are recommended for risk-based standards, screening criteria or individual risk assessment that are based on an RME scenario. A value of 175 g/day is recommended as a state-wide default value. These values are summarized in Table ES-3 below:

Table ES - 3
Default Consumption Rates

Fish Type	**Consumption Rate (g/day) at 90`h % of Exposure Distribution**
Freshwater - finfish	175
Marine - finfish	110
Marine - shellfish	68
State-wide Default	177

The default values are intended for situations where resources are limited and an analysis by a professional toxicologist/risk assessor is not available. They are not intended for every situation where consumption rates are used. In site-specific risk assessments or projects where a professional toxicologist or risk assessor is available, the RAF recommends the range of consumption rates, as provided in Table ES-1.

[2] See USEPA (1992) for a detailed discussion of reasonable maximum or reasonable worst case.

It is also important to note that the exposure assumptions (consumption rate, exposure duration, frequency, and bodyweight) will be combined with other terms in the risk equation such as concentration and toxicity factor. Both of these latter terms are expected to have some measure of conservatism associated with them. For example, the concentration term may be based on the upper 95"' confidence limit on the mean, and the toxicity term may be based on the upper 95"' confidence limit on the slope of a dose-response curve for a carcinogen. Thus, the overall degree of conservatism or protectiveness in the final estimate is likely to be above the 90"' percentile of risk or exposure, although the final degree of protectiveness cannot be quantitatively determined.

Recommendations

Because some risk-based screening levels will be used throughout the state, such as MTCA values that would apply in both marine and freshwater areas, the two consumption rates above (178 and 175 g/day) were averaged to one value (177 g/day) as a statewide, RME default consumption rate.

In addition to providing final consumption rates, the RAF also recommends that Ecology continue research in a few key areas that would shed light on human health risks from eating contaminated fish. First, the RAF did not find data to estimate the number of different, areas an angler might use. Thus, the RAF recommended that risk assessors assume individuals obtain all their fish from one, presumably contaminated, location. Because this is unlikely to be the case, the RAF recommends that Ecology, in conjunction with interested groups, obtain information on the number of areas used by anglers.

Second, several consumption surveys are currently underway for other Washington State groups such as Asian Americans and shoreside anglers. These surveys, when they are released, should be reviewed by Ecology. They may provide additional information on consumption rates of various species of fish and source apportionment.

Third, the RAF recommends that Ecology programs consider methods to determine consumption rates for different species. Because some species may accumulate more local contaminants than others, species-specific consumption rates would provide more accurate contaminant exposure estimates.

Fourth, the RAF recommends that the Water Quality Program consider the findings of this report when reviewing and updating the water quality standards. This program may wish to consider higher consumption rates in light of the information currently available.

Finally, the RAF recommends that Ecology develop more formal guidance for using distributional analyses in agency regulations and risk assessments. The MTCA Policy Advisory Committee has also recommended that Ecology's Toxics Cleanup Program develop guidance for this type of analysis.

I. INTRODUCTION

The Risk Assessment Forum (RAF) developed this document to provide technical support and recommendations for selecting fish consumption rates used in Washington State Department of Ecology (Ecology) rules, guidelines, and risk assessments. It is intended for both agency staff and non-agency consultants (e.g., toxicologists and risk assessors) who are involved in the evaluation of health risks to Washington State citizens.

Description of Problem

The Washington State Department of Ecology (Ecology) implements several programs designed to limit effluent to Washington State waters and cleanup hazardous waste sites that may affect local waterbodies. Each of these programs operates under state and federal statutes that require protection of human health and the environment. Consumption of contaminated fish is a significant pathway of human exposure, and forms the basis for determining potential human health effects in several regulations.

To date, however, differing assumptions and approaches have been used that vary in terms of protectiveness and scientific information. In some instances, attempts to be consistent with past program decisions result in assumptions that do not reflect more recent information, particularly when new scientific studies are available. For example, fish consumption rates used in older regulations do not reflect more recent scientific data published in later years.

Similarly, a Program's attempt to be consistent with a policy decision made under a national directive can result in a less protective decision under a state directive. For example, the consumption rate used in water quality standards from the National Toxics Rule reflects a national average. This rate may not be appropriate for state regulations affecting local fishing areas, particularly when data on local populations are available.

Finally, other standard assumptions in the risk equation have varying degrees of protectiveness or uncertainty associated with them. The combination of multiple high-end exposure values could result in exposure rates that are extremely unlikely. For example, calculating risks from consuming contaminated fish requires estimates of both the consumption rate and the duration of exposure. While a few individuals may consume large amounts of fish (e.g., multiple meals per day), it is unlikely that they would do so for an extended period of time (e.g., 30 to 70 years) from one highly contaminated location. In order to recommend appropriate values for risk-based guidelines, the degree of uncertainty and variability associated with other exposure parameters in the risk equation should be considered.

Purpose

The purpose of this document is to recommend fish consumption rates for multiple programs in risk assessments and risk-based standards or guidelines.

Characteristics

The RAF considered five primary characteristics in developing fish consumption recommendations that address the problems described above:

1) Scientific Defensibility:

The RAF identified relevant and appropriate studies by evaluating and critiquing studies conducted among Washington State fish consumers. Limitations and uncertainties associated with each of these studies are considered and discussed in this paper.

2) Legal Defensibility/Sound Public Policy:

Ecology Programs typically use risk assessment to meet legislative directives to evaluate potential health impacts or derive health-protective concentrations in water or sediments. Sound public policy must be consistent with statutory directives.

Statutes directly applicable to Programs that use fish consumption rates include the Model Toxics Control Act (MTCA) and the Water Pollution Control Act (WPCA).

In addition, agency actions are subject to directives from the executive branch through executive orders. In accordance with the Executive Order 12898 on Environmental Justice, Ecology must apply policies that do not result in a disproportionate risk to minorities. To comply with this order, the RAF considered exposure rates of minorities whose diets contain more fish as well as exposure rates for the population at large. Finally, Ecology often applies regulations in areas covered under judicial orders such as tribal fishing grounds (e.g., Native American Usual and Accustomed fishing areas).

3) Interprogram Consistency:

In order to provide consistency, the RAF targeted specific populations of Washington state citizens that require protection from contaminants in fish. Based on the need for consistency and the requirements noted above, the RAF recommends that Ecology use consumption rates based on Native American data. These rates should also provide protection for other populations such as Asian Americans or recreational anglers who consume a high proportion of locally-caught fish. The recommendations provide consistency by specifying the level of protection given to this group. For example, the RAF recommends a level of protection at approximately the 90^{th} percentile of exposures. In other words, exposure estimates should cover at least 90% of the range of potential exposures.

4) Consistency with Federal Programs/Guidance and other governments:

The RAF also considers guidance from USEPA and the National Research Council in order to provide some level of consistency with federal guidance and actions. Both these groups recommend using regional or site-specific data where available. In addition, the RAF considers consumption rates used in water quality standards proposed by Washington State tribal governments such as the Tulalip Tribes.

5) Flexibility:

The RAF also sought to build flexibility into the recommendations for several reasons. First, Programs need to be responsive to new information, and should be able to use new scientific data as they become available. Second, each program needs to respond to the legislative directives that guide its actions. Finally, there may be unanticipated situations that use consumption rates where these RAF recommendations would not apply.

Organization of Document

The balance of this document is divided into the following sections:

II. REVIEW OF RELEVANT FISH CONSUMPTION STUDIES

Studies conducted among Washington State populations are described and reviewed with respect to general criteria. Results and limitations associated with each study are summarized and discussed.

III. SELECTION OF KEY STUDIES

Key studies are discussed and the most useful ones are selected. These studies form the basis of the final recommendations.

IV. SELECTION OF DEFAULT VALUES

Risk equations typically use point estimates for the fish consumption parameter that depend on the level of protectiveness, and other assumptions in the equation. This section discusses and provides recommendations for specific default values that may be used with common exposure assumptions to represent a reasonable maximum exposure scenario

V. SUMMARY OF CONCLUSIONS/RECOMMENDATIONS

A brief summary of conclusions and recommendations for further actions the agency should consider are presented.

Appendix *A. Population Estimates*

Appendix *B. Distributional Analyses*

Appendix C. Re-creation of Shore-side Angler Consumption Distribution from USEPA (1988)

II. REVIEW OF RELEVANT CONSUMPTION STUDIES

This section presents a general review of fish consumption studies relevant to Washington State citizens. A total of nine consumption studies are identified from previous reviews conducted by the Washington Department of Health, literature searches on MEDLINE and TOXLINE, and USEPA guidance documents. Additional studies are identified from current researchers (pers. comm. R. Lorenzana: USEPA, Paul White:. USEPA, Gillian Mittlestaedt: Tulalip Tribes, and Joan Hardy: Washington Department of Health with L.Keill, September, 1995). Overall, five studies are reviewed for shore-side anglers in Washington State waterbodies, two studies for tribal populations, and one study for a tribal "subsistence[3]" population in Washington. One on-going survey is discussed in relation to Laotian fish consumers, an Asian American sub-population in Washington State.

Each study is reviewed for experimental design, target population, sample size, location, and potential bias. Problems expected to significantly affect final consumption rates are highlighted. This review is not intended to be a comprehensive analysis, but to focus on issues that will markedly affect study results and use of those results in Ecology regulations and risk assessments.

Although not specifically required in every survey, some study design issues are considered to be pertinent to fish consumption surveys. These include

- *Pilot Tests*

  Because the administration of consumption surveys is a complex process, pilot tests can help to identify potential problems and refine data collection techniques.

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[3] Subsistence fisher populations are defined as those individuals for whom fish is the primary source of protein in their diet. For example, a 72 kg male would have to consume somewhere between 252 to 414 g of fish/day wet weight. This is calculated by assuming a protein requirement of 58 g/day (NRC, 1989) and dividing by the protein content of fish (ranging from 0.14 to 0.23 g protein/g fish wet weight (Lagler et al., 1977)). For the purposes of this paper, subsistence population is used to refer to individuals for whom fish is their primary source of protein. Depending on the nutritional requirements of the individual and protein content of the fish, subsistence consumption rates can be expected to range between 61 (for a 9 kg infant) to 414 g/day. The term subsistence consumer is not used interchangeably with any specific minority group, although many minority groups can include subsistence consumers.

- *Timing of Interviews*

  Ideally, interviews should be conducted over the entire year to avoid seasonal bias. Individuals tend to change their food consumption habits with season as some foods become more or less available, or as weather and activities change with the season. This may be especially true with fish consumption as species availability and frequency of fishing trips change with season. Results from surveys conducted during only one part of the year may tend to overestimate yearly consumption of fish consumed during the survey period and underestimate consumption of fish consumed during other parts of the year.

- *Training Interviewers*

  Training interviewers to ask questions in a particular manner and to adhere to wording specified in a questionnaire can help to alleviate potential interviewer bias. If the survey covers one or several minority groups, interviews should be conducted by a member of each ethnic group or sub-population, respectively. For some populations, particularly minorities such as Native Americans or Asian Americans, respondents may be reluctant to participate in studies that are conducted outside their population.

- *Combining Recording Methods*

  Recording methods can be combined to reduce intra-individual variability (Willet, 1990). For example, an annual or seasonal food frequency questionnaire can be combined with a 24-hour dietary recall to verify consumption rates reported in the annual questionnaire.

- *Consideration of All Fish Species*

  All fish species consumed by the study population should be included in the survey. Some researchers may choose to exclude certain types of fish due to assumptions regarding potential contamination or expected consumption habits. This makes overall consumption rates difficult to compare among surveys. In addition, more recent studies indicate preferences for species previously excluded from some surveys. For example, Landolt et al. (1985) excluded most shellfish species (except Red Rock Crab) from their Puget Sound survey, yet more recent data from two Puget Sound tribes indicate high consumption of locally caught shellfish (Toy et al., 1996).

- *Consideration of the Source of the Fish*

General information on the source of the consumed fish is particularly important for exposure assessments (USEPA, 1992b). Exposure to potential contamination can be more accurately defined if sources are identified during the survey process.

- *Random Selection of Participants or Time Periods* Survey participants should be randomly drawn from the identified study population to avoid potential selection bias. For example, in a creel survey, a researcher can limit bias by randomly selecting time periods (throughout the day, week and year) to conduct interviews. Personal interview survey design can limit selection bias by randomly drawing participants from a list of population members (e.g., two of the tribal studies randomly selected participants from individuals listed on health registries).

Other study design issues are noted as each study is reviewed. Consumption rates are summarized in table format at the end of this section.

A. Creel Surveys

Creel surveys evaluate consumption by estimating the number of fish caught by each angler encountered at given fishing locations, and dividing this value by the number of people who will share in the catch and the number of days elapsed since fish caught at the same site were eaten. The reader is referred to Landolt et al. 1985, USEPA, 1992b for a more detailed discussion of methods to calculate consumption rate from creel surveys.

Five studies were reviewed that estimate fish consumption rates for Washington state using the creel study design. They are the following:

1) Landolt ML, A Nevissi, G van Belle, K Van Ness, and C Rockwell, *Potential Toxicant Exposure Among Consumers of Recreationally Caught Fish. from Urban Embayments of Puget Sound'.* National Oceanic and Atmospheric Administration Technical Memorandum. Rockville, Maryland. 1985 (Final Report),

2) Pierce D, Noviello DT, and SH Rogers. *Commencement Bay Seafood Consumption Study. Preliminary Report .* Tacoma-Pierce County Health Department. Tacoma, Washington. 1981,

3) Adolfson Associates, Inc. *Technical Memorandum on the Results of the 199.5 Fish Consumption and Recreational Use surveys.* April 19, 1995,

4) 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 State Division of Health, Epidemiology Section. January 1985.

5) Patrick, G. and C. Marten. *Consumption Patterns of Anglers who Frequently Fish Lake Roosevelt.* Washington Department of Health, Office of Environmental Health Assessment Services. September 1997.

Landolt et al., 1985

Landolt et al. (1985) of the National Oceanic and Atmospheric Administration and the University of Washington interviewed anglers along the shores (creel study) of four urban bays in Puget Sound to determine exposure to fish tissue contaminants. Personal interviews with shore-side and boating anglers were conducted for 13 continuous months in Elliott, Commencement, Everett, and Sinclair Inlet bays. A total of 4,181 (96% shoreside) successful anglers (anglers who had "catch") were interviewed in the study. Interviewers were trained to question anglers, identify species, and measure fish catch, limiting the potential for error in the data collection process. Anglers were asked the number of times they fish in a given area, number of people with whom they would share their catch, and demographics and socio-economic information. Consumption of the catch was assumed to be divided equally among family members, and edible fish weight was based on a 30% cleaning factor.

Survey Design Issues

The study design used in the Landolt et al. study reduces the potential for bias in a number of areas. Because interviews are conducted by trained interviewers using standardized questionnaires, the potential for measurement and recording errors are reduced. A trial period was used to refine survey techniques and determine appropriate survey times and locations. Interviews were also conducted throughout the entire year, limiting the effect of seasonal variation in fishing behaviors on final consumption rates. However, non-response rates for minority groups were higher than for Caucasians, suggesting that some minority groups may have been reluctant to participate in the study, particularly if they feared that their fishing activity was prohibited for some reason (e.g., no license, restricted areas, etc.). It is not clear if the lack of response from minority anglers underestimates consumption rates for these groups. Interviews for shore-side anglers (as opposed to boating anglers) were conducted at various times during each fishing trip, rather than at the end of each fishing trip. The authors note that this may have resulted in an underestimate of fish consumption rates for shore-side anglers. Finally, it is important to note that this study only collected data on "selected" shellfish (one species of crab), and thus probably underestimated total shellfish consumption.

Pierce 1), 1)T Noniello, and SH Rogers. 1981

Pierce et al., estimated fish consumption rates for Commencement Bay anglers in an effort to determine health risks from eating contaminated fish and shellfish. The study was conducted in two parts, part one from July - September 11 and September 11 through November 23, and a total of 508 interviews were conducted by the researchers over nine survey days. Shore-side anglers (450) were interviewed at four separate shore areas, and boating anglers (58) were interviewed as they left one boat ramp on

Commencement Bay. Anglers were interviewed regarding their current catch, number of people with whom they would share the catch, socio-demographic information, and the number of times they frequented the fishing area. Salmon catch was not included in this study.

Survey Design Issues

This study suffers from limited sample location (only Commencement Bay) and other study design problems. The authors noted some bias on fishing frequency as interviewees interpreted the question to mean the number of times during the fishing season, rather than the entire year. This probably resulted in an overestimate of consumption rates. No pilot tests or survey period was conducted but anglers who provided phone numbers were contacted as a follow-up to ensure that they had in fact consumed the fish they caught. No information was provided regarding training of interviewers, although a standardized questionnaire was used. The author notes that Asian anglers (and others) who fished early morning hours may not have been adequately sampled in the study. As noted with the Landolt study, it is not clear how this affected final consumption rates. The study also excludes consumption of salmon in the overall rates, as the goal of the study was to estimate consumption of bottomfeeders.

Adolfcon Associates, Inc., 1996

Adolfson Associates, Inc. (AAI) was hired by the City of Portland, Oregon to survey fishing habits, racial background of anglers and fish preparation habits in anglers fishing the Columbia Slough and Sauvie Island, both of which are located in the Columbia River. The survey sought to determine fish and shellfish (e.g., crayfish) consumption rates to be used in a human health risk assessment. A creel survey was conducted along the shores of these areas in two phases, Phase I. from July 9, 1994 to October 1, 1994 (28 sampling days), and Phase II. from June 3 through July 3, 1995 (20 sampling days). A total of 364 and 146 interviews were conducted in Phase I and Phase II, respectively. Sample times were selected randomly and reflected both weekdays and weekends. The authors used a range of edible fish weights (30 to 75% of fish weight) to tabulate consumption rates, and provided confidence limits on the mean consumption rates. However, the range of consumption rates of the surveyed populations is not reported. The study also found that the most commonly caught fish were bass and carp in Phase I, and perch, brown bullhead, squawfish, starry flounder, and sturgeon in Phase II. Salmon did not appear to be commonly caught in either phase of this survey. Overall mean values are reported for the range of edible fish weights in Phase II of the study (5.23 to 13.08 g/day with upper 90th confidence limits of 9.77 to 24.42 g/day, respectively).

Survey Design Issues

This survey limited interviewer bias by using trained interviewers and conducting interviews in other languages, where appropriate. However, a number of issues indicate that results are limited in their application to other areas in the state, and consumption rates may still be somewhat underestimated. While surveyors were trained, and interviews were practiced and appropriately conducted with multi-lingual translators (Eastern European, Vietnamese, and Hispanic), sample size was relatively small in Phase II and sample times were not clear. Warning signs have been posted along the Columbia Slough and fish advisories distributed at the time of the interviews may have resulted in decreased angling in the Slough area. In addition, the authors note that on "numerous occasions," interviewers were not able to tabulate fish catch from surveyed anglers. Also, mean consumption rate values are reported but the distribution of consumption rates for the study population is not included.

McCallum M. (1985)

The Washington State Department of Health conducted a creel design survey to determine species of fish and shellfish consumed, the amount consumed, the frequency of consumption, and the location of collection for anglers in three urban bays in Puget Sound. The author was also particularly concerned with whether Southeast Asian immigrants or other low-income groups were frequent users of urban fishing sites and whether they consumed more contaminated species. The survey was conducted from July 1983 through June 1984, and used a survey form almost identical to that used in Landolt et al. (1985) as described above. A total of 1500 interviews were conducted during the survey period. The authors reported that approximately 43 - 67% of the interviewed anglers were Caucasian, 27 - 55% were Asian and 1 -18% were African American, depending upon the specific urban bay. Native Americans comprised 0 - 11%. The authors also found that 52 - 74% of the individuals sampled were seeking bottomfish in general (cod, sablefish, and perch comprised 77% of the total measured catch by weight). The study reported that the most common response for frequency of fishing was once per week, with another third of those sampled answering one to four times per month. No consumption rates were reported in grams per day for the total sample population or for specific minority groups. Similarly, ranges of consumption rates are not provided in the document.

Survey Design Issues

Interviewers do not appear to have been trained, and the study does not mention whether or not minority individuals were included as surveyors in' the study. Surveying was conducted throughout the day on both weekdays and weekends, but did not cover times between midnight and 6 am. Also, only those people who were seeking bottomfeeders, crab or clams were fully interviewed. Those who indicated that they were fishing for salmon or squid (one of the first questions on the survey form) were not asked any further questions. The authors also note that language was a problem in approximately 10 - 24% of the interviews conducted in the three urban bays, although only 26 of the 1500 interviews refused to be interviewed. The authors note that individuals tended to overestimate the amount of times they actually fished in a given area, and that responses were more likely to reflect the number of times anglers fished in a given season, rather than the entire year. However, the authors also note that many individuals answered that they would not eat fish due to "pollution," and the concern that they would experience health effects from consumption of contaminated fish.

Patrick G and C Marien (1997)

The Washington State Department of Health, in conjunction with the Spokane Tribe of Indians, conducted a creel survey of boat anglers in Franklin D. Roosevelt Lake (Lake Roosevelt) which is located in the northeast corner of Washington State. The researchers conducted the survey over two periods; August through November of 1994 and May through September of 1995. Boat anglers (N = 377) were surveyed by a member of the Spokane Tribe at the boat launch facilities as they returned from their trip. Survey collection during the fall of 1994 covered only the lower and middle parts of the lake, while summer of 1995 collection covered all three parts of the lake. A pilot survey was conducted to adjust the survey questionnaire.

Study Design Issues

It is likely that this study did not include many of the consumers of self-caught fish from Lake Roosevelt since the study focused entirely on boat anglers rather than shoreside anglers (Landolt et al. 1985). In addition, the consumption results reflect the sum of the two years of the survey.. Since the questions regarding consumption of fish from the lake changed from one year to the next, it may not be appropriate to add the consumption results from each year. The survey days are randomly selected, but no interview times are recorded or described. The researchers do provide information on race, however, it is based on "interviewer judgment" and may not be accurate. As with many other creel surveys, the researchers note some reluctance on the part of the interviewees to participate in the study. Finally, the confidence intervals seem to suggest a large amount . of uncertainty associated with the results (e.g., the average of 42 meals per year plus or minus 48 meals per year).

B. Personal Interview Consumption Studies

In addition to creel surveys, consumption rates may also be estimated using personal interviews, where participants are asked to estimate how much fish they eat over certain periods of time. Three studies using personal interviews have recently been completed on fish consumption rates, all of which were conducted for tribal members in Washington and Oregon. In addition, one on-going study is currently being conducted among Laotians in Washington State, although some preliminary results have been reported. These studies are the following:

1) Columbia River Inter-Tribal Fish Commission. *A Fish Consumption Survey of the (Imatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin.* CRITFC Technical Report No. 94-3. Portland, OR, 1994.

2) Toy KA, Polissar NL, Liao S, and Gawne-Mittelstaedt GD. *A Fish Consumption Survey of the Tulalip and Sguaxin Island Tribes of the Puget Sound Region.* Tulalip Tribes, Natural Resources Department, Marysville, WA October, 1996.

3) Harris, SG and Harper BL. *A Native American Exposure Scenario.* Risk Analysis. Vol. 17, No. 6. 1997.

4) Keill, L, Soukhaphonh S, and LaFlamme, D, *A Fish Consumption Survey of Laotians in Washington State.* Washington Department of Ecology and Washington State Department of Health. Abstract in Western Regional Applied Toxicologists/Western Regional Epidemiology Network Conference Presentation, Ashland, Oregon. May, 1997.

Columbia River Inter-Tribal Fish Commission (CRITFC) (1994)

The Columbia River Inter-Tribal Fish Commission surveyed fish consumption patterns of four tribes (Nez Perce, Umatilla, Yakama, and Warm Springs) who fish along the Columbia River. Tribal members were hired and trained to conduct personal interviews with standardized questionnaires. Of the 744 subjects randomly selected from the Indian Health Service database, a total of 5 13 subjects were queried about annual consumption rates, seasonal consumption rates and 24-hour diet recall. Subjects were asked to provide information on species of fish consumed, and foam-sponge food models were used as visual aids to estimate portion sizes. Information about the source of the fish (such as harvesting themselves, other tribal members, or from grocery stores) consumed was also obtained. A survey pretest was performed to identify and resolve potential problems **(e.g.,** subject interpretation of interview questions, etc.). A technical review committee oversaw completion of the study.

Study Design Issues

The CRITFC study design limits the potential for bias by using trained members of each respective tribe as interviewers, using standardized questionnaires, sampling randomly, conducting a survey pretest, and using food models to more accurately estimate portion size. Although the interviews were conducted only during one month, rather than the entire year, seasonal bias and intra-individual variability were reduced by combining seasonal and annual fish consumption rates with a 24-hour diet recall. Paying respondents for their interview could result in an overestimate of consumption rates if financial need were related to subsistence fishing behavior (e.g., individuals who cannot afford to purchase as much food may rely on fish as their primary source of protein and would be more likely to enter the study). However, the Toy et al. study, discussed in the following section, could not demonstrate an association between income and consumption rates, suggesting that payment for interviews may not have had a significant influence over final results.

Toy KA, NL Polissar, S Liao, and GD Gawne-Mittelstaedt (1996)

Researchers from the Tulalip Tribes in northwestern Washington conducted a fish consumption study, similar in study design to the CRITFC study, to assess consumption of fish and shellfish of two tribes in the Puget Sound. Personal interviews were conducted with randomly selected Tulalip (73) and Squaxin Island (117) tribal members in spring of 1994 by trained tribal members. Detailed questions on types and sources (e.g., self-caught, tribal member caught, or store bought) of fish and shellfish consumed were asked. Food models were used to estimate portion sizes for members. Consumption rates from the personal interviews were compared to self-administered food frequency questionnaire responses (filled out before the interviews) and re-interviews that were conducted over the phone. Questions regarding preferred fishing locations and methods of fish preparation were also included in the interviews.

Study Design Issues

The study design reduced the potential for measurement error in a number of ways. Interviewees were asked to complete a food frequency questionnaire prior to the interview, and answers were compared with interview results. Although there was some disagreement between the two consumption estimates, the authors note that self-administered food frequency questionnaires do not have an interviewer to probe for answers from respondents, and included fewer types of fish or shellfish. These factors may account for lower consumption rates reported in self-administered questionnaires than in personal interviews. Physical display models were used to assist subjects in identifying portion sizes and fish species for both finfish and shellfish. Pilot tests were performed to identify and address potential problems, and repeat interviews were conducted by phone as an added quality assurance measure. As discussed above, respondents were paid for their interviews but this is not expected to significantly influence results. A technical review committee also oversaw completion of the study.

Harris SG and Harper BL (1997)

Researchers from the Confederated Tribes of the Umatilla Reservation (CTUIR) and Yakama Indian Nation conducted personal interviews with 35 tribal members in an effort to determine subsistence fish consumption rates, or rates associated with tribal members who engaged in a more traditional lifestyle. The researchers used expert elicitation and unstructured surveys to gather information from tribal members. This information was supplemented with information from the open literature. The literature citations include two studies of subsistence economies (one in rural Alaska and another of "pre-contact" times in the Pacific Salmon area) and several general Native American populations in the US. From this information, Harris and Harper estimate a consumption rate of 540 g/day (wet weight), one quarter of which is assumed to be fresh fish with the remaining three quarters assumed to be dried. The researchers state that this is a mean value that reflects approximately the 7_5`x' percentile of the range of subsistence consumers.

Study Design Issues

The researchers used tribal members to query subjects on fish consumption practices, to improve response accuracy. However, specific. details about key information is not included such as which questions were asked, how respondents were selected, or what efforts were made to validate estimates (e.g., no measurements of catch, or food models to estimate serving size). Also, the study did not provide information regarding the time of year in which the survey was conducted, or the time period associated with consumption rate questions (e.g., over a day, month or year). Thus, without more details, the study was difficult to evaluate. Subsistence consumption rates in the cited literature

(Wolfe and Walker, 1987, Hunn 1990, and Harden, 1996) are derived primarily from 1) annual fish harvest estimates divided by population estimates and 2) protein and/or caloric requirements under the assumption that salmon is the primary source of protein. Although both methods provide general estimates of consumption, a number of uncertainties such as types of fish consumed and seasonal variation are not addressed.

Keill, L, Soukhaphonh, S, and LaFlanznze, D. (1997)

A fish consumption survey of Laotians who live in Washington State is currently being conducted by the Washington State Departments of Ecology and Health to obtain information on consumption rates, preparation methods, and species preferences. Phase I of this survey consisted of a pilot survey (conducted in April 1996) where questionnaires, written in Laotian, were administered to a number of Laotian communities located throughout the state. An interviewer of Laotian descent administered consumption questionnaires during religious celebrations (the Laotian New Year) with the assistance of monks and community leaders. In some communities, questionnaires were administered by community leaders and representatives. Of the 1300 surveys released, a total of 462 surveys were completed and returned. Phase II of this survey was conducted in April 1997 with a smaller sample size (N = 84) at one religious celebration event (Laotian New Year). The questionnaire from Phase I was improved by adding questions on specific fish dishes to obtain more accurate information about fish preparation methods and total consumption rates. Preliminary results from both Phase I and Phase II indicate that Laotians routinely catch and consume non-anadromous fish species such as catfish, squid, crappie, and sucker. In addition, they commonly report eating all parts of the fish, including internal organs, head, and skin. Finally, Laotians typically prepare fish dishes in ways that do not result in a reduction of contaminants (e.g., raw or fermented fish).

Study Design Issues

Because this survey has not been completed, results. and a final report have not been released. Thus, preliminary information from this survey should be viewed with caution, and quantitative results, at this time, should not be used as the basis for regulatory consumption rates. However, some aspects of the study design are appropriate, such as conducting a pilot survey and adjusting survey techniques accordingly. Unfortunately, no follow-up surveys were conducted with respondents to check responses. In addition, estimates of consumption were reported as meals per month, and gram per day estimates are extrapolated. Thus, quantitative results are not as robust as those obtained from the tribal studies. However, preliminary results appear to confirm anecdotal evidence that at least one Asian American sub-population, Laotians, regularly catch and consume non-anadromous fish. In addition, they typically prepare dishes that use all parts of the fish and may not reduce the levels of contaminants in fish tissues.

C Discussion and Comparison of Consumption Survey Results

In this section, results from the studies are compared and discussed. The amounts of fish consumed by various study populations are presented and discussed, along with other relevant consumption behaviors such as species and sources of fish consumed.

Populations Consuming Self-caught Fish

Overall, the studies describe fish consumption patterns for shore-side anglers in urban areas of Puget Sound, shore-side anglers in one area of the Columbia River, boat anglers in Lake Roosevelt, several Washington State tribes, and some general information for one Asian American group in Washington State.

Of the personal interview studies, tribal members and Laotians report consuming self-caught (those caught by friends or family members) fish. The source of the fish consumed by these populations is discussed later in this section (II.C.).

The ethnicity of the populations in the shore-side and boating studies reviewed in this analysis varied considerably. In addition, there appears to be a difference in ethnicity between those who consume and do not consume. self-caught fish. For example, Adolfson Associates (1995) report that between 30 and 40% of those surveyed said they would eat the fish they caught. Caucasians (excluding Eastern European descent) account for approximately 42% *of all anglers* fishing in the Columbia Slough, while the remainder are various minority groups. Of those consuming fish from this area, 92% were minority groups. Of these, 47% were of Eastern European descent and others were Hispanic (22%) and African American (19%). Caucasians of non- European descent comprised only 8% of this group. Alternatively, the ethnicity is very similar between those fishing versus those reporting eating fish from the cleaner area, Sauvie Island.

The ethnicity of those consuming catch is reported in McCallum (1985) and Landolt et al. (1985), although it appears to vary depending on location. For example, both Landolt and McCallum report approximately 45% of those fishing in Elliot Bay as minorities. However, in Sinclair Inlet, McCallum reported 33% minority, while Landolt reported only 14%. It is not clear why these two surveys report such differing results for the same embayment over the same time period, using the same questionnaire. It is possible that McCallum results show a higher percentage of minorities (primarily Asians) because she excludes anglers seeking salmon. Anecdotal evidence and preliminary data (Keill et al., 1997) suggest that some Asian groups would not say that they are fishing for salmon because they prefer other species of fish. However, this does not explain the similar percentage of minority groups found at Elliot Bay in both surveys.

Amount of Fish Consumed

Consumption rates from the studies are presented in Table #1 for comparison. As indicated in Table #1, considerable variability exists between and within studied populations. Limitations and issues associated with each distribution are discussed below.

Distribution for Landolt et al. (1985) and McCallum (1985)

The only distributions currently available for the Landolt and McCallum data sets were derived for USEPA by Tetra Tech, Inc. (USEPA, 1988). Ecology attempted to recreate the derived distribution for Landolt to ensure that Tetra Tech procedures were understood and calculated accurately. However, the distributions could not be recreated exactly, as described in Appendix C. It is also important to note that the median consumption value presented in the Landolt et al. (1985) report itself is somewhat different from the median estimated by Tetra Tech. These values are l 1 g/day and 26 g/day, respectively. Thus, quantitative estimates derived by Tetra Tech (USEPA, 1988) based on Landolt et al. (1985), and McCallum (1985) are interpreted with caution.

Distribution for Pierce et a!. (1981)

USEPA re-analyzed data from the Pierce et al., study in the 1989 Exposure Factors Handbook (USEPA, 1989) and provides the same values in the draft 1997 update (USEPA, 1997). Alternative distributions have also been proposed in an article published by Price et al. (1994) that evaluates the effect of sampling design on consumption rate estimates in creel surveys, as described below.

Price etl al. (1994)

Price et al. (1994) states that creel surveys may over-sample "frequent" anglers (e.g., those who fish more regularly such as once a month) in relation to less frequent anglers (e.g., those who fish once a year), and thus overestimate consumption rates for the entire shore-side angler population. Price et al. recommend adjusting distributions from creel surveys to account for this design problem. By multiplying the number of infrequent anglers by the inverse of the number of days that they fish per year, greater weight is given to the less frequent angler. In other words, the number of individuals who fish less often is adjusted so that they comprise a much greater percentage of the angler population.

The results of this statistical adjustment are that the consumption rates associated with a given percentile of the shore-side population also reflect the greater weight given to less frequent anglers. For example; in Price et al. (1996) the adjustment results in reducing the consumption rate of the 50th percentile of Commencement Bay anglers in Pierce, (1981) from 19 to 1 g/day and the 90th percentile from 155 to 13 g/day (Price et al. 1994).

The RAF believes it is inappropriate to apply this adjustment to survey results from the creel studies. While the decision to assign less frequent anglers greater weight may be appropriate if one is interested in the overall consumption rates of the entire population of recreational anglers, Ecology (and others as discussed below) is primarily concerned with those individuals who are likely to incur exposure to local contamination. The Price et al. argument assumes that the amount of fish consumed per trip is constant and independent of the frequency of fishing (e.g., a less frequent angler is likely to catch an equal number of fish per trip as a more frequent angler). This assumption may not be accurate if more frequent anglers may become better skilled and more successful fishermen per fishing trip.

Creel surveys are designed specifically to sample those individuals who frequently fish shore-side areas because those are the anglers who are likely to be exposed to local contamination. Anglers who are more likely to consume fish from those areas may be more likely to experience adverse health effects from contamination. Thus, those anglers who fish an area only once a year should not be given greater weight than those who fish an area more regularly. Aggregating the variability in this case, as proposed by Price et al. (1996) only serves to obscure consumption rates of those who frequent shore-side areas.

It is also interesting to note that other researchers have chosen to exclude infrequent anglers from study populations of self-caught fish consumers (West et al., 1989). In a mail survey (self administered questionnaire) of licensed sport anglers in Michigan, West et al. (1989) excluded persons who held one day fishing licenses for Michigan waters and focused on anglers who purchased annual fishing licenses.

Similarly, researchers Murray and Burmaster, in their re-analysis of the West et al. data, specifically recommend excluding individuals who did not consume fish during the survey period in the Michigan sport angler study. Their re-analysis demonstrates that the portion of sport anglers who did not consume self-caught fish greatly. overwhelms the consumption rate distributions (Murray and Burmaster, 1994). In addition, the researchers specifically recommend the resulting distributions for use in Monte Carlo analyses (Murray and Burmaster, 1994). Findings reported by Murray and Burmaster (1994) are similar to those found in Washington State studies with the arithmetic mean of the "self-caught fish-consuming" group at approximately 42 g/day, although the 90`" percentile of approximately 82 g/day is much less than tribal estimates.

Final Distributions

Consumption rates for all surveys are summarized in Table #1 below. Results from CRITFC (1994), Toy et al. (1996) and Landolt et al. (1985) are illustrated graphically in Figure #1:

Table # 1
Summary of Finfish Consumption Rates in grams/day

Authors (date)	***50th Percentile (g/day)***	***90th Percentile (g/day)***	***95th Percentile (g/day)***	***Arithmetic mean (g/day)***
Pierce et al. (1981) (USEPA, 1995 estimates)	*10*	78	146	39
Landolt et al. (1985) Shore anglers[a]	31	176	277	61
McCallum (1985)[a]	1.9	na	24.3	na
Adolfson Assoc. (1996)[a]	~24[4]	na	na	na
Freshwater CRITFC (1994)[5]`	*42*	*127*	182	63
Marine Toy et al (1996)'[6] *(Finfish and Shell fish)*	30	171	278	61

a - adapted from USEPA
na - not available

As discussed above, studies vary considerably in their design and study populations,

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[4] This value was calculated by multiplying the 50% kg/person/year estimate by 1000 g/kg, and dividing by 365 days.

[5] These values are taken from distributions that were fit to data reported in the respective referenced consumption surveys. Thus, the values included in the tables are found in Appendix B. and vary slightly from those reported in the CRITFC study.

[6] These values are taken from distributions that were fit to data reported in the respective referenced consumption surveys. Thus, the values included in the tables are found in Appendix B,. and vary slightly from those reported in the Toy et. al. study.

and comparisons among the results should be limited. For example, Pierce and Landolt use similar study designs and survey similar populations, but since they do not measure consumption of the same species, the rates differ considerably (e.g., Pierce does not include salmon).

Overall, the results appear to compare reasonably well among those studies that include all fish species. Arithmetic means tend to fall somewhere between 40 and 60 g/day, while 50th percentiles range from 20 to 40 g/day. Upper percentiles indicate a much wider range, with 90th percentiles between 100 to 165, and 95th percentiles ranging from 160 to 250 g/day.

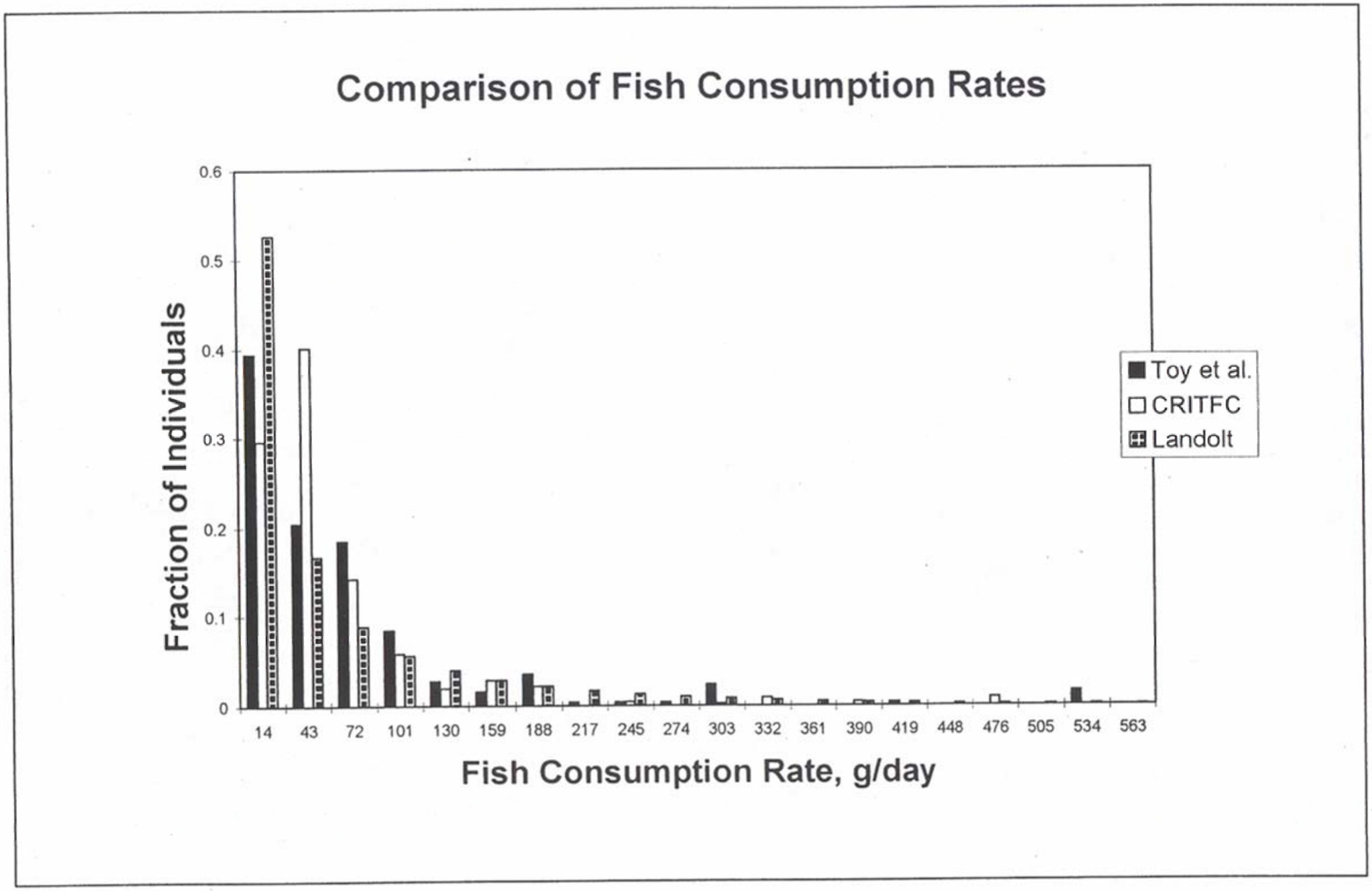

Comparison of Fish Consumption Rates
Fraction of Individuals
0.6
0.5
0.4
0.3
0.2
0.1
0
14 43 72 101 130 159 188 217 245 274 303 332 361 390 419 448 476 505 534 563
Fish Consumption Rate, g/day
Toy et al.
CRITFC
Landolt

Figure 1

Table # 2
Summary of Consumption Studies

Authors (date)	*Pilot*	*Entire Year*	*Trained Interviewers*	*Source of Fish*	*All Species Included*	*Random Selection*	*Combined Record*	*Other Study Design Issues*
Pierce et al. (1981) (USEPA, 1995 estimates)			*X*	*X*				Limited description of study design and methods.
Landolt et al. (1985) Shore anglers	*X*	*X*	*X*	*X*	*X*	*X*		Limited interviewing of some minority groups. Data not in usable format.
McCallum (1985)	*X*	*X*	*X*	*X*				Includes both consumers and non-consumers of fish
Adolfson Assoc. (1996)	*X*		*X*	*X*	*X*	*X*		Limited location, no range of values presented
Patrick and Marien (1997)	*X*		*X*	*X*	*X*			Does not include shore-side anglers. Large confidence limits suggests data uncertainty
CRITFC (1994)	*X*	*X* (Recall)	*X*	X	X	X	X	Possible seasonal bias for recall.
Toy et al (1996)	*X*	*X* (Recall)	*X*	X	X	X	X	Possible seasonal bias for recall.
Harris and Harper (1998)		*X* (Recall)	X					Limited description of study methods
Keill et al. (1997)	*X*	*X* (Recall)	*X*	X	X			No food models, serving size estimated, possible seasonal bias.

Types** of **Fish Consumed

Although the ranges of consumption rates appear to be reasonably similar, the types of fish consumed vary considerably among different populations. For example, Landolt et al. (1985) reports the three species most consumed by Asians as hake, pollock, and squid, while Caucasians are reported to consume squid, sablefish, and cod. McCallum (1985) report sablefish, pollock, and cod as the top three species caught (by weight) in Elliott Bay, while perch and cod are reported most for the other three bays. However, McCallum (1985) did not include salmon in the survey. Adolfson Associates (1996) report the most commonly caught fish are carp, squawfish, yellow perch and bullhead.

Tribal consumption rates appear to be somewhat more consistent across tribes, but still reflect some variability in species preferred. For example, the Tulalip tribal members consume significantly more shellfish than the Squaxin members (Toy et al., 1996). CRITFC (1994) reports approximately 29 g/day as a mean consumption rate of anadromous species, while Toy et al. (1996) report a mean consumption rate of approximately 41 g/day for anadromous species (primarily salmon and steelhead) among the Squaxin. Assuming that the Squaxin tribal members in the Toy et al. study consume fish from the Puget Sound, it is reasonable to conclude that consumption of types of fish can vary significantly with cultural preferences, fish availability, and fishing practices. Thus, adjustment of overall consumption rates for individual fish species is not recommended at this time. However, this is an area that might benefit from further research.

Shellfish

Only two studies, Toy et al. (1996) and McCallum (1985), report shellfish consumption rates in their results. Although McCallum (1985) includes shellfish, the consumption results are combined with bottomfeeders, and a distribution for the study population is not reported. Thus, only one study, Toy et al. (1996) provides a range of shellfish consumption rates.

Source of Consumed Fish

All the reviewed surveys contained some information on the source of the fish consumed.

All four creel surveys demonstrate fish are consumed regularly from specific local areas and urban bays such as Elliott Bay. Two of the personal interview studies include information on the percent of fish obtained from local or regional fishing locations versus store-bought fish, as discussed below.

For the Toy et al. (1996) survey, the authors report that percent of store-bought versus self-caught varies depending on fish species and individual tribe. For example, both the Tulalip and Squaxin tribe report that approximately 80 to 90% of the salmon and steelhead is caught (either inside or outside of Puget Sound). However, only about 30% of pelagic fish such as cod, perch, and rockfish are caught either inside or outside Puget Sound. Similarly, approximately 40 to 50% of bottom feeders such as halibut, flounder and sturgeon are caught (either inside or outside Puget Sound). The remaining percentage of fish in these categories is primarily bought in either restaurants or grocery stores.

The CRITFC (1994) survey reports a somewhat different distribution for sources of fish consumed. On average, approximately 80% of the fish consumed are obtained from either self or family harvesting, friends, ceremonies, or tribal distribution, and most of these fish are reported to originate from the Columbia River. The remaining 20% of fish are obtained from restaurants or stores. CRITFC (1994) does not report source of fish as a percentage of fish species, however, the majority of fish consumed are reported to be salmon.

The Laotian survey (Keill et al. 1997) does not report sources as a percentage of fish consumed. While survey respondents do report consuming self-caught fish from a variety of areas, consumption cannot be apportioned between local and store-bought fish.

Some limited information is reported in creel surveys regarding source of fish consumed. For example, Adolfson Associates found that more minorities consumed fish from contaminated areas (e.g., areas that had risk information posted) than pristine areas.

Although Caucasians (excluding those from Eastern European) comprised 42% of the total anglers interviewed in their survey, those who responded that they ate the fish from the contaminated area consisted mostly of Caucasians of Eastern European descent (47%), Hispanics (22%), and African Americans (19%). Non-Eastern European Caucasians made up only 8% of the group eating from posted areas.

Although fish from grocery stores or restaurants may be from local or regional water bodies such as the Puget Sound, they are unlikely to be caught from locally contaminated areas. It may be reasonable, in some instances, to adjust tribal consumption rates to reflect source preferences of the population. However, it is difficult to generalize the results on the source of consumed fish to other groups (including tribes) who may have different consumption patterns. In addition, results from the creel surveys reflect consumption rates from one specific local source. Thus, apportionment from a given source is conservatively recommended to be 100% at this time. Because of the considerable uncertainty associated with this assumption, more research in this area is included as one of the final recommendations in this document (see Section V).

III. SELECTION OF KEY STUDIES

In selecting studies that form the basis of the fish consumption recommendations, the RAF considered 1) applicability of the study to legislative/executive directives from statutes and policies under which Ecology programs currently operate, and 2) the overall scientific rigor of various studies. Legislative directives directly affecting Ecology programs that use fish consumption rates in risk assessment are discussed below. In addition, other factors such as executive orders or treaties that may influence agency policies, are presented and discussed.

Legislation and executive orders provide direction to Ecology in deciding which study populations, and thus which studies, should be protected. It is important to note that selection of key studies and relevant populations is a separate issue from the degree of protection afforded those populations. The degree of protection, e.g., the 90^{th} or 95^{th} percentile, is discussed in following section, *Selection of Recommended Point Estimates.*

Statutory Directives

Although each of the studies described above provides relevant information for their respective study population, regulatory policies and legislative directives are intended to provide a safe and healthful environment for all current and future citizens of Washington State. Thus the selection of fish consumption estimates should provide protection for all potential fish consumers, including minorities or other populations with high fish consumption.

Programs that are bound by specific statutory directives include the Toxics Cleanup Program, the Water Quality Program, and Central Programs. These directives are:

- <u>Model Toxics Control Act (MTCA):</u> Calculation of cleanup levels and risk assessments for contaminated sites, either in sediments or waterbodies, require consideration of fish consumption rates. MTCA states that "...[e]ach person has a fundamental and unalienable right to a healthful environment..." (RCW

70.105D). In order to comply with this directive, consumption rates should reflect exposures of minority groups such as Native Americans or Asian and Pacific Islanders.

- State Environmental Policy Act (SEPA): In the event that a risk assessment is conducted under a SEPA Environmental Impact Statement (EIS), the RAF believes it is appropriate to consider exposures to minority groups and future generations as described under the language in RCW 43.21A.010 and . 43.21C.020. These sections describe the "responsibilities of each generation as trustee of the environment for succeeding generations," "assure for all people of Washington safe, [and] healthful... surroundings," and "maintain, wherever possible, an environment which supports diversity and variety of individual choice."(Title 43 RCW).

- Tribal Governments: A few Washington state tribes such as the Tulalip Tribes have recently issued water quality standards affecting waterbodies on their respective reservations (Tulalip Tribes, 1995). Ecology actions that affect reservation waterbodies must meet tribal water quality standards that are likely to use tribal consumption rates.

In addition to legislative directives, all agency programs, including the Toxics Cleanup and Water Quality, must consider other executive or judicial findings that direct the agency to protect exposed individuals, particularly if those individuals are members of certain minority groups. Such findings include the following:

- Stevens Treaties: Of the 27 federally recognized Tribes of Washington State, 22 are party to treaties with the United States. Current Tribal use of fish and shellfish is based on the exercise of rights protected under treaties and a tradition of subsistence use inherent in the tribal culture of the Pacific Northwest. The Stevens Treaties ceding Indian territory to the United States for the creation of Washington State are:

Medicine Creek Treaty (1854; Puyallup, Nisqually, and Squaxin Island Tribes)

Point Elliott Treaty (1855; Nooksack, Lummi, Swinomish, Upper Skagit, Sauk-Suiattle, Stiliguamish, Tulalip, Suquamish, Muckleshoot, and possibly Samish)
Point No Point Treaty (1855; Skokomish, Port Gamble S'Klallam, Jamestown S'Klallam, and Elwha S'Klallum)
Quinault River Treaty (aka Olympia Treaty)(1855, Quinault, Hoh, Quileute)
Neah Bay Treaty (1855; Makah)
Camp Stevens Treaty (1855; Confederated Tribes of the Yakima Nation)
Umatilla and Walla Walla Treaty (1855; Umatilla.Confederated Tribe) Nez Perce Treaty (1855; Nez Perce Tribe)

The treaties are viewed as a way of guaranteeing the continuation of Tribal life that revolves around the use of fisheries resources. In 1974, Stevens Treaty Tribes won a landmark decision in <u>United States v. State of Washington</u> in which Judge Bolt recognized the "...generally paramount dependence upon the product of an aquatic economy ... These fish were vital to the Indian diet, played an important role in their religious life, and constituted a major element of their trade and economy." <u>U.S. v. Washington</u> specifically reserve for the tribes the aboriginal right to take fish and shellfish from their "usual and accustomed grounds and stations." In many cases, usual and accustomed areas overlap and extend beyond the areas ceded under treaty (for example, Quinault and Yakama usual and accustomed areas).

- <u>Environmental Justice:</u> Executive Order 12989 on Environmental Justice requires that federal programs protect minority-group and low-income populations from disproportionately high exposures and adverse human health and environmental effects.
- <u>Civil Rights Statutes and Case Law:</u> The failure to take into account fish consumption patterns for minorities and other protected groups would violate Title VI of the Civil Rights Act of 1964. Consistent with Title VI, EPA

> regulations state that a "recipient [of EPA financial assistance] shall not use criteria or methods of administering its program which will have the effect of subjecting individuals to discrimination." (42 U.S.C. 2000d (1988)). Because Washington State receives federal funds for implementing its water quality program, it is subject to Title VI and may not implement any regulations that result in a negative impact on a protected subpopulation. In this case, a regulation based on a fish consumption rate that ignores or undervalues the higher fish consumption rates of some subpopulations would violate Title VI.

Any cross-media risk assessments conducted by other programs such as the Air Quality Program would also be required to protect sensitive individuals, as stated in both the federal and state air quality legislation.

Finally, guidance from national organizations such as the National Research Council and USEPA also recommends and encourages the use of region-specific or site-specific data when such data are available and appropriate (NRC, 1994 and USEPA, 1992).

Recommended *Studies*

The Native American studies, CRITFC (1994) and Toy et al. (1996), are selected to form the basis of the final recommended fish consumption estimates. These studies address most of the technical considerations discussed in Section 11 and appear to be based on sound methodology. Although these results from these studies may reflect some seasonal bias, they are likely to be more accurate than consumption estimates from creel surveys because serving sizes are based on actual food models. Estimates from creel surveys may over or underestimate consumption rates due to several issues of uncertainty, as discussed in Section II.

In addition to study design considerations, statutory mandates and legal issues, as described above, indicate that Ecology programs using fish consumption rates must insure protection for minority groups, particularly in their local fishing grounds. Alternative distributions such as those for the average consumer (AIHC, 1994) or recreational anglers as proposed by Price et al. (1994), reflect significantly lower consumption rates that would not be protective of Native Americans. Finally, Native American consumption rates are comparable to other high end consumers, such as shore-side anglers, and may provide reasonable estimates for populations whose consumption rates are uncertain, but are expected to be relatively high (e.g., Asian American and Pacific Islanders).

In addition, the RAF considered using consumption rates based on Landolt et al. (1985), particularly since consumption rates from shore-side anglers could be slightly higher than Native American rates. However, the Landolt (1985) consumption distributions from the USEPA (1988) report could not be accurately reproduced (see Appendix C), and no other reliable distributions were available for this data set. Also, the survey may have under-sampled minority populations as some groups may have been reluctant to participate, as discussed in the previous section of this document.

Other creel surveys discussed in Section II were also considered, but surveys such as Pierce et al. (1981) and McCallum (1985) do not include all fish species that could be contaminated and then consumed by high fish consumers. These studies also may have under-sampled minority anglers. Adolfson Associates (1996) made serious attempts to correct for potential under-sampling of minority individuals, but the study suffers from a relatively small sample size, limited sampling area, and does not include a distribution of consumption rates.

Species Consumed

In comparing data among the tribes (Tulalip, Squaxin, and four CRITFC tribes combined) tribal groups appear to vary in their consumption of different types of fish/shellfish species. For example, Toy et al. report that Squaxin tribal members consume more bottom feeding fish than Tulalip, while the CRITFC tribal members consume more trout than either the Squaxin or Tulalip members. This may reflect cultural or regional preferences or access to certain types of fish (e.g., it is likely that coastal tribes consume more shellfish than in-land tribes). Other populations, such as

Asian Americans and Pacific Islanders may prefer species not commonly consumed by Native Americans (e.g., crappie, bullhead, etc.)(Landolt et al. 1985, Keill et al., 1997). However, it should be noted that while consumption of different species may vary, overall consumption rates appear to be similar.

In an effort to address potential regional differences, the RAF recommends using the CRITFC estimates for freshwaters and Toy et al. data for marine waters. Consumption rates should not be adjusted to reflect specific types of fish consumed (except for shellfish component of the Toy et al. values). Although the Native American studies indicate higher consumption rates for anadromous species such as salmon, comparisons with results from other populations suggest that species preferences vary considerably among populations. Thus, calculating consumption rates based only on non-anadromous species from the Native American studies could result in an underestimate of exposure for other populations.

Consumption estimates for these two studies are summarized in Table #2 below. Recommended shellfish consumption rates are based on Toy et al. (1996) and calculated separately.

Table #3
Tribal Fish Consumption Rates (grams/day)[7]
(Freshwater and Marine Areas)

Area Authors (date)	***~50th Percentile***	***~90th Percentile***	***~95th Percentile***	***~98th Percentile***	***Arithmetic Mean***
Freshwater CRITFC	*41*	*127*	*182*	*318*	*63*
Marine Toy et al *Finfish* *Shellfish* *Total*	 *17* <u>*13*</u> *30*	 *104* <u>*67*</u> *171*	 *174* <u>*104*</u> *278*	 *313* <u>*179*</u> *492*	 *42* <u>*19*</u> *61*

[7] These values are taken from distributions that were fit to data reported in the respective referenced consumption surveys. Thus, the. values included in the tables are found in Appendix B, and vary slightly from those reported in the CRITFC and Toy et al. studies.

In the absence of other tribe-specific data, these results may be generalized to other Washington State tribes. Studies currently underway are expected to provide insight on fish consumption rates and species preferences for other minority groups such as Asian Americans and Pacific Islanders, particularly in Washington State and Puget Sound (USEPA, *1996).* Results from other consumption studies will be reviewed by Ecology upon their completion.

IV. SELECTION OF RECOMMENDED DEFAULT VALUES

The document thus far has addressed three of the five characteristics in that 1) scientifically sound consumption rates have been identified 2) the consumption rates provide protection for individuals as prescribed by statutory, judicial and executive directives, and 3) these recommendations appear to be consistent with guidance from federal organizations in that they are region specific and are reasonably consistent with other relevant government issues (e.g., tribal governments).

When to Use the Default Consumption Rates

This section specifically addresses the remaining two objectives *Inter program Consistency* and *Flexibility. As* noted in section 1, Inter-program consistency is achieved in part by identifying specific ranges of consumption to use in risk equations. In addition to a range of values, Ecology management requested specific point estimates as default values. These values are intended for programs or projects that do not have sufficient resources to conduct detailed analyses under the direction of a qualified toxicologist/risk assessor. The value(s) are intended for situations such as the following:

1) Calculating standards or risk-based guidelines during rule development.
Some programs may develop risk-based standards or guidelines for large numbers of chemicals. It may be helpful to use one consumption rate that is used in each equation. For example, TCP may wish to use a default value in the MTCA method B clean-up levels. Similarly, if WQP elects to develop water quality standards, they may wish to use a default value.

2) Conducting individual risk assessments that cannot be extensively reviewed by Ecology or DOH toxicology/risk assessment staff.
Ecology and/or DOH may not have adequate resources to address the multitude of issues that can arise in reviewing and developing individual risk assessments. In these instances, staff may elect to use a default consumption rate so that attention

can be focused on other more significant issues in the risk evaluation or larger project.

Deriving Default Values

To select appropriate point estimates of consumption as defaults, particularly for screening criteria or standards where conservative estimates are required, it is necessary to consider

1) the level or degree of protectiveness, or what percentage of the exposed population (or range of potential exposures) should be protected, and

2) the effect of multiplying several exposure assumptions (e.g., exposure duration, exposure frequency and bodyweight) together with the fish consumption rate on the overall degree of conservatism or protectiveness associated with the exposure equation.

The first issue is addressed by specifying a level (or range) of protection for agency risk assessments and regulations. After identifying a level of protection, the second issue is addressed by assessing the degree of conservatism associated with the exposure equation as a whole. These two issues are discussed in more detail below.

Identifying Level of Protection

Risk assessments typically provide a range of exposure estimates that includes central tendencies (e.g., medians and/or means) and upper-bounds (either a 90th, 95th percentile, or both). Risk managers then decide what level of protection is appropriate, given the uncertainties and other characteristics of the situation under study.

Alternatively, screening criteria or standards that set pollutant concentration limits in water or sediments are based on *a single* value of exposure. In these situations, the level of protection is decided *a priori.* Screening criteria and standards are typically designed to be health-protective (conservative) to ensure that potential risks are addressed. As such, they are often based on upper-bound or conservative estimate of exposure. Therefore, the default consumption rates derived here should reflect an upper-bound or conservative level of protection. The RAF elected to derive a value that, when used in conjunction with other exposure parameters (see below), would result in *a reasonable maximum exposure* (RME) estimate.

USEPA guidelines define *a reasonable worst case* or *reasonable maximum exposure* (RME) scenario as

> a semi-quantitative term referring to the lower portion of the high end of the exposure, dose or risk distribution ... [I]t is sometimes useful to refer to individual exposures, doses, or risks that, while in the high end of the distribution, are not in the extreme tail. For consistency, it should refer to a range that can conceptually be described as above the 90th percentile in the distribution but below the 98th percentile. (USEPA, 1992a)

To be consistent with USEPA guidance documents (USEPA 1989, USEPA 1992b), the RAF uses the term reasonable maximum exposure (RME) to refer to reasonable worst case. Thus, the RAF elected to use a level of protection that is above the 90^{t} but below the 98^{th} percentile in the *exposure* distribution.

The exposure distribution should not be confused with the fish consumption distribution. The exposure distribution is the distribution that results from combining the individual distributions (fish consumption is one along with bodyweight, etc.) and point estimates for the terms in the exposure equation. The exposure equation is the following:

$$E = \frac{C \times IR \times ED \times EF \times CF}{BW \times AT}$$

Where

E = exposure (mg contaminant/ kg bodyweight/day)
C = concentration (mg/kg)
IR = fish consumption rate (g/day)

ED = exposure duration (years)
EF = exposure frequency (days/year)
BW = bodyweight (kg)
AT = averaging time (days)
CF = conversion factor (1 kg/1000 g)

Exposure assumptions or terms in the equation include concentration, consumption rate, exposure duration, exposure frequency, bodyweight, and averaging time.

Combining Exposure Assumptions

As discussed above, USEPA defines a reasonable worst case as an exposure value that falls above the 90th and below the 98th percentile of the exposure distribution. If other assumptions in the exposure equation represent upper-bound values, the consumption value does not necessarily have to fall between the 90th and 98th percentile for the overall exposure value to have this level of protection. Therefore, the RAF considered the combined effect of multiple exposure assumptions on the overall level of protection in selecting default consumption rates. This evaluation was done using a technique referred to as distributional analysis. A general overview of this process is included in this section of the report.[8] However, the reader is referred to Appendix B for more detail.

This evaluation involved three basic steps. First, exposure distributions were developed. Second, point estimates of exposure were calculated using common exposure assumptions and varying consumption rates. Third, the point estimates are compared to the exposure distribution to determine the level of protection afforded by various fish consumption rates (when used in combination with the same exposure parameters). Default consumption rates are those rates that, when combined with common exposure assumptions, result in an exposure estimate that is at approximately the 90th percentile of the exposure distribution. Common exposure assumptions include values such as a 70 kg bodyweight, 30 year exposure duration, and a 70 year lifespan (see below).

[8] In an effort to provide an analysis that applies to most programs, and because guidance is still forthcoming, this distributional analysis is relatively constrained by distributing parameters that are likely to remain constant among sites and projects (e.g., bodyweight, etc.). This approach does not represent agency policy for conducting distributional analyses.

This approach also allows for a quantitative evaluation of variability in the exposure equation, as directed by a number of federal guidance documents and academic papers (USEPA(b), 1995, NRC, 1994; PCRARM, 1997; Frey and Cullen, 1995; Hattis and Burmaster, 1993).

Developing Exposure Distributions

Exposure distributions were developed by entering distributions for certain parameters in the exposure equation into a distributional analysis computer program (Crystal Ball). Parameters that vary with reasonable certainty (or whose distributions are known), such as bodyweight, averaging time, and consumption rate, were entered as distributions. The specific distributions for these terms are presented and discussed in Appendix B.

Parameters for which distributions are not known or would vary on a site by site basis, such as chemical concentration and exposure duration, were entered as point values. Guidance for selecting distributions for highly uncertain terms has not been developed by either USEPA or Ecology (USEPA, 1997). Uncertainties associated with these and other terms in the equation are typically addressed qualitatively by risk assessors (USEPA, 1995b, USEPA, 1997, USEPA, 1992a, PCRARM, 1997). In addition, chemical concentration distributions reflect site-specific or contaminant specific variation or uncertainty, and thus would not be appropriate for this generic exercise.

Exposure duration was also entered as a point estimate in the distributional analysis. The RAF considered using a distribution of residence times to represent this term in the analysis. USEPA recommends using general US residence time as a measure of exposure duration in the fish consumption exposure pathway (USEPA, 1989). However, a number of peer-reviewers commented that 1) Native Americans who live on reservations may have longer residence times than the general US population, and 2) changes in residence do not necessarily result in changes of fishing location, particularly for tribal members using usual and accustomed fishing areas.

In response to the first comment, Native American residence times for several tribes were compared to general US residence times. No significant difference was found (see Figure 17 in Appendix B). In response to the second comment, no information was available to establish the relationship between residence location/duration and use of tribal fishing areas. Thus, the exposure duration term remains highly uncertain and this term is represented with a point value.

The RAF recognizes that it is likely that Native Americans and other fish consuming groups would obtain fish from a variety of areas, and that those areas might vary in their contamination levels. The RAF encourages reviewers to provide suggestions and recommendations to address these uncertainties in this evaluation.

Due to slight differences in consumption distributions, analyses are conducted with three separate fish consumption distributions, Toy et al. (1996) and CRITFC (1994) represent tribal consumption in marine and freshwater areas, while the USEPA (1988)/Landolt et al. (1985) distribution is used to calculate recreational consumption rates for comparison purposes.

Calculating Point Estimates of Exposure

Point estimates of exposure are calculated to determine the percentile associated with combinations of exposure assumptions and various consumption rates. Consumption rates, when used in conjunction with exposure estimates, that result in exposure estimates above the 90th but below the 98th percentile of exposure are selected as the range of possible RME rates.

Exposure assumptions used in calculating the point estimates of exposure are those used by USEPA and Ecology programs. The assumptions are taken from the following documents: *Risk Assessment Guidance for Superfund* (USEPA, 1989), *WAC173-340* (Ecology's Model Toxics Control Act regulations), and *Ambient Water Quality Criteria Derivation Methodology: Technical Support Document* (USEPA, 1998). The assumptions are listed in the table below:

Table # 4
Exposure Assumptions Used in RME Derivations

Exposure Assumption	**Value (units)**
Exposure Duration	30 years
Exposure Frequency	365 days/year
Body-weight	70 kg
Averaging Time/lifespan[1]	70 years (25,550 days)

[1]averaging time only applies to carcinogens

Other terms in the equation that are not distributed, such as tissue concentration remain constant between the exposure distribution and point estimates of exposure, as described above.

Comparing Point Estimates to Exposure Distributions (Results)

Results from these analyses indicate that, when used with other standard exposure equation assumptions (Table # 3), marine finfish consumption rates of 110 and 184 g/day provide protection at the 90th and 95th percentile levels, respectively. Similarly, consumption rates of 175 and 262 g/day provide protection at the 90"' and 95th percentile for freshwater finfish, respectively.

For state-wide criteria that may be used **in** both freshwater and marine areas, a value of 177 g/day represents the mid-point between the freshwater and marine values 90th percentiles. The shellfish values are 27 and 46 g/day at the 90th and 9_5'x' percentiles, respectively. These values are summarized in Table #4 below:

Table #5
Consumption Rates for RME Exposure Estimates

Fish Type	**Consumption Rate (g/day) at ~90th % of Exposure Distribution**	**Consumption Rate (g/day) at ~95th % of Exposure Distribution**
Freshwater - finfish	175`	262
Marine - finfish	178	294
State-wide Average	**177**	**223**
Shellfish Only	68	110

In order to select final point estimates for screening criteria, risk-based standards, and RIME estimates in risk assessments within the range of values discussed, a specific level of protection must be identified. The RAF recommends that Ecology adopt consumption rates that are towards the lower end of the exposure range (corresponding to consumption values between 178 and 175 g/day) for the following reasons:

- Some exposure assumptions tend to err on the side of conservatism (or public health and safety). Several conservative assumptions are already incorporated into the exposure assumptions, such as the fact that the individual is assumed to obtain all their fish from one, presumably contaminated source.

- The exposure estimates will likely be combined with health-protective toxicity terms, usually from USEPA's IRIS database.

- The RAF does not recommend that programs adjust fish species consumption to reflect a greater proportion of potentially less contaminated species due to uncertainties in species consumed. However, by including anadromous fish in the consumption rate, these default values may overestimate exposure from local contamination sources that have minor contributions to fish tissue concentrations.

The protectiveness of the assumptions described in the bullets above is not demonstrated in the, distributional analyses but the assumptions are likely to ensure more conservative risk estimates. Thus, the default values are likely to be used in highly conservative exposure scenarios.

Thus, the RAF recommends final default consumption values of approximately 178 and 175 g/day for marine and freshwater areas, respectively. These values represent approximately the 90th percentile of the *fish consumption rate* distribution from the Toy et al. study and the 95th percentile from the CRITFC study, respectively. State-wide criteria may use the mid-point between these values, or 177 g/day as a reasonably protective default. Shellfish may be separated out from the marine values. Shellfish RUE estimates are recommended as 68 g/day based on the Toy et al. study.

V. CONCLUSIONS AND RECOMMENDATIONS

The results from this analysis indicate that consumption estimates should be protective of high fish consumers such as Native and Asian Americans, in light of the available data and as directed by legislative, executive and judicial considerations. For the range of consumption rates suggested in the Native American studies, the RAF recommends the values listed in the table below:

Table #6
Recommended Fish Consumption Rates (grams/day)""[9]
(Freshwater and Marine Areas)

Area Authors (date)	*~50th Percentile*	*~90th Percentile*	*~95th Percentile*	*~-98th Percentile*	*Arithmetic Mean*
Freshwater CRITFC	*41*	*127*	*182*	*318*	*63*
Marine Toy et al					
Finfish	*17*	*104*	*174*	*313*	*42*
Shellfish	*13*	*67*	*104*	*179*	*19*
Total	*30*	*171*	*278*	*492*	*61*

In using these values, risk assessors and managers should consider the size and nature of sites, the likely populations at risk, and the degree of chemical contamination associated with the site or area under investigation.

In. response to requests for default consumption rates for use in regulations and risk assessments, the RAF recommends RME estimates of approximately 110 and *175* g/day for marine and freshwater areas, respectively. A default value of *143* g/day is recommended for water quality screening criteria or standards that must be used state-wide in both marine and freshwater areas. These should only be used with the exposure assumptions listed in Table #3 such as 70 kg bodyweight and 30 year exposure duration.

[9] These values are taken from distributions that were fit to data reported in the respective referenced consumption surveys. Thus, the values included in the tables are found in Appendix B, and vary slightly from those reported in the CRITFC and Toy et al. studies.

Estimates of shellfish consumption should also be based on the Native American (Toy et al.) study in marine fish. Consumption rates range from 13 to 67 g/day for median and 90th percentiles (respectively) of the consumption rate distribution. Default RME values for regulatory screening values or standards are recommended at approximately 68 g/day. This value falls at approximately the 90th percentile of consumption rate and results in an exposure estimate at approximately the 90^{th} percentile.

These recommendations are expected to meet the objectives stated in the Section I of the paper of *Consistency, Scientific defensibility, Legal Defensibility,* and *Flexibility.* The recommendations provide consistency in that specific studies and ranges of rates are identified that form the basis of selected consumption rates. Default values are to be used with specified exposure assumptions and are based on an RME scenario. The default values may be used by Ecology programs in risk assessments and risk-based regulations.

The objective of scientific defensibility is met in that the recommended values are based on a scientific review of the fish consumption surveys conducted in Washington State. The strengths and weaknesses of each survey are identified and discussed. This review includes recently completed studies, however, more studies may become available in the near future. The RAF encourages the agency to review new information as it becomes available. The default values are scientifically defensible in that they are based on a quantitative analysis that accounts for variability in several exposure assumptions. Each distribution used in the analysis was evaluated and the limitations are described in Appendix B.

The recommendations are consistent with policies and legislation that guide agency actions such as legislative, judicial and executive directives. The document considers the Executive Order on Environmental Justice, the Civil Rights Act, and the Stevens Treaties. The recommendations are flexible in that users may select from the range of values in the Native American studies for individual risk assessments or in other situations with unforeseen issues.

In addition to specific consumption rates, the RAF strongly recommends that Ecology programs research specific areas of the fish consumption exposure pathway. First, the fraction of fish consumed from a contaminated source has conservatively assumed to be one in this analysis. While there is considerable anecdotal evidence suggesting that anglers catch fish from a variety of areas, no surveys have attempted to evaluate the number of fishing sites frequented by anglers. Ecology should encourage interested parties to gather information on the number of potential fishing sites used by anglers, particularly Native Americans who may frequent usual and accustomed areas for most of their lifetime.

Second, the RAF recommends that agency programs undertake a more thorough review of types of species consumed by different subgroups. Interested parties have argued that anadromous fish do not accumulate local contaminants because they are not exposed for long periods of time, and should be removed from the consumption rate. As discussed in section II and Ill, consumption of various fish species reflects cultural preferences and access to certain types of fish. While Native Americans appear to consume higher rates of anadromous fish, other high fish consuming groups such as Asian Americans or shore-side anglers may consume more non-anadromous species. On-going consumption surveys (e.g., Asian American and Pacific Islander Seafood Consumption Survey, and Fish Consumption Among Laotians in Washington State) that are attempting to evaluate the types of fish consumed by different subgroups should be considered when determining if anadromous fish should be excluded from the consumption rate. The RAF encourages interested parties to submit suggestions and recommendations that address possible methods to evaluate species consumed.

Finally, the RAF recommends that Ecology develop more formal guidance for using distributional analysis in agency regulations and risk assessments. The MTCA Policy Advisory Committee has also recommended that Ecology develop appropriate guidance for distributional analysis.

Appendix A

Population Estimates

Licensed Anglers

In addition to tribal members, state licensed anglers also frequently consume self-caught fish that may be contaminated. According to reports by the Department of Fish and Wildlife, over 300,000 residents purchased sport personal use foodfish licenses in Washington state in 1993 (Dept. of Fish and Wildlife, 1995), and approximately 4,000 commercial fishermen purchased licenses in Washington state in 1993 (Dept. of Fish and Wildlife, 1996). Assuming a percentage of self-caught fish consumers similar to those cited by Murray and Burmaster (1994), approximately 24,000 anglers consume fish from Washington State waters. This value significantly underestimates the number of consumers because the families of those licensed fishermen are not included.

Washington State Tribes

Approximately 50,000 tribal members currently live in .the state of Washington, and form a total of 26 separate tribes. Although not all these tribes are coastal, or expected to be engaged in subsistence fishing, many tribes use fish in religious ceremonies and may be high fish consumers.

Asian Americans and Pacific Islanders

Some Asian American and Pacific Islander groups may also-be considered high fish consumer, particularly in urban areas (personal comm. C. Nakano, AAFRC; Landolt, et al. 1985, and Soukhaphonh et al., 1997). These groups may include immigrant populations such as Laotians, Cambodians, and Vietnamese. Population estimates from the Washington State Office of Refugee and Immigrant Assistance indicate that approximately 63,000 South and East Asian individuals currently reside in this state. This does not mean that all individuals consume self-caught fish, however, the estimates suggest that significant numbers of these individuals currently reside in Washington state who may be consuming locally caught fish.

APPENDIX **B**

RME FISH CONSUMPTION RATES DERIVED USING DISTRIBUTIONAL ANALYSIS

Summary

Specific fish and shellfish consumption rates for calculation of reasonable maximum exposure (RME) are derived using a distributional analysis approach.

Exposure probability distributions are developed using exposure parameter distributions for averaging time, body weight, and fish/shellfish consumption rate. Chemical concentration and exposure duration were treated as point values. Point estimates of exposure are calculated using standard exposure assumptions (e.g. 70 kg body weight, 30 year exposure duration, and 70 year lifespan) and varying fish consumption rates. Percentiles of exposure distributions corresponding to point estimates of exposure are identified. Point estimates of exposure associated with the 90"' to 98"' percentiles of exposure distributions are deemed to be RME. Seafood consumption rates resulting. in RME point estimates of exposure are possible choices for RUE consumption rates. RME consumption rates are identified for fin fish consumption in both marine and freshwater areas, and shellfish.

Graphical and numerical information on each exposure parameter distribution is provided. Standard exposure assumptions are obtained from USEPA guidance documents. Additional topics addressed include: the effects of correlated exposure assumptions on exposure distributions, and the sensitivity of exposure distributions to individual exposure parameters.

Contents

Introduction

Calculation of exposure using standard risk assessment techniques has been criticized as greatly exaggerating the true exposure associated with a situation (Cullen, 1994). Part of the basis for this criticism is that exposure is calculated by using multiple high-end input parameter values, potentially leading to overly conservative exposure estimates. Distributional analysis is a tool that may be used to evaluate the degree of conservatism in a point estimate of exposure. This paper uses distributional analysis to derive fish and shellfish consumption rates that, in conjunction with other assumptions, produce estimates of reasonable maximum exposure (RME). The approach used here considers measured differences among individuals (heterogeneity), but does not take into account other uncertainties in the assessment process (e.g., distribution shape and parameter uncertainty, exposure model uncertainty, representativeness of data, etc.)

EPA (1992) defines an RME estimate of exposure as a value that falls between the 90' and 98[1]" percentiles of an exposure distribution. This criterion is illustrated in Figure 1. The objective of this appendix is to determine point estimates of fish and shellfish consumption, which in conjunction with other exposure parameters, result in point estimates of exposure falling between the 90[t]" and 98"' percentiles of exposure distributions.

The following sections discuss: 1) the model for calculating exposure, 2) characterization of exposure model input parameters (e.g., exposure duration, body weight, and fish consumption rate); 3) Monte Carlo simulation of exposure distributions; 4) selection of point estimates for variables other than fish consumption rate, and 5) determination of point estimates of fish consumption rate such that resulting exposure estimates fall at the 90th, 95th, and 98th percentiles of the exposure distribution. Also included in this appendix are analyses of the effects of distributing exposure duration, the impacts of potential correlation among exposure parameters,' and the sensitivity of the exposure distribution to various input parameters.

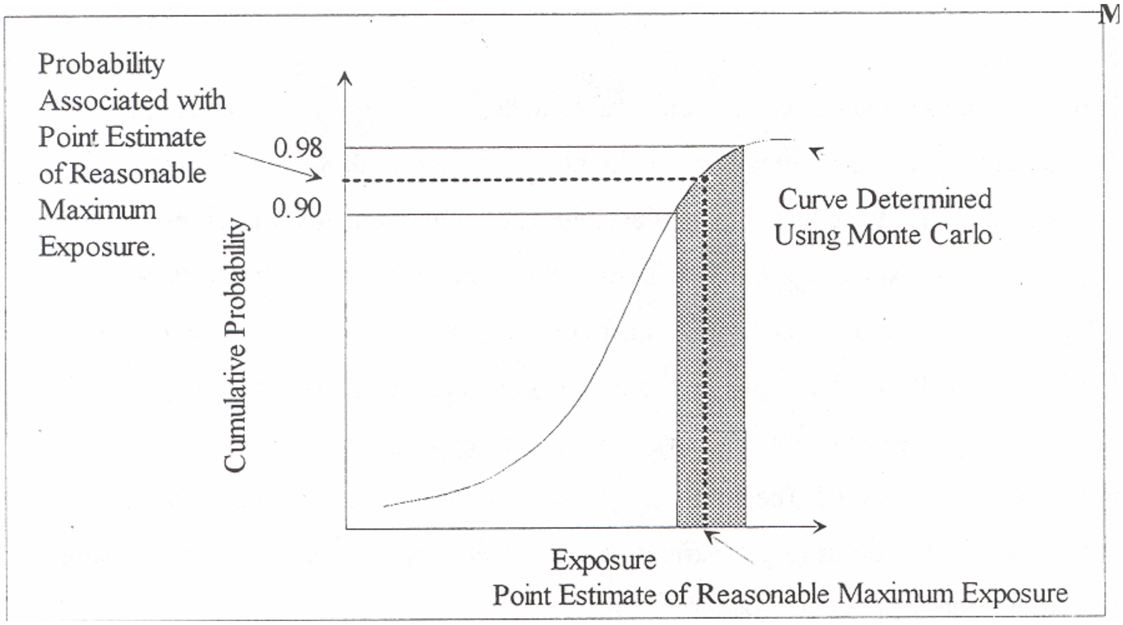
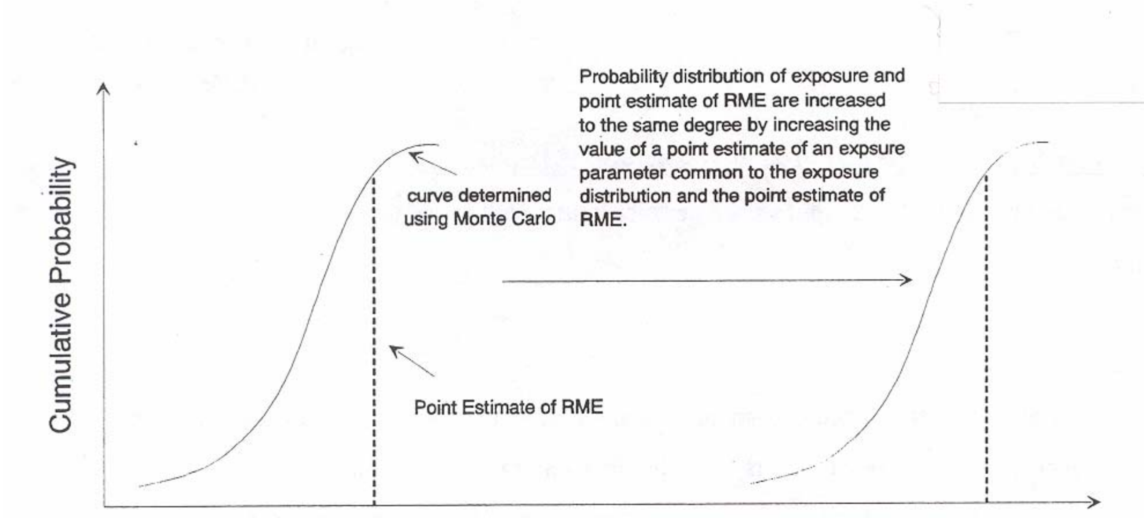


Figure 1: Use of Exposure Probability Distributions to Develop a Point Estimate of RME

It should be emphasized that the purpose of this analysis is to establish the relationship between point estimates of exposure and the corresponding percentiles of the exposure distribution. We are not interested, in the value of the point estimate of exposure or in the values associated with percentiles of the exposure distribution. Further, the position (percentile) of an exposure point estimate in the exposure distribution is not affected by changes in input parameter point estimates, because in such instances the entire distribution is simply shifted to the left or right. Chemical concentration is an example of such a parameter. This is illustrated in the figure 2.



Exposure

Figure 2: Effect of Changing Point Exposure Parameter Values on the Relationship Between an RME Estimate of Risk and the Matching Percentile of the Risk Distribution

Calculating Exposure

USEPA calculates exposure to chemical contaminants by the fish consumption pathway by means of
the following equation (USEPA, 1989):

$$\text{Exposure} = \frac{CF \times IR \times FI \times ED}{BW \times AT \times UCF}$$

Where:

CF: contaminant concentration in fish (mg/kg)
IR: ingestion rate (g/day)
FI: fraction ingested from contaminated source (unitless), assumed to be one.
ED: exposure duration (days)
BW: body weight (kg)
AT: averaging time (days)
UCF nit conversion factor (kg/1000 g)

In deterministic exposure assessment each of the input parameters is a single value, resulting in a single estimate of exposure. In a probabilistic analysis of exposure, certain input parameters are replaced with distributions. Point estimates are retained for input parameters when distributions for that input parameter cannot be identified or adequately characterized. The exposure distribution is then created by: 1) Randomly drawing a single value from each exposure parameter distribution; 2) Calculating a single exposure estimate for the set of input parameter values drawn; 3) Repeating steps 1 and 2 many times; and 4) Grouping single exposure estimates into ranges of exposure and generating an exposure histogram.

Input Parameter Selections for Distributional Analysis of Exposure

This section discusses the choice of input parameter distributions/point values used to develop exposure distributions.

Tissue Concentration

The concentration of a toxic substance that an individual might be exposed to is highly site specific and is further affected by a number of factors, including but not limited to chemical specific characteristics and species preferences of the consumer. Because of these issues, it was felt that deriving a representative distribution of chemical concentration was not possible. Chemical concentration was treated as a point value in both the deterministic and Monte Carlo calculations of exposure.

Assuming that fish are randomly selected for consumption by all individuals, the Central Limit Theorem indicates that over the course of a lifetime, any individual would be exposed to the mean chemical concentration in fish. Although individuals may select fish differentially based on personal preferences, no generally representative information was available for relating these preferences to contaminant concentrations, so we chose to represent the contaminant concentration using the mean value.

Again, this paper is not concerned with assessing actual exposures but rather the relationship between a point estimate of exposure and percentiles of an exposure distribution. The value of tissue concentration, being common to both the point estimate of exposure and the exposure distribution, does not affect the relationship between the two.

It is true that factoring an input distribution of tissue chemical concentration into the exposure analysis will change the relationship between a point estimate of exposure and its associated exposure distribution percentile. In cases where tissue chemical concentrations are well characterized, further distributional analysis using chemical concentration distribution data might lead to selection of consumption rates other than those suggested here.

Sampling data, either from fish tissue samples or media samples, from an individual site under consideration are typically used to calculate an average site concentration. An upper-bound confidence limit on the average was used in the risk equations. The substance selected for the case study was 2,3,7,8-tetrachlorodibenzodioxin (TCDD). The TCDD concentration was the 95% upper confidence limit on the mean, a value of 1.11 x 10"6 mg / kg fish tissue. This statistic was calculated from tissue concentration data for Chinook salmon taken from the lower Columbia River (Obtained from Table 3-4, Tetratech, 1995).

Fish Consumption Rate

The shape of an exposure distribution is affected by the shape of the input distributions used to develop that exposure distribution. Variability in the shape of the exposure distribution caused by use of different fish consumption rate distributions was of concern. Consequently, three Monte Carlo runs are conducted using distributions of ingestion rates (IR) based on: 1) Squaxin Island and Tulalip Tribal data (Toy et al., 1996); 2) CRITFC (1994) data, and 3) a USEPA contractor analysis of the Landolt shore data (USEPA, 1988)[110].

Toy et al., 1996

Fish consumption rate data from the Tulalip and Squaxin Tribes (Toy et al., 1996), expressed in grams per kilogram per day, were obtained from the paper's authors (Polissar, 1997). Four lognonmal distributions were fit to the data, one for each combination of gender and tribe. A Monte Carlo approach was used to create a composite distribution. The sampling frequencies were weighted by the different numbers in each tribe (1398 Tulalip tribal members, 500 Squaxin tribal members) and by assuming a

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[10] The Landolt data were used for comparison purposes. RUE exposures were developed using Toy et al., 1996 and CRITFC 1994 data.

50:50 gender ratio. The parameters for each distribution are given in Table 2. The composite distribution created by sampling these lognormal distributions is plotted in Figure 3.

Table 2: **Parameters for Lognormal Fish Consumption Distributions, g/kg/day (Toy et al., 1996)**

	Tribe:			
	Tulalip		Squaxin	
Gender:	Mean	Std. Dev.	Mean	Std. Dev.
Females	0.44	0.84	0.77	1.99
Males	0.83	2.59	0.83	1.49

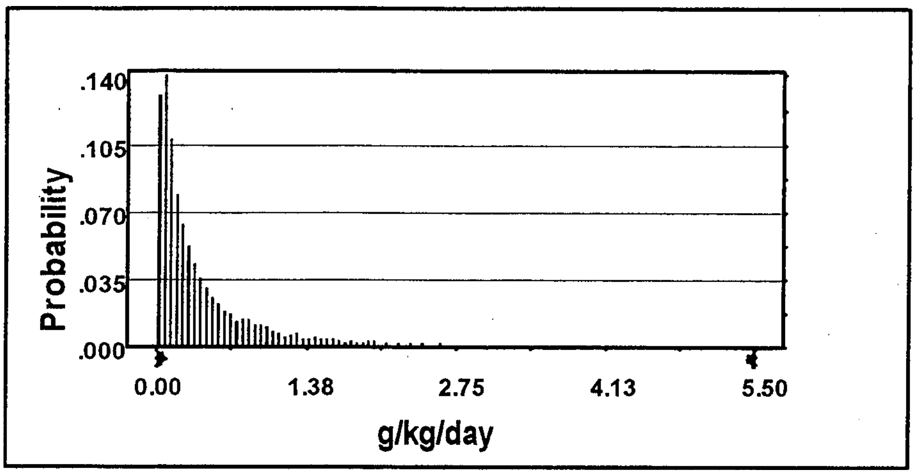

Figure 3: Composite Distribution Obtained from Lognormal Finfish Consumption Distributions, Toy et al., 1996

CRITFC, 1994

Data were obtained from a table of grams of fish consumed per day by adult fish consumers (Table 10, CRITFC 1994). A lognormal distribution was fit to this data having an arithmetic mean of 71.86 and a standard deviation of 109.22. The original CRITFC data are given in Figure 4.

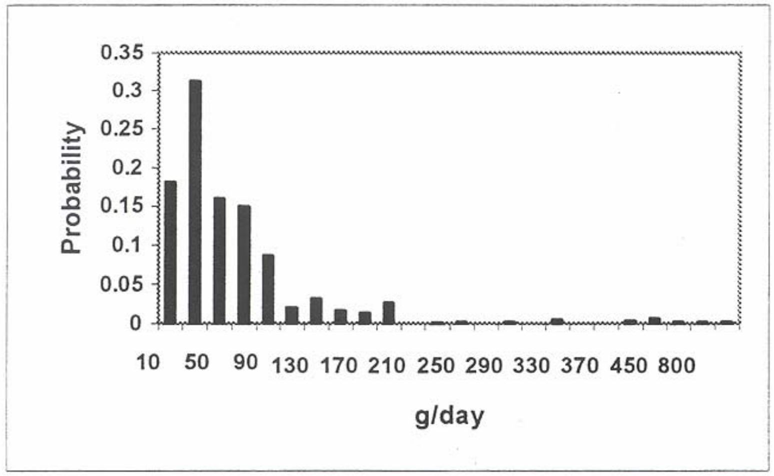

Figure 4: Data from CRITFC, 1994

Table 3: Data for the CRITFC, 1994 Fish Ingestion Probability Distribution		
Fish Ingestion, grams/day		***Probability***
From	***To***	
0	*20*	*0.181*
20	*40*	*0.312*
40	*60*	*0.159*
60	*80*	*0.149*
80	*100*	*0.086*
100	*120*	*0.02*
120	*140*	*0.031*
140	*160*	*0.016*
160	*180*	*0.013*
180	*200*	*0.026*
200	*220*	*0*
220	*240*	*0.001*
240	*260*	*0.002*
260	*280*	*0*
280	*300*	*0.002*
300	*320*	*0*
320	*340*	*0.005*
340	*360*	*0*
360	*380*	
380	*400*	*0.003*
400	*500*	*0.006*
500	*700*	*0.002*
700	*900*	*0.002*
900	*975*	*0.002*

USEPA, 1988
The actual data from the Landolt et al. (1985) report were not available in a form permitting derivation of a probability histogram for fish consumption rates. However, a contractor to EPA, Tetratech, fit a function to the Landolt data that permitted derivation of such a histogram. Ecology was unable to verify Tetratech's work due to an inability to reconstruct the Landolt data from existing materials (SEE Appendix C). The Tetratech function involves a log/arcsine transformation. Such a transformation is commonly used to convert non-linear data involving proportions to a linear form. The exact function is: arcsin (p0-5) = 32.95 x logio (IR) - 1.63, where p is cumulative probability and IR is ingestion rate in grams per day. The data is plotted in Figure 3 and listed in Table 1. In Figure 5, probabilities are shown for the midpoints of ingestion rate ranges in Table 1.

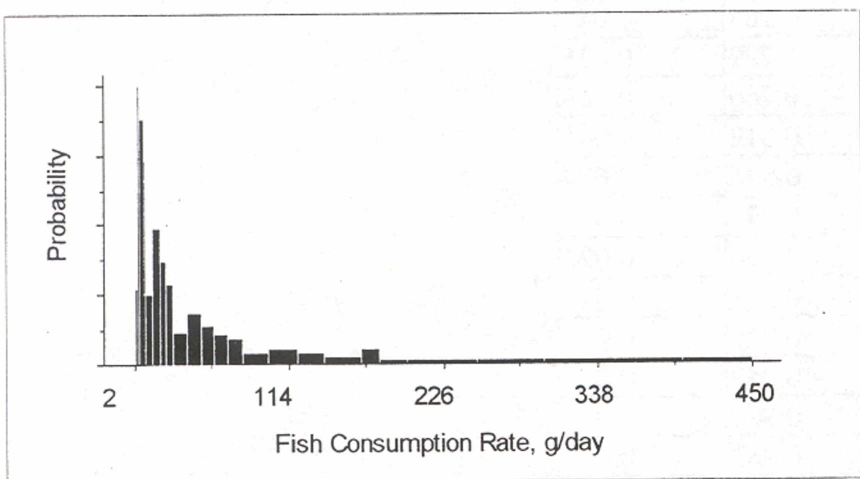

Figure 5: Fish Consumption Rate Data, Landolt et al., 1985

Table 1: Data for the Landolt et al. Fish Ingestion Probability Distribution				
Ingestion Rate (IR)	**Log IR**	Arcsin($p^{0.5}$)	**Cumulative Probability**	**Probability**
2	0.301	8.29	0.021	
4	0.602	18.21	0.098	0.077
6	0.778	24.01	0.166	0.068
8	0.903	28.13	0.222	0.057
10	1.000	31.32	0.270	0.048
15	1.176	37.12	0.364	0.094
20	1.301	41.24	0.435	0.070
25	1.398	44.43	0.490	0.056
30	1.477	47.04	0.536	0.046
40	1.602	51.16	0.607	0.071
50	1.699	54.35	0.660	0.054
60	1.778	56.96	0.703	0.042
70	1.845	59.17	0.737	0.035
80	1.903	61.08	0.766	0.029
100	2.000	64.27	0.812	0.045
120	2.079	66.88	0.846	0.034
140	2.146	69.08	0.873	0.027
167	2.223	71.61	0.900	0.028
180	2.255	72.68	0.911	0.011
200	2.301	74.19	0.926	0.014
250	2.398	77.38	0.952	0.027
300	2.477	79.99	0.970	0.018
350	2.544	82.20	0.982	0.012
400	2.602	84.11	0.989	0.008
450	2.653	85.79	0.995	0.005

Shellfish Consumption, Toy et al., 1996

Shellfish consumption rate data from the Tulalip and Squaxin Tribes (Toy et al., 1996), expressed in grams per kilogram per day, were obtained from the paper's authors (Polissar, 1997). Four lognormal distributions were fit to the data, one for each combination of gender and tribe. A Monte Carlo approach was used to create a composite distribution. The sampling frequencies were weighted by the different numbers in each tribe (1398 Tulalip tribal members, 500 Squaxin tribal members) and by assuming a

50:50 gender ratio. The parameters for each distribution are given in Table 4. The composite distribution created by sampling these lognormal distributions is plotted in Figure 6.

Table 4: Parameters for Lognormal Shellfish Consumption Distributions, g/kg/day (Toy et al., 1996)

	Tribe:			
	Tulalip		Squaxin	
Gender:	Mean	Std. Dev.	Mean	Std. Dev.
Females	0.44	0.77	0.28	0.76
Males	0.47	0.97	0.33	0.87

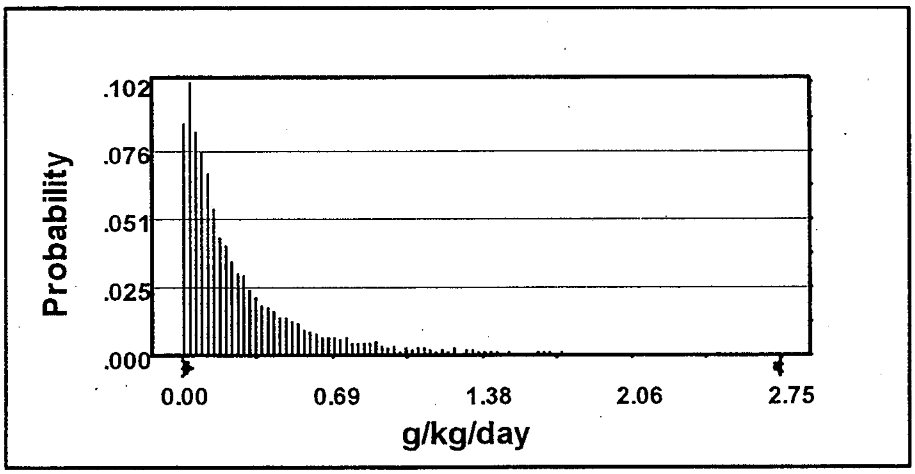

Figure 6: Composite Distribution Obtained from Lognormal Shellfish Consumption Distributions, Toy et al., 1996

Exposure Duration

Risk assessors often treat exposure duration as being equivalent to residence time (EPA, 1989). However, residence time may not be an appropriate surrogate for exposure duration when assessing risks associated with fish consumption. For example, as noted by Male (1992), individuals can relocate within a local geographic area, but continue to use the same fishing locations. This issue may be of particular concern for Native Americans, who may change their place of residence but continue to fish in usual and accustomed fishing areas under their rights as tribal members. Anecdotally, it has been suggested that the majority of Squaxin and Tulalip tribal members reside for their entire lives on or in close proximity to reservation lands (Toy, personal communication, 1998).

Another reason that residence time may be an inappropriate indicator of exposure duration is that certain types of pollutants may be distributed over broad ranges (e.g. PCBs). Changing residence would not end exposure in such cases.

In this analysis, exposure duration will be treated as a point value and assigned a value of 30 years. This is the 90`" percentile of residence time frequently used in EPA Superfund risk assessment (EPA, 1989). The effect of distributing exposure duration on RME fish consumption rates is noted in a subsequent section (SEE: Effect of Distributing Exposure Duration on RME Consumption Rates).

The RAF invites comment on the way that exposure duration was treated in this analysis. Again, the points that led us to treat exposure duration as a point value rather than a distribution of residence time were:
1) Potentially widespread distribution of contamination in Washington State such that relocation would not eliminate exposure.
2) A lack of certainty in:
  a) How change of residence affected use of usual and accustomed fishing areas
  b) The nature of the distribution of time spent on reservation lands by Native Americans.
  c) How duration of residence on reservations affected use of usual and accustomed areas.

Body weight

Body weight distributions for 18-24 year old males and females were used in this analysis. Lognormal distributions were fit to body weight data obtained from the National Health and Nutrition Examination Survey II (Burmaster and Crouch, 1997). A single, composite distribution was created by sampling both distributions and assuming a 50:50 ratio of men and women in the population. Parameters for these distributions are given in Table 6. Tribal body weights may not be equivalent to U.S. values, but should be reasonably similar.

Table 6: Parameters for Lognormal Body Weight Distributions of Burmaster and Crouch, 1997		
	Log Mean (log kg)	Log Standard Deviation
Females	4.08	0.17
Males	4.29	0.16

Averaging Time

Averaging time (AT) is the life span of an individual. The probability distribution for lifespan was developed from data available in the "Washington State Vital Statistics Survey." Data from this survey are aggregated over the years 1986, 1987, 1988, 1989, and 1990. Since this analysis addresses adult exposure (i.e. individuals living 18 years or longer), the probability distribution for age is truncated to include age of death from 20 to 120. The total probability was then re-normalized to one. These data are plotted in Figure 7 and listed in Table 7.

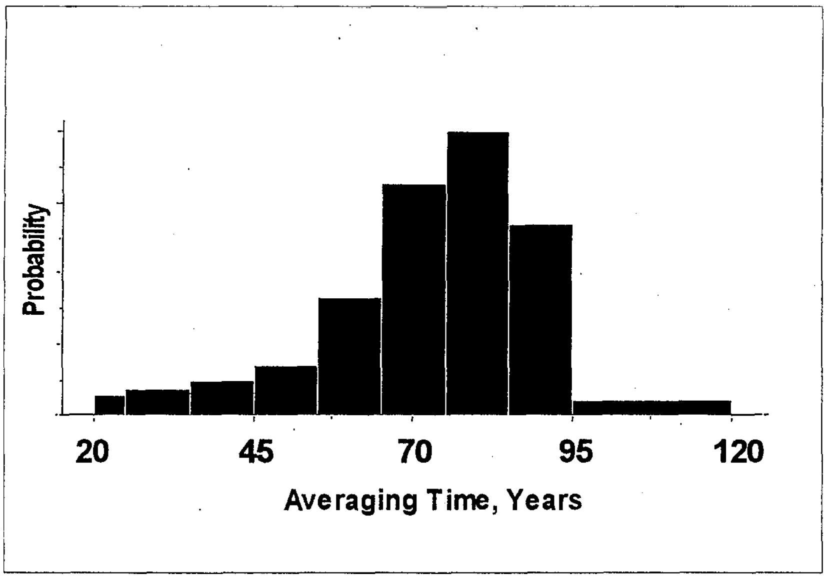

Figure 7: Averaging Time, Washington State Vital Statistics Survey, 1986-1990

Table 7: Averaging Time Distribution		
Years		Probability
20	25	0.00992
25	35	0.02625
35	45	0.03474
45	55	0.04932
55	65	0.11443
65	75	0.22641
75	85	0.27797
85	95	0.18851
95	120	0.03785

Exposure Distributions

Following the characterization of exposure parameter input distributions, exposure distributions were generated.. The software used to conduct these analyses was "Crystal Ball." Each simulation involved 10,000 iterations using a Monte Carlo sampling protocol. Exposure duration was not permitted to exceed averaging time in the Monte Carlo simulation.

Body weight distributions were not used in the simulations using the Toy et al. data, as fish consumption rates were expressed in grams of fish consumed per kilogram body weight per day. Simulations for the CRITFC and Landolt data used the Burmaster/Crouch body weight distributions.

Figures 8-10 display representative exposure distributions obtained using the three different fish consumption studies. Figure 11 displays a representative exposure distribution obtained for shellfish consumption.

There is some variation in the values obtained for the upper percentiles of the exposure distribution between Monte Carlo simulations. Five simulations (of 10,000 iterations each) were therefore run to obtain an average exposure associated with each percentile.

Exposure distribution values for the fish consumption studies are listed in Table 8. Exposure distribution values for shellfish consumption are listed in Table 9.

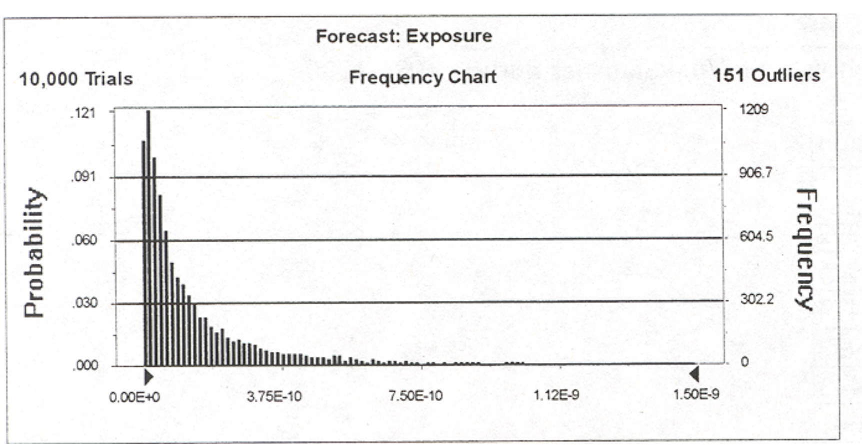

Figure 8: Exposure Distribution for Finfish Consumption Using Toy et al., 1996 Data

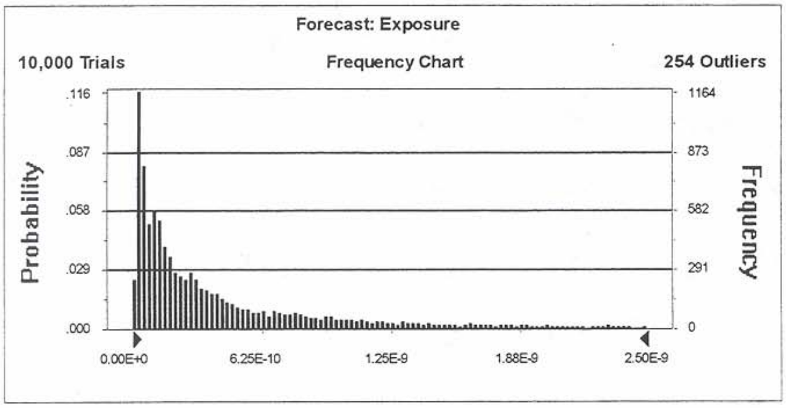

Figure 9: Exposure Distribution for Finfish Consumption Using CRITFC, 1994 Data

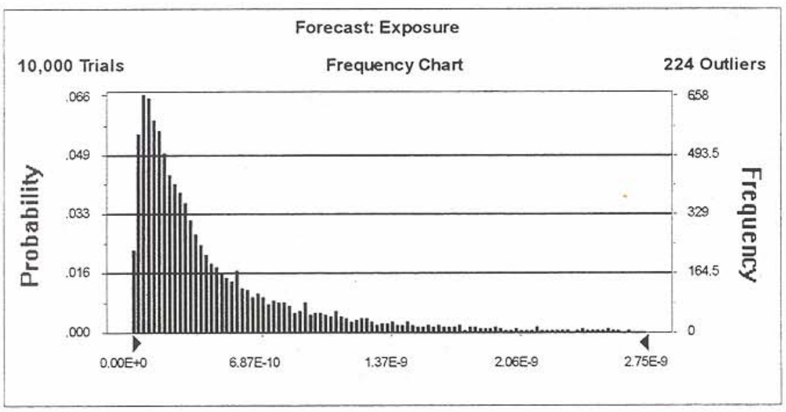

Figure 11: Exposure Distribution for Shellfish Consumption Using Toy et al., 1996 Data

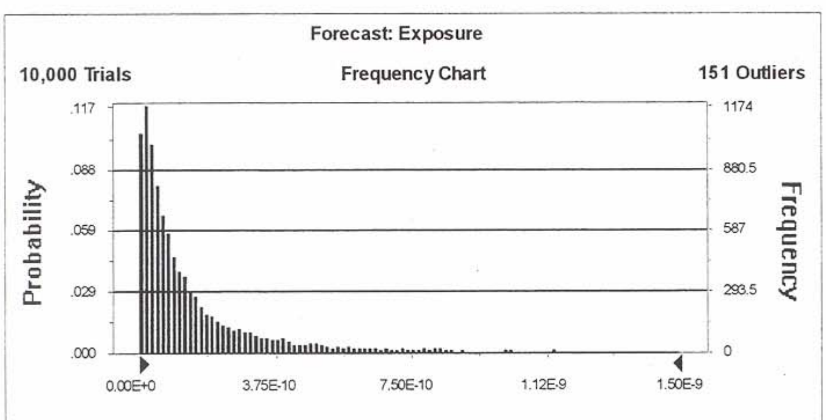

Figure 10: Exposure Distribution for Finfish Consumption Using Landolt et al., 1985 Data

Table 8: Percentiles of Exposure Distributions by Fish Consumption Study, mg TCDD/kg body weight/day			
	CRITFC, Finfish	Toy, Finfish	Landolt, Finfish
0%	3.85E-12	3.26E-13	9.68E-12
5%	4.40E-11	8.58E-12	3.12E-11
10%	6.61E-11	1.46E-11	4.12E-11
15%	8.73E-11	2.06E-11	5.21E-11
20%	1.09E-10	2.67E-11	6.71E-11
25%	1.31E-10	3.39E-11	8.93E-11
30%	1.55E-10	4.16E-11	1.11E-10
35%	1.81E-10	5.04E-11	1.33E-10
40%	2.10E-10	6.03E-11	1.58E-10
45%	2.43E-10	7.14E-11	1.90E-10
50%	2.79E-10	8.48E-11	2.34E-10
55%	3.21E-10	1.01E-10	2.85E-10
60%	3.71E-10	1.20E-10	3.39E-10
65%	4.33E-10	1.43E-10	4.06E-10
70%	5.07E-10	1.70E-10	5.00E-10
75%	6.04E-10	2.09E-10	6.34E-10
80%	7.31E-10	2.60E-10	8.02E-10
85%	9.08E-10	3.35E-10	1.01E-09
90%	1.19E-09	4.59E-10	.1.35E-09
95%	1.78E-09	7.44E-10	2.00E-09
98%	2.87E-09	1.25E-09	2.70E-09
99%	4.02E-09	1.78E-09	3.22E-09

Table 9: Percentiles of Exposure Distributions for Shellfish Consumption, mg TCDD/kg body weight/day	
0%	2.65E-13
5%	8.73E-12
10%	1.45E-11
15%	2.06E-11
20%	2.71E-11
25%	3.39E-11
30%	4.16E-11
35%	5.02E-11
40%	6.01E-11
45%	7.12E-11
50%	8.36E-11
55%	9.90E-11
60%	1.17E-10
65%	1.40E-10
70%	1.68E-10
75%	2.06E-10
80%	2.57E-10
85%	3.31E-10
90%	4.64E-10
95%	7.49E-10
98%	1.31E-09
99%	1.94E-09

Percentiles of Fish and Shellfish Consumption Distributions

Percentiles of each fish consumption distribution and the shellfish distribution were determined by: 1) inputting the distributions into Crystal Ball, 2) running five 10,000 iteration simulations, and 3) determining averages for each percentile. The results of this analysis are given in Table 10 for fish consumption and Table 11 for shellfish consumption.

Table 10: Percentiles of Fish Consumption Studies, g/day			
	Study:		
Percentile	Toy	Landolt	CRITFC
1%	0.7	3.0	1.1
5%	1.8	4.8	5.5
10%	2.9	6.1	11.2
15%	4.2	7.5	16.7
20%	5.4	9.1	21.3
25%	6.8	12.5	24.5
30%	8.4	16.4	27.7
35%	10.2	19.0	31.0
40%	12.2	22.2	34.3
45%	14.7	26.1	37.5
50%	17.4	31.4	41.5
55%	20.8	41.4	48.1
60%	24.8	48.2	54.7
65%	29.8	57.0	61.3
70%	36.3	67.8	68.4
75%	44.8	83.7	75.3
80%	56.5	111.4	83.6
85%	74.1	137.5	95.3
90%	103.6	175.5	127.2
95%	174.2	276.9	182.0
98%	313.0	352.2	317.7
99%	475.3	393.6	436.0

Table 11: Percentiles of Shellfish Consumption Studies, g/day			
Percentile	g/day	Percentile	g/day
1%	0.5	50%	12.8
5%	1.3	60%	17.8
10%	2.2	70%	25.3
15%	3.1	75%	30.6
20%	4.1	80%	37.7
25%	5.2	85%	48.5
30%	6.3	90%	66.5
35%	7.7	95%	104.3
40%	9.2	98%	179
45%	10.9	99%	252.4

<u>Selection of Point Values for Exposure Parameters for Reasonable Maximum Exposure Calculations</u>

The next objective was to select RME input parameter values to use with fish consumption rates to calculate point estimates of exposure. It should be noted that when point values were used in the distributional analysis, they were the same values used for calculating point estimates of exposure. Exposure assumptions typically used by risk assessors were employed.

Concentration of Substance in Fish Tissue, CF

The chemical concentration used was 1.11 x 10"^{6} mg 2,3,7,8-TCDD / kg fish tissue, the 95% upper confidence limit on the average.

Exposure Duration, ED

An exposure duration of 30 years was used. When compared to the distribution of residence time data (USEPA, 1989), this value falls at approximately the 95th percentile of the distribution.

Body Weight, BW

A mean body weight of 70 kg was used, in accordance with USEPA (1989).

Life-span or Averaging Time, AT

A life span of 70 years was also used in the equation, in accordance with USEPA (1989)

<u>Reasonable Maximum Fish Consumption Rates and the Associated Percentiles of Exposure Distributions</u>

As noted earlier, exposure is calculated using the following equation:

Exposure = (CF X IR X FI X ED) / (BW x AT x UCF) Where:

FI = fraction ingested from contaminated source
UCF = units conversion factor
(other parameters defined above)

Having calculated exposure distributions, upper percentiles of the exposure distribution may now be used to derive RME consumption rates. If the 90'" percentile of the exposure distribution is noted as Ego, then the fish consumption rate associated with this percentile and other RME input parameters is:

IR = (CF X FI X ED) / (BW x AT x UCF x E_{90})

Recommended consumption rates are based on comparison of point estimates of exposure and exposure distributions using the same fish consumption data. The data of Toy et al. are used for marine scenarios while CRITFC data are used for freshwater. As mentioned earlier, the Landolt data could not be verified, however this information is included to compare a study involving recreational anglers to studies involving Native Americans.

EPA suggests that a reasonable maximum estimate of exposure should fall between the 90'" to 98'" percentiles of the exposure distribution. Using this criterion, the fish consumption rates associated with upper percentiles of the different exposure distributions are given in Table 12. The shellfish consumption rates associated with upper percentiles of the exposure distribution are given in Table 13.

Table 12: RME Fin Fish Consumption Rates, g/day

Exposure Percentile	CRITFC, Finfish	Toy, Finfish	Landolt, Finfish
90%	175	109.5	199
95%	262	184	295
98%	592	262	397

Table 13: RME Shellfish Consumption Rates, g/day, Toy et al., 1996

Exposure Percentile	g/day
90%	68.3
95%	110.2
98%	193

<u>Correlation</u>

Description of the Effects of Correlation

Distributional analysis frequently assumes for convenience that input distributions of exposure parameters are independent of each other. That is, for each iteration of the Monte Carlo analysis, selection of a value from one input exposure parameter distribution has no influence on the value selected from another distribution. When an exposure variable value selected from one distribution affects the value from another distribution, the variables are said to be correlated. Correlation between input variables can affect the resultant shape of the output exposure distribution.

Linear correlation is described in terms of correlation coefficients. A correlation coefficient of 0 implies that two variables are completely independent of each other. The maximum correlation coefficient of 1.0 means that the variables are completely dependent on each other and that an increase in one variable will result in an increase in the other. The minimum correlation coefficient of -1.0 means that the variables are also completely dependent on each other, but that an increase in one variable results in a decrease in the other. Crystal Ball uses rank correlation to represent dependence between variables.

Approach

Correlation was analyzed for the relationship between ingestion rate and body weight. Determination of correlation coefficients for two variables requires measurements of their values for a sample of individuals. However, these data were not available for the relationships in question. Therefore, a modeling approach was used to determine the potential effect of correlation. Distributional analyses were conducted assuming a range of degrees of correlation (e.g. not correlated to highly correlated. This analysis was also used to determine whether or not more data should be collected to better define correlations.

Positive correlations were assumed. That is, as body weight increases, the amount of fish consumed increases. A person who weighs more is assumed to eat greater amounts of fish than a person who weighs less.

Crystal Ball permits the user to specify different levels of correlation for a pair of variables by specifying correlation coefficients for those variables. Five 10,000 iteration runs were done for different degrees of correlation (i.e. correlation coefficients ranging from 0, no correlation, to 1.0, complete correlation, using incremental changes in the correlation coefficient of 0.1.). The CRITFC data was used as the input data for fish consumption rate.

The effect of correlation on exposure distributions was examined by looking at how the values for different percentiles of the distribution changed with increasing correlation. This analysis was done for the 50th, 90th, 95th, and 98th percentiles of the exposure distribution. Rather than displaying percentiles of the exposure distributions, results are expressed in terms of fish consumption rate as a function of the correlation coefficient. This was done by back calculating the fish consumption rate from the percentile of the exposure distribution using RME values for the other input variables. *Impact of Correlation Between Ingestion Rate and Body Weight*

Increasing correlation between ingestion rate and body weight had no apparent effect on exposure.

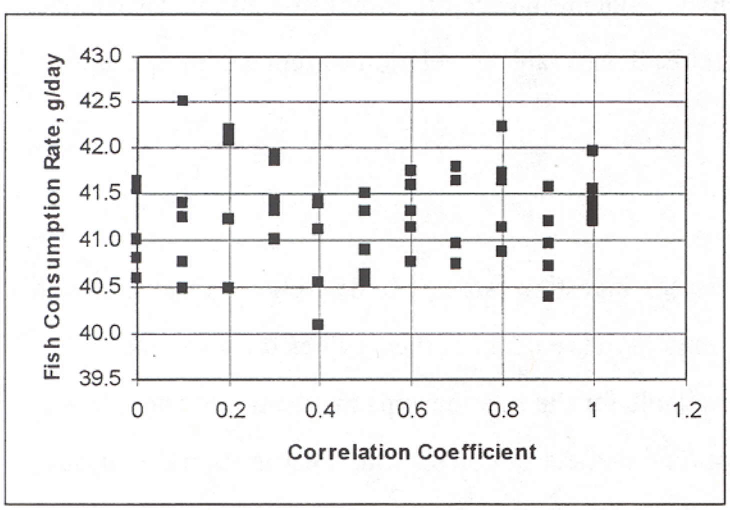

Figure 12: Effect of Increasing Correlation Between Body Weight and Fish Consumption Rate on the 50'" Percentile of Exposure Expressed as a Fish Consumption Rate

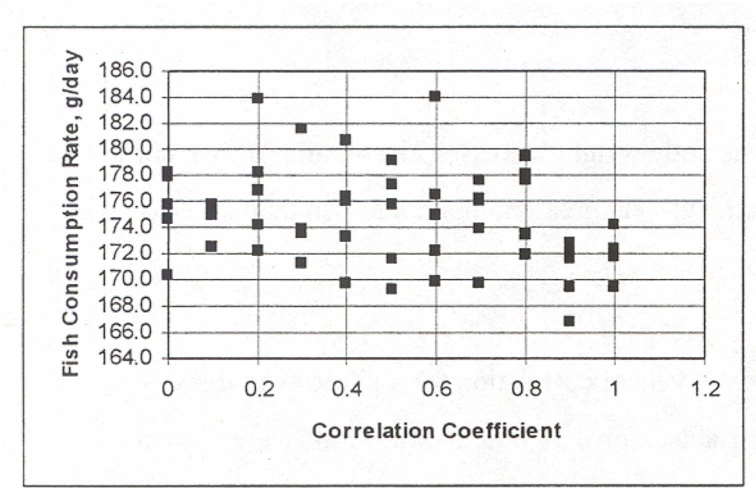

Figure 13: Effect of Increasing Correlation Between Body Weight and Fish Consumption Rate on the 90th Percentile of Exposure Expressed as a Fish Consumption

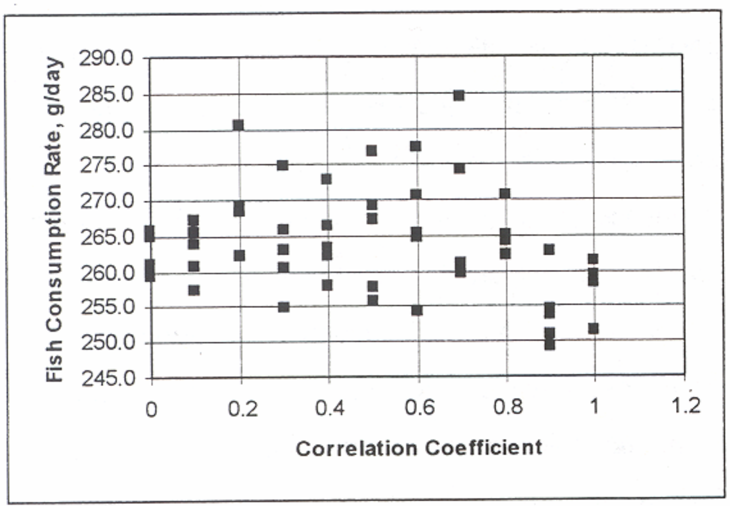

Figure 14: Effect of Increasing Correlation Between Body Weight and Fish Consumption Rate on the 95th Percentile of Exposure Expressed as a Fish Consumption Rate

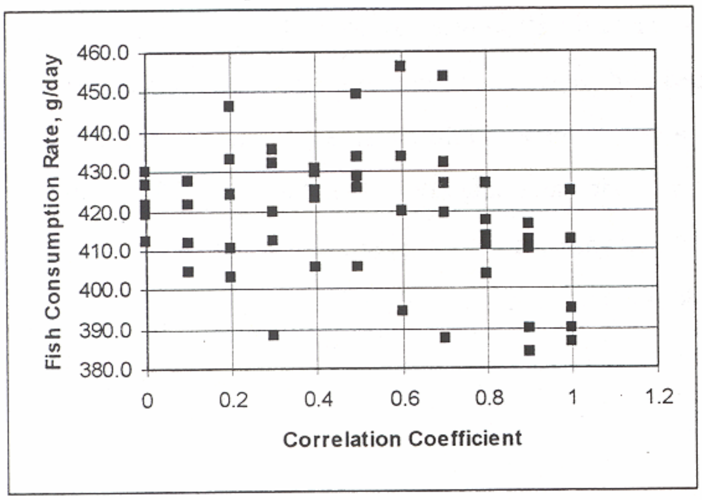

Figure 15: Effect of Increasing Correlation Between Body Weight and Fish Consumption Rate on the 98th Percentile of Exposure Expressed as a Fish Consumption Rate

Effect of Distributing Exposure Duration on RME Fish Consumption Rates

This section of the paper compares RME fish consumption rates where exposure duration is treated as a residence time distribution to RME fish consumption rates where exposure duration is treated as a point value.

The fish consumption distribution derived from CRITFC, 1996, was used for this analysis.

Choice of Exposure Duration Distribution

The distribution of choice for exposure duration would be one characterizing frequency of relocation over large distances, which should reflect changing customary fishing areas. Because no such data were located,[11] residence time was used as the surrogate for exposure duration. Some reviewers suggested that tribal members may have longer residence times than general population, due to strong ties with their reservations or communities. In an effort to evaluate this, residence times of a number of tribes were obtained from US Census data and compared with the US general population (US Census 1990). This data suggests that residence time for Native Americans is similar to the general U.S. population (SEE: Figurel7). However, it is still possible that relocation could be occurring within the area of a reservation, and that individuals would continue to use the same fishing areas.

[11] Tribal representatives from the Squaxin and Tulalip Tribes as well as the tribes participating in the CRITFC study in an effort to determine reservation residency times.

The residence time distribution used to define exposure duration was developed by Johnson and Capel (1992). A Monte Carlo approach was used to develop a distribution of residential occupancy period (ROP). ROP denotes the years between a person moving into a residence and the time that person moves out or dies. Johnson and Capel's approach and data are included in the 1995 Update to EPA's Exposure Factors Handbook. Table 14 lists the data for this simulation and was drawn from Table 5-49 of the Exposure Factors Handbook. The data is plotted in Figure 16.

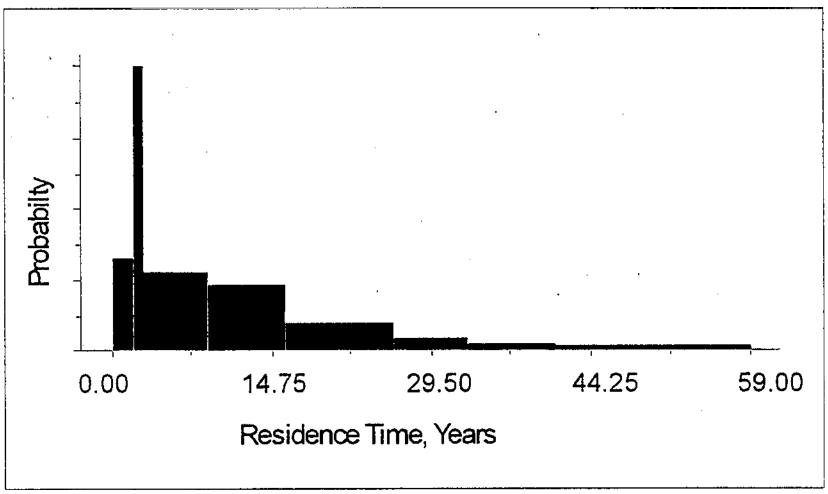

Figure 16: Residence Time (i.e. Exposure Duration) Distribution (Johnson and Capel, 1992)

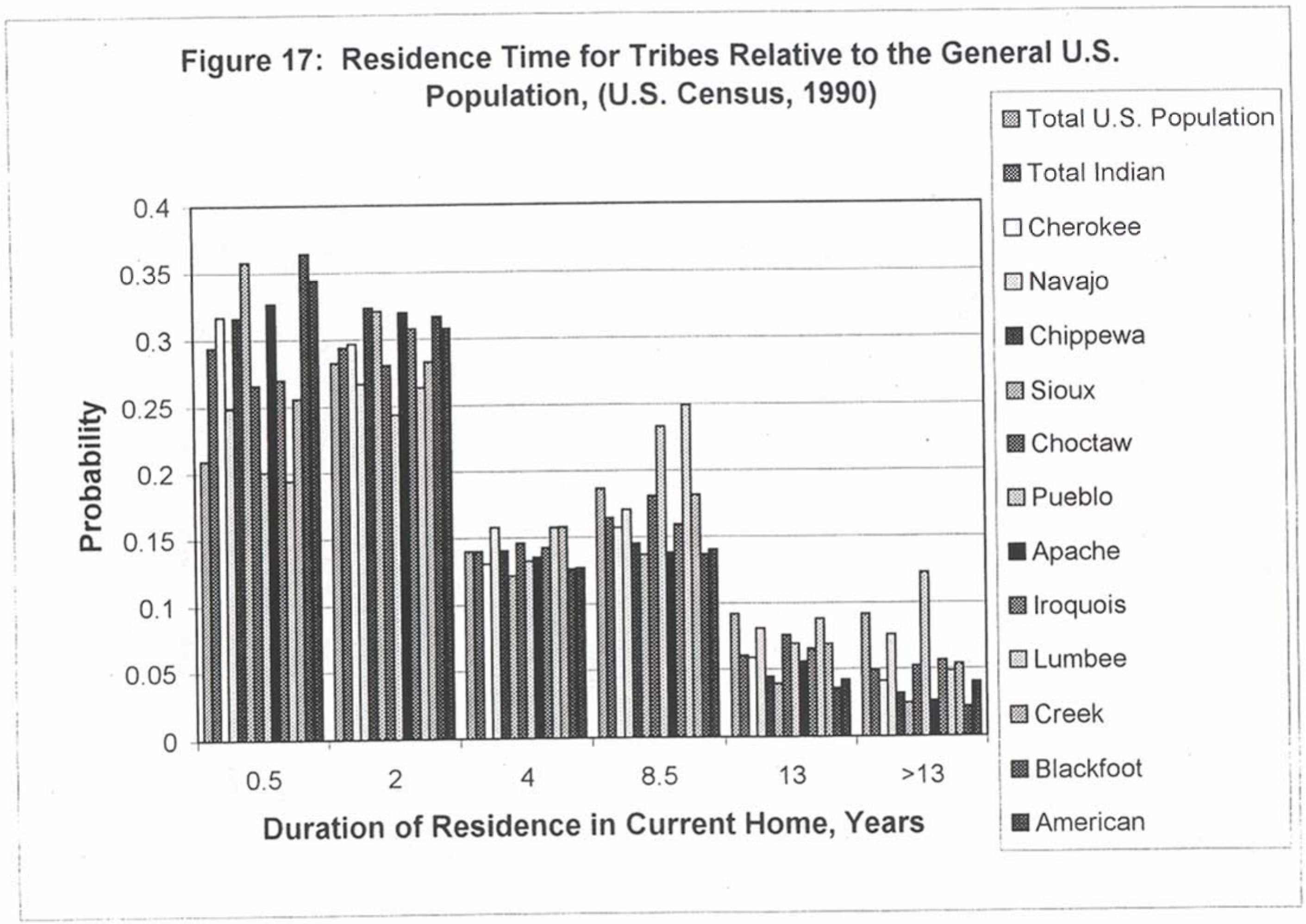
Figure 17: Residence Time for Tribes Relative to the General U.S. Population, (U.S. Census, 1990)
Probability
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.5
2
4
8.5
13
>13
Duration of Residence in Current Home, Years
Total U.S. Population
Total Indian
Cherokee
Navajo
Chippewa
Sioux
Choctaw
Pueblo
Apache
Iroquois
Lumbee
Creek
Blackfoot
American

Table 14: Data for Exposure Duration (Residence Time), U.S. EPA 1995		
Residence Time (years)		**Probability**
From	**To**	
0	2	0.1
2	3	0.15
3	9	0.25
9	16	0.25
16	26	0.15
26	33	0.05
33	41	0.03
41	47	0.01
47	51	0.005
51	55	0.003
55	59	0.001

RME consumption rates were derived as noted previously (SEE: Reasonable Maximum Fish Consumption Rates and the Associated Percentiles of Exposure Distributions).

Results

Treating exposure duration as a distribution results in RME consumption rates that are approximately a factor of two lower than RME rates recommended for the case where exposure duration is treated as a point value.

Table 14: Effect of Not Distributing Exposure Duration on Exposure Expressed in Terms of Fish Consumption		
	Exposure Duration:	
Percentile	Distributed	Not Distributed
90	73	175
95	122	262
98	215	592

Sensitivity Analysis,

Crystal Ball calculates sensitivity by computing rank correlation coefficients between input distribution values and exposure. Correlation coefficients provide a meaningful measure of the degree to which input distributions and the risk forecast change together. If an input distribution and the exposure distribution are highly correlated, it means that the input distribution has a significant effect on the exposure distribution. The larger the absolute value of the correlation coefficient, the stronger the effect. The sensitivity analysis is graphed in Figure 18.

Knowledge of which input variables have the greatest affect on the exposure distribution can assist in maximizing resources to reduce uncertainty in characterizing the exposure distribution. Uncertainty pertains to our lack of knowledge of an input distribution. Variability pertains to the range of values that an input parameter has as a result of the properties of the variable (e.g. body weight). The range of values observed for an input distribution is dependent on both uncertainty and variability. Variability can't be eliminated, only better understood. Uncertainty can sometimes be reduced through further study. Sensitivity analysis should be used to identify the input parameters which most strongly affect the exposure distribution and which have uncertainty that can be reduced through further study. Expending effort to reduce uncertainty in an input distribution that does not strongly affect the exposure distribution is pointless. The sensitivity analysis employed here is only valid for those variables that were distributed. The exposure distribution could easily be more dependent on variables that were not distributed (e.g. chemical concentration, exposure duration).

The sensitivity analysis indicates that the, risk estimate is most strongly correlated with fish consumption. Fortunately, there is a large amount of information on fish consumption by the most exposed populations in Washington State. There is substantial agreement between these studies. Therefore, despite the strong dependence of exposure on fish consumption, further efforts to characterize the fish consumption input distribution are not likely to reduce the variability associated with this distribution.

Earlier sensitivity analyses treating exposure duration as a residence time distribution indicated that the exposure distribution was highly dependent on exposure duration. Studies of correlation between residence time and ingestion rate indicated that correlation, if present, would have a major effect on the values of the upper percentiles of the exposure distribution. We have treated exposure duration as a moderately conservative point value. Sensitivity analysis indicates that this is an area deserving further investigation (i.e. an input parameter which strongly affects the output distribution and is subject to considerable uncertainty). The points noted in the previous section need further research.

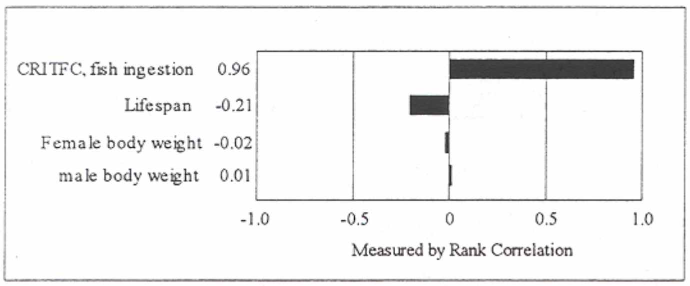

Figure 18: Sensitivity of Exposure Distribution to Input Distributions as Measured by Rank Correlation

Conclusion

Final recommended fish consumption rates that can be used in typical situations as estimators of reasonable maximum exposure are 175 g/day and 110 g/day for marine and freshwater areas, respectively. These are the rates associated with the 90th percentiles of the respective exposure distributions. Because some programs will require one consumption rate that applies statewide, the RAF recommends the mid-point between these values, or 142 g/day, as a statewide default value. A value of 68.3 g/day is recommended as an RME shellfish consumption rate. This is the value associated with the 90''' percentile of the shellfish exposure distribution. Reasons for using the 90''' percentile of the exposure distribution as the basis for RME are discussed in the body of the paper.

APPENDIX C
ECOLOGY RE-ANALYSIS OF USEPA (TETRA TECH'S) 1988 REPORT USING THE LANDOLT STUDY

The Tetra Tech report calculated average daily fish consumption using the

equation: $ADC_i = (E_i \times W \times F) / (C \times 365 \text{ days/year})$

where:

E_i*: Is* the angler fishing effort expressed in units of days/year

W.• Is the average daily weight of all fish caught during the survey period expressed in units of g/day.

F.• Is the edible fraction of fish (0.3 for finfish and 0.49 for squid). C:

The average number of consumers splitting the catch.

Variable Estimates
An estimate of *E,* was obtained by using tables 4 and 21 from the Landolt et al. (1985) analysis. Table 21 lists various measures of fishing activity for respondents in four urban bays. (Note that table 21 is included under Appendix Al.) The percentage of respondents having a particular level of activity is listed. All measures of fishing activity were converted to days per year, for example, fishing once per week is equivalent to 52 days per year, fishing three times per month is equivalent to fishing 36 days per year, etc.. A weighted average was determined for each level of fishing effort by multiplying all fishing effort percentages for a particular urban bay by the fraction of anglers fishing in that bay. The fraction of anglers fishing in each urban bay was noted in table 4 and are as follows: Commencement Bay: 0.289; Elliott Bay: 0.324; Sinclair Inlet: 0.055; and Edmonds: 0.332.

There was no frequency information associated with individuals who visited urban embayments from 4 through 7 times. It was decided to treat this data as though 1st time was equivalent to once per year; 2d time was equivalent to twice per year; 3rd time was equivalent to thrice per year. The 4 through 7 category was treated as 5.5 times per year.

The percentages of anglers reporting each of these levels of effort were combined in a common percentage. The preceding calculations permit us to approximate the same data set used for Tetra Tech's 1988 analysis of the data. The data set is given in Table 1.

The product of Wand F was estimated using Table 27 from the Landolt et al. (1985) report. Table 27 lists the weight of each species of fish taken during the survey period. The cleaning factor, F, is 0.3 for finfish and 0.49 for marketable squid. The product of F and W is the weight of edible fish for each species. The total weight of edible fish was determined to be 3556 g/day.

C, the number of individuals who eat the fish caught by anglers was determined using Table 39 (Landolt et al., 1985). Table 39 lists the percentages of anglers who split their catch with specific numbers of consumers. These figures are broken down by ethnic groups. In order to come up with an average value, it was felt that percentages for each ethnic group should be weighted by the fraction of anglers belonging to each ethnic group. Ethnic group fractions for anglers were calculated from tables 4 and 11 (Landolt et al., 1985). The value for C was calculated to be 3.733:

Table 1: Fish Ingestion Rate Data as a Function of the Probabilities Associated with Different Levels of Fishing Effort

Ingestion Rate (IR) Associated with Level of Fishing Effort	Probability Associated with Ingestion Rate	Cumulative Probability Associated with Ingestion Rate	Log IR	Arcsin of Square Root of Cumulative Probability
2.6	0.188	0.187	0.416	0.447
5.2	0.098	0.285	0.717	0.564
7.8	0.022	0.307	0.893	0.587
13.0	0.013	0.320	1.115	0.601
14.3	0.004	0.324	1.156	0.606
15.6	0.003	0.328	1.194	0.609
18.2	0.009	0.336	1.261	0.619
20.9	0.003	0.339	1.319	0.622
23.5	0.003	0.342	1.370	0.625
31.3	0.085	0.428	1.495	0.713
62.6	0.085	0.512	1.796	0.798
93.8	0.019	0.531	1.972	0.817
135.5	0.144	0.676	2.132	0.965
156.4	0.006	0.682	2.194	0.971
271.1	0.136	0.817	2.433	1.129
406.6	0.067	0.885	2.609	1.225
542.1	0.032	0.917	2.734	1.278
677.7	0.022	0.939	2.831	1.321
813.2	0.008	0.946	2.910	1.337
948.7	0.034	0.980	2.977	1.430

ANALYSIS OF THE DATA SET

If we plot ingestion rate on the X axis and cumulative probability on the Y axis (Figure 1), we can see that the relationship is distinctly non-linear. In the Tetra Tech analysis, the data was transformed by taking the $\log_{10}$ of the ingestion rate and the square root and arcsin of the cumulative probability. These transformations are tabulated in Table 1. Transforming the data results in a roughly linear plot (SEE: Figure 2). If a linear regression is performed on the transformed data set a y intercept of 0.1697 and a slope of 0.3903 are obtained. The correlation coefficient for the regression line is 0.9768. The equation for the regression is therefore:

$$\arcsin(P^{0.5}) = 0.3903 \times 1\mathrm{og}_{10}(IR) + 0.1698$$

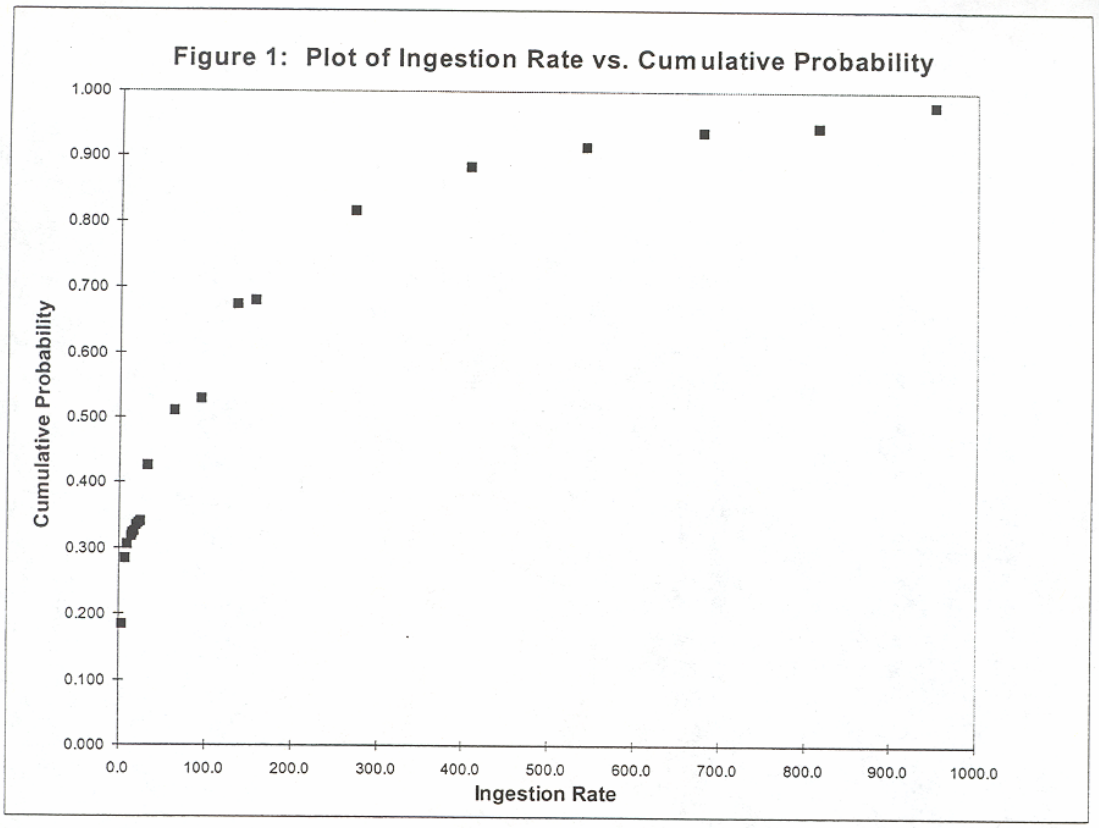

Figure 1: Plot of Ingestion Rate vs. Cumulative Probability

LANDOLT DATA PERCENTILES OBTAINED USING DIFFERENT METHODS OF ANALYSIS

The ingestion rates associated with different percentiles may be calculated by solving this equation for ingestion rate:

$$IR = 10(\arcsin(P^{05}) - 0.1698)/0.3903)$$

Various percentiles associated with the regression line are summarized in Table 2.

It is also possible to calculate percentiles directly from the data in Table 1 without performing data transformation and regression. This was done by entering the first two columns of Table 1, ingestion rate and probability, into "Crystal Ball"[1] and conducting a Monte Carlo analysis. The Monte Carlo analyses are included as attachments at the end of this document.

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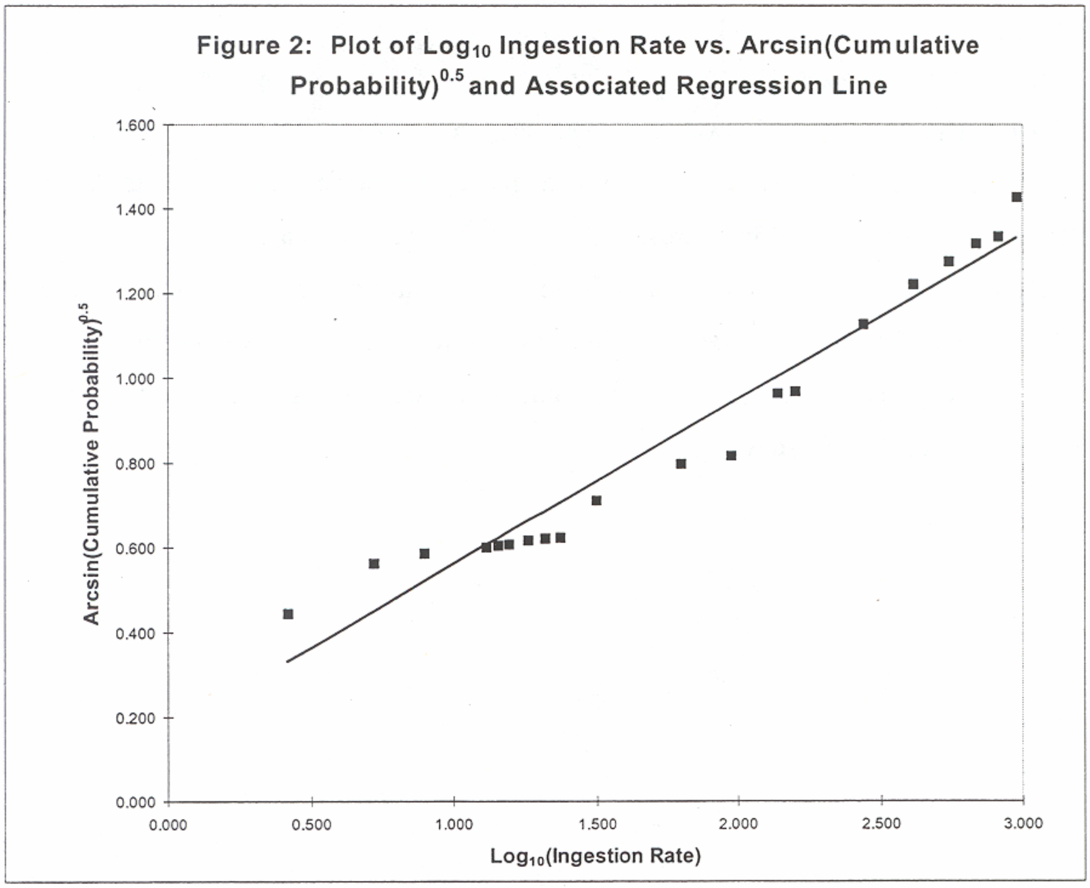
[1]Crystal Ball is a software package commonly used to conduct probabilistic analyses.



Regressions and Monte Carlo Analyses were run using the full data set and the data set less extremely high values of fish consumption.

Table 2: Percentiles of Fish Consumption as Determined from the Landolt Data Using Various Approaches

	Ingestion Rate as Determined Using:				
Percentile	Tetra Tech Regression	Regression Including Extreme Values	Regression Excluding Extreme Values	Monte Carlo Including Extreme Values	Monte Carlo Excluding Extreme Values
50th	26.1[2]	37.8	42.4326	64.6	61.9
90th	167[3]	582	983.701	409.3	271.25
95th	246.2[2]	1026	1888.96	679.7	271.7

[2]Values obtained from Table 10 (USEPA, 1988).
[3]Obtained using regression coefficients for Tetra Tech analysis as noted by Jim Male, consultant to Ecology's Sediment Management Unit.

DISCUSSION

The transformed data set obtained is similar in shape to the data set plotted in figure 5 (c) of the Tetra Tech analysis. However, a good many more data points are present in the Tetra Tech results. Perhaps Tetra Tech did not average the percentages associated with different levels of fishing effort across embayments but treated each percentage separately. There is also the problem of the maximum value associated with the data set. USEPA (1988) figure 5 (c) suggests that the maximum consumption rate obtained was in the 400 - 500 g/day range. The maximum value obtained from this analysis of the data was approximately 950 g/day.

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