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CHEMICALS IN FISH:

CONSUMPTION OF FISH AND SHELLFISH IN CALIFORNIA AND THE UNITED STATES

FINAL REPORT

October 2001

Pesticide and Environmental Toxicology Section
Office of Environmental Health Hazard Assessment
California Environmental Protection Agency

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For more information:

Pesticide and Environmental Toxicology Section (PETS)
1515 Clay Street 16th Floor
Oakland, California 94612
(510) 622-3170

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CONTRIBUTORS

Margy Gassel, Ph.D., Principal Author and Researcher
Research Scientist
Fish and Water Quality Evaluation
Pesticide and Environmental Toxicology Section

Robert K. Brodberg, Ph.D.
Senior Toxicologist
Chief, Fish and Water Quality Evaluation
Pesticide and Environmental Toxicology Section

Gerald A. Pollock, Ph.D.
Staff Toxicologist
Fish and Water Quality Evaluation
Pesticide and Environmental Toxicology Section
Current affiliation: Department of Toxic Substances Control,
Sacramento, California

Anna M. Fan, Ph.D.
Chief, Pesticide and Environmental Toxicology Section

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INTERNAL REVIEW (FIRST DRAFT)

Robert Blaisdell, Ph.D., Associate Toxicologist
Air Toxicology and Epidemiology Section

David Ting, Ph.D., Staff Toxicologist
Hazardous Waste Toxicology Section
Current affiliation: Pesticide and Environmental Toxicology Section

EXTERNAL PEER REVIEW (REVISED DRAFT)

M. James Allen, Ph.D.
Southern California Coastal Water Research Project

Barbara A. Knuth, Ph.D.
Human Dimensions Research Unit, Cornell University

Ronald S. Tjerdeema, Ph.D., D.A.B.T.
University of California, Davis

PREFACE

The Office of Environmental Health Hazard Assessment (OEHHA) is a department within the California Environmental Protection Agency (Cal/EPA). Its charter is to support the agency's mission of improving environmental quality and protecting public health, the welfare of our citizens, and California's natural resources. OEHHA provides scientific leadership consistent with the principles of health risk assessment. OEHHA's responsibilities include:

- assessing health risks to the public from pesticide and other chemical contaminants in food, seafood, drinking water, air, and consumer products, and developing health-protective concentrations to support state programs;
- making recommendations to the California Department of Fish and Game and the State Water Resources Control Board with respect to sport and commercial fishing in areas where fish may be contaminated; and
- issuing fish consumption advisories for California where sport fish and/or shellfish contain chemical contaminants at levels that pose a potential health concern.

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FOREWORD

The following report presents results from fish consumption studies and draws conclusions based on the studies reviewed. An important point that became apparent in the course of review and critical evaluation of the studies is that there is no foolproof methodology that will provide an accurate depiction of all people in a population that consume sport fish. This is due in part to the inherent variability in fish-consuming populations and in part to the inability of any survey (methodology) to achieve unbiased sampling. Factors contributing to variability and bias are elaborated in detail in the ensuing report. Let it be said, then, that when using the results of fish consumption surveys, it is important to recognize the limitations of the estimates derived. In addition, it is equally important to exercise prudence and discretion in making generalizations or assumptions about study results and their validity.

In order to be as precise, representative, and scientifically based as possible, it is crucial to carefully evaluate any studies used, with the explicit intention of finding and using those that are most appropriate to the questions and intended applications of the selected estimates of fish consumption. To this end, this report provides review of many of the surveys that have been conducted in the U.S., and information and discussion of the central issues bearing on their interpretation. Readers recognizing the importance of using appropriate consumption rates are encouraged to use the issues raised in this report to critically evaluate consumption studies themselves, and to identify studies and methods that best characterize fish consumption for their population of interest.

I. EXECUTIVE SUMMARY

Fishing and fish consumption provide recreational, cultural, and nutritional benefits to fishers and their families. However, because many water bodies and the fish that inhabit them contain chemical contaminants, human consumption of fish and shellfish poses a potential health risk. The magnitude of the risk depends on the amount of fish consumed and the degree of contamination. Evaluation of the potential risks to populations that may be exposed to chemically contaminated fish and/or shellfish requires knowledge of the patterns and rates of fish consumption by these populations. Additionally, fish consumption rates are considered in the development of water quality criteria. Therefore, representative estimates of fish consumption rates are fundamental to agencies and programs that have responsibilities in the protection of human health and aquatic resources.

In order to characterize human exposure to contaminated fish and shellfish, the potentially exposed population must be identified, and the likely types and quantities of fish and shellfish consumed must be determined. Historically, a variety of fish and shellfish consumption rates have been reported and used by different researchers and agencies. However, the default consumption rates that have been proposed may not be representative of the fish-consuming populations for which exposure assessments or other evaluations are being done. Additionally, data that describe local consumption patterns and population characteristics for the population of concern may not be available or feasible to collect. Thus, exposure assessments often have to rely on rates reported in existing studies conducted in other regions and/or for other purposes. Estimates of consumption rates that describe fish and shellfish consumption for a particular population(s) of concern must be derived from the most reliable studies and from those that are most applicable to the population(s) of interest.

When selecting the most appropriate estimates of fish and shellfish consumption, it is essential to identify the context in which the estimated fish consumption rates will be used. In particular, one needs to clearly define the population of concern or "target population." In order to characterize potential risks to public health from consuming contaminated fish and/or shellfish, consumption studies that represent people who actually consume fish and/or shellfish should be used to derive consumption rates for risk assessments where fish consumption is a major exposure pathway and risk factor. Where fish consumption is a minor pathway, as in multipathway assessments for general population exposures, studies that include a broader population (e.g., including infrequent consumers) are more representative of the general population target. The selection of consumption studies and rates to develop water quality criteria must be flexible so that criteria can be targeted to protect different populations. For some chemicals, some regions, and some populations, fish consumption is a major exposure pathway, and for others, it is not. The United States Environmental Protection Agency (U.S. EPA)'s national water quality criteria are targeted at protecting the majority of the general population from chronic adverse health effects. Fish consumption rates from the upper percentiles of the national survey population are considered protective in this case. National general population studies also lend themselves to promoting national consistency where fish consumption is not a major exposure pathway and risk factor. In regions or populations where fish consumption is a major demonstrable exposure pathway, U.S. EPA has developed options

for using regional or local consumption studies and fish consumption rates. U.S. EPA encourages states or tribal authorities to select the most appropriate data to adequately protect the most highly exposed population when developing state or local criteria. Alternatively, water quality criteria can be developed without the use of specific local data, but should be based on representative consumption rates such that the criteria will support consumption of fish from the water body at rates at which local users consume fish. In addition, assessors must consider the sources of contaminants for which exposure is being assessed. If the chemical(s) of concern is one with a global distribution, such as methylmercury, then estimates of total fish consumption from all sources, including commercial and sport fish, may be needed to fully evaluate the potential health risks from exposure to this chemical via ingestion of fish and/or shellfish.

In this report, broad definitions of "fish and shellfish" will be used. The term "seafood" is considered here to include any edible organism from any water body. It generally is synonymous with the phrase "fish and shellfish" which is used throughout the report to denote any type of edible aquatic animal, but not including marine mammals, amphibians, or reptiles. "Fish" includes any of various aquatic vertebrate animals having gills and commonly fins, including the bony fishes (those having bony skeletons) and more primitive forms with cartilaginous skeletons (such as sharks and rays). "Shellfish" includes any edible invertebrate animal usually belonging to one of the following taxonomic categories: 1) mollusks, including bivalves, gastropods, and cephalopods; 2) crustaceans; and 3) echinoderms. However, it should be noted that consistency among studies is lacking in terms of which types of seafood were actually included in the study. Therefore, estimates of consumption of fish and particularly shellfish across studies may not (and likely will not) include the same types of organisms.

Per capita consumption rates are estimates derived for the general population inclusive of both consumers and nonconsumers. Thus, per capita rates are primarily useful for trend analyses rather than representing actual consumption. Average per capita rates derived from national surveys for consumption of fish and shellfish by the general population ranged from 10 to 17.9 grams per day. Several analyses of data used to estimate per capita consumption of fish and shellfish found an increase of approximately 25 percent between 1970 and the early 1990's, indicating that the U.S. population as a whole consumed more fish in more recent years.

Consumption rates derived for consumers are preferable to per capita rates for use in describing actual consumption of fish and shellfish in the U.S. However, national data that apply to "consumers only" are limited in several ways. National surveys that have targeted the general U.S. population have determined "acute" consumption patterns for respondents reporting consumption of fish and/or shellfish during the short-term reporting period of the survey. Therefore, the results may not characterize long-term or "usual" consumption rates for consumers. National studies that have been conducted thus far were not designed to fully address consumption of sport fish and shellfish, and are designed to describe the health and diet of the general U.S. population. Therefore, the results of these national surveys are applicable mainly to consumption of commercial fish and shellfish by the general population and are less appropriate for characterizing consumption by fishers or other consumers of sport fish and shellfish.

Regional studies of sport fishing populations reviewed in this report reported overall mean rates for consumption of sport fish ranging from 12.3 to 63.2 grams per day. These studies can be used to derive estimates of sport fish and shellfish consumption for populations in regions where geographic and population characteristics are similar, provided that the limitations of a given study are considered. However, it should be noted that many of these regional studies were conducted at locations where consumption advisories were in place. It is recommended that a range or distribution of consumption rates be used to represent the population as a whole. At the minimum, a measure of central tendency (the median and/or mean values) can be applied if used in concert with an upper percentile rate. The overall mean rates for total fish consumption calculated from the studies that targeted fishing populations and reported on consumption of both sport and commercial fish and shellfish ranged from 16.1 to 61.3 grams per day. These studies indicated that sport fishers consumed commercially available species in addition to sport-caught fish and shellfish.

Consumption rates can vary among subpopulations by race or ethnicity, age, sex, income, fishing mode, region of the country, and other demographic variables. A number of studies have demonstrated trends in higher rates of fish consumption for certain racial or ethnic subpopulations. These studies showed that fish consumption rates were higher for some Asian populations, Blacks, Native Americans, and other minority groups. However, results from various studies are not consistent in the trends reported, and caution should be exercised in making assumptions about subpopulations. In particular, the way in which ethnic or other subgroups are defined can be crucial in shaping the results that are found. In general, however, higher-consuming ethnic subpopulations and other high-end consumers are likely to be represented by upper percentile consumption rates (such as the 95th percentile) derived from a distributional analysis of the data. Some studies also found differences in the patterns of fish consumption (e.g., eating different fish parts) and fishing behavior among subpopulations.

Studies that differentiated fish consumption rates (in grams per day) by age and sex showed that, generally, males consumed more than females did, and the amount of fish consumed increased with age. In many cases, although not all, these differences are likely to correspond to differences in body weight. Exposure assessments should consider body weight as a parameter and use sex and age-specific consumption rates, when available, or adjust for differences in body weight when evaluating subsets of the population. Additionally, there is limited evidence that some elderly fishers consume fish and/or shellfish at rates that exceed (by two to three times) the average for adult sport fish consumers. Although sufficient data may not be available for specific subpopulations of interest, higher consuming individuals and subgroups in the population are likely to be represented by the upper percentile consumption rates derived from a distributional analysis of the dataset (or from default distributions).

Difficulties in defining and evaluating subsistence fishers have resulted in limited information pertaining to consumption rates for subsistence populations. In addition, definitions of what constitutes "subsistence fishing" tend to differ by geographic region and be influenced by perceptions. A few datasets are currently available for sport fishing populations believed to represent or include subsistence fishers (e.g., Native Americans and low-income urban populations). For exposure assessments, use of an upper level intake rate (such as the 95th percentile) from distributions that include subsistence fishers would encompass consumption

rates for individuals reporting above-average consumption within these populations and may be representative of consumption by subsistence fishers within these populations. However, in locations where exceptionally high consumption by subsistence populations, or other people, is expected, using data for the subpopulation of interest would be preferable to fully or to better characterize the population.

When fish consumption estimates are to be used to conduct exposure assessments for locally abundant pollutants only, where fish consumption is a major exposure pathway, consumption rates that are applicable to sport fish consumption from the affected water bodies should be used. The first choice for "applicable" consumption rates would be those derived from surveys of the water body in question. When studies from the water body in question are not available, the results of other well-conducted studies deemed appropriate for application to the population at risk and/or water body of concern can be used. Additionally, in order to characterize potential risks to public health from consuming contaminated fish and/or shellfish, consumption rates that apply to people who actually consume sport fish and/or shellfish, rather than per capita estimates, should be used.

In some circumstances, estimates of consumption of fish and/or shellfish from all sources may be appropriate. For example, if a risk assessment is conducted to evaluate exposure to a chemical(s) of concern with a global distribution, such as methylmercury, then rates for total fish consumption from all sources, including commercial and sport fish, may be relevant for evaluating total exposure to the chemical of concern. In addition, for multipathway exposure assessments, it may be appropriate to apply fish consumption estimates that represent individuals who consume sport fish less frequently, or not at all, as well as those who are frequent consumers. High-end rates (e.g., an upper bound consumption rate) from such studies would be protective of the majority of the population.

Estimates of consumption of fish and shellfish derived from consumption studies are useful for risk assessment, and locally applicable data can enhance exposure assessment for local populations. However, estimates of consumption are not critical or necessarily applicable to the development of the recommended guidelines included in fish consumption advisories. Estimates of the rates of consumption by the population using a water body for which an advisory has been developed can be compared to the recommended guidelines, but are not needed to determine acceptable or safe levels of consumption.

The selection of consumption studies and consumption rates to develop water quality criteria is a special situation. In this case, the rates are not used to assess risk but to set limits to prevent the potential for excess risk developing. Selection of consumption rates in these cases must be flexible so that criteria can be targeted to protect different populations. U.S. EPA's national water quality criteria are aimed at protecting the majority of the general population from chronic adverse health effects. National consumption studies and high-end consumption rates from such studies of the entire general population (consumers and nonconsumers) are considered protective in this case. These studies and consumption rates, however, may not be protective of state or local target populations. U.S. EPA has developed a series of preferences for states selecting consumption rates to use to develop water quality criteria. The preferred option for states is to

use regional or local consumption studies and consumption rates to adequately protect the most highly exposed population when developing state or local criteria.

The Santa Monica Bay Seafood Consumption Study provides the best available dataset for estimating consumption of sport fish and shellfish in California. This study provided a distribution of consumption rates for the population that regularly fishes and consumes fish and shellfish from Santa Monica Bay, and reflects the range of values and the variability within the population. Consumption of sport fish and/or shellfish by populations in California can be described either by using the full distribution in a stochastic analysis or by using, at a minimum, a measure of central tendency (the median or mean) in concert with an upper percentile intake rate from this distribution. Although this study was conducted on a population fishing from a marine water body, a similar distribution of consumption rates was determined from data on a population fishing from fresh water bodies. Thus, the default values derived from the Santa Monica Bay study can reasonably be applied to fishers using any productive water body in the state. Until reliable data become available which describe consumption of freshwater sport fish in California, it is recommended that the rounded unadjusted values from the Santa Monica Bay study of 21 grams per day for the median, 50 grams per day for the mean, 107 grams per day for the 90th percentile, and 161 grams per day for the 95th percentile rate be used to estimate consumption from both marine and freshwater sources of sport fish and shellfish in California. These values are most applicable to fishers that consume sport fish and shellfish on a regular and frequent basis (*i.e.*, at least once a month). For cases where the target population is the general fishing population and fish is not a major exposure pathway, the adjusted (weighted) results of 30.5 grams per day for the mean value and 85.2 grams per day at the 95th percentile can be used.

Other available data from the studies reviewed suggest that consumption rates for sport-caught marine and estuarine fish tend to be comparable to those for sport-caught freshwater fish. Additional data may be useful to evaluate the potential for differences in consumption of fish obtained from water bodies in specific regions of the U.S. where variables such as access, availability, and productivity of fish and/or shellfish may differ substantially. However, in general, for exposure assessments in which potential risks to consumers from consumption of sport-caught fish from productive water bodies are to be evaluated, the available data do not support using different rates of consumption for fish obtained from marine and fresh water bodies based solely on salinity type.

Studies that specifically address consumption rates for commercial fish and shellfish in California are lacking, although several analyses of national data have indicated that people in the Pacific region consumed slightly more, on average (and per capita), than the overall U.S. population. Therefore, national estimates for consumption of commercial species can be used to approximate consumption by the general population in California that consumes only commercial species. However, studies which address "usual" (versus short-term) intake are needed to more accurately estimate typical rates of consumption of commercial seafood. Additionally, several studies have indicated that total fish consumption by fishers is greater than sport fish consumption (fishers supplement their catch with commercially available species). Therefore, estimates for sport fish consumers should be increased to account for supplemental consumption of commercial species, or total consumption, by sport fishing populations in California. Limited data from the studies reviewed suggested that the difference in amount

between sport and total consumption ranged from approximately 8 to 42 grams per day. The proportion of sport and commercial fish and shellfish in the diet may also be influenced by the presence of consumption advisories for fish obtained from local water bodies.

Data are generally unavailable to estimate consumption rates for shellfish, although several studies have shown that shellfish and other invertebrate species were among the most commonly caught species by sport fishers, particularly in certain areas including the Pacific region. In the absence of reliable data on shellfish consumption in California, the rates derived for sport fish consumption by fishing populations in California can reasonably be applied to consumption of shellfish species by those people who catch shellfish as opposed to finfish.

Although reliable estimates of portion size are essential to deriving accurate estimates of consumption rates, data on actual meal size are limited. Assumptions about portion sizes are inconsistent among fish and shellfish consumption studies, but typically ranged from four to eight ounces of fish and/or shellfish per meal. Actual mean meal or portion sizes, when reported, usually ranged from four to eight ounces. Differences in the reporting of raw versus cooked weights, the parts of fish consumed, and methods of preparation can affect the accuracy of estimates of consumption rates that are used in risk assessment or in the development of advisories or water quality criteria. Differences in the ways portion sizes were estimated in surveys may also have a significant impact on the resulting estimates of consumption. U.S. EPA (2000a) suggested that a default value of eight ounces (227 grams) of uncooked fish fillet be used as an average meal size for the general adult population (for a 72-kilogram person) for exposure assessments and fish advisories if population-specific data are not available.

Distributional analyses rather than single point estimates of fish consumption rates are preferred to describe exposure within a population. Using a stochastic analysis will allow a better characterization of consumption in a population and the variability within that population. Each value in a distribution represents a different point in the distribution and, therefore, a different segment of the population. Selection of one over another of these values (*i.e.*, a single point estimate) should only be done when the single value, and what it represents, is appropriate to the question at hand or intended use of the consumption rate estimate. At a minimum, a measure of central tendency (the median or mean) should be selected to represent an average level of consumption in a given population, and should be used in concert with an upper percentile rate of intake derived from a distributional analysis to represent a higher level of consumption, or exposure, in the population.

Studies on fish and shellfish consumption continue to be performed and released. Therefore, review of the fish consumption literature is an ongoing process, but in order to finalize this report, it was necessary to exclude newer work on the subject. Nevertheless, new information that is pertinent should be considered along with this report, as it becomes available.

II. INTRODUCTION

Chemical contamination of fish and shellfish from marine, estuarine, and fresh water bodies is a widespread problem in the U.S. Water bodies are among the ultimate repositories of pollutants released from human activities as well as from natural sources of potentially toxic materials. Once chemical contaminants reach water bodies, they may concentrate through aquatic food chains and accumulate in fish and shellfish tissues. Human consumption of chemically contaminated fish and shellfish poses a potential health risk, the magnitude of which depends on the amount of fish consumed and the degree of contamination.

Fish consumption has also been shown to provide nutritional, cultural, and health benefits. Nevertheless, when the concentrations of chemical contaminants reach levels of potential health concern, the potential for exposure and adverse health effects must be evaluated and measures taken to protect the public when warranted. For health protection, many states have issued health advisories to recommend restricted consumption of chemically contaminated sport-caught fish and shellfish species from specified water bodies. These advisories enable fishers to reduce their exposure to chemical contaminants and still enjoy benefits from fish consumption. U.S. EPA maintains a national listing of state and tribal fish advisories in the U.S. on the Internet at <http://www.epa.gov/waterscience/fish/>. Evaluation of the potential risks to the populations that may be exposed to chemically contaminated fish and/or shellfish requires knowledge of the patterns and rates of fish and shellfish consumption by these populations. Additionally, fish consumption rates are used in the development of water quality criteria (U.S. EPA, 1989a; Ruffle *et al.*, 1994; Ebert *et al.*, 1994) and local site-assessment models. Therefore, representative estimates of fish consumption rates are important to agencies and programs that have responsibilities in the protection of human health and aquatic resources.

In order to characterize human exposure to contaminated fish and shellfish, the potentially exposed population must be identified, the concentrations of contaminants in fish and shellfish tissues that are consumed must be measured, and the likely types and quantities of fish and shellfish consumed must be determined. For estimating the health risk associated with the consumption of contaminated fish and shellfish tissue for a population or any particular subset of that population (such as children or pregnant women), it is necessary to determine consumption rates that reliably represent that population or subpopulation. A number of factors make establishing consumption rates difficult. Differences in study design and the methodologies used to conduct consumption surveys can result in different estimates of consumption, and can mask any real differences if they exist among populations. Data from the same study have even been analyzed and interpreted differently by different researchers. Also, a variety of methods are available for conducting studies on fish consumption; the appropriateness of a given design or methodology will depend on the purpose of the study and other factors including budget and other resource constraints. There are no absolute, consistent, or comprehensive methods or guidelines for data collection and analysis. Furthermore, there is considerable variability within fish-consuming populations and no simple way of describing, especially quantitatively, this variability. These factors, which are elaborated later in this report, should be recognized when evaluating data to derive representative consumption rates for populations of interest.

Historically, a variety of fish and shellfish consumption rates have been reported and used by different researchers and agencies. In their fish advisory guidance materials, U.S. EPA has advocated using or collecting data on local consumption patterns and population characteristics to estimate consumption rates for the population of concern (U.S. EPA, 1996b). However, locally applicable data may not be available, and it may not be feasible to collect them. Thus, exposure assessments often have to rely on rates reported in existing studies conducted in other regions and/or for other purposes. The question arises as to whether default values can be derived from these studies that would be reasonably representative of the population(s) of interest and how one can discern the reliability and the applicability of the results.

This review and report were undertaken to address numerous questions being raised about fish and shellfish consumption, as enumerated below. The goal was to summarize and evaluate the available literature that describes fish and shellfish consumption for the general population, for consumers, and for those who catch and consume sport fish and/or shellfish, and to describe the potential sources of variability in reported fish consumption rates. This comprehensive review was intended to provide a single concise resource that not only summarizes the results of fish and shellfish consumption studies, but also facilitates distinguishing the most appropriate and reliable studies. The report includes information that can help to clarify confusion regarding different fish consumption rates that have been cited or used by different individuals or groups. This report can be used as a reference by different state programs in California and other states in the U.S. The information can be used by agencies and programs that have responsibilities in the protection of human health and aquatic resources, as well as anyone interested in understanding or conducting studies of fish and shellfish consumption. As newer studies on fish and shellfish consumption are conducted and released, information that is pertinent should be considered along with this report, as it becomes available. It should be noted that because the availability of new studies and information is part of an ongoing dynamic process, it would not be possible to complete and release this report without setting limits on the incorporation of newer studies. This report was developed and distributed for public and peer review in 1997, and since then, considerable discussion and investigation of underlying concepts and methodologies has occurred. The evaluation and review of core studies conducted at that time may serve to provide historical background and/or perspectives on various methodologies, their use, and their evolution. Additional studies have been conducted in recent years, and an effort was made to update portions of the report as efficiently as possible. A list of fish consumption surveys conducted in recent years, organized by state or region, is included in Appendix III. The reader is advised to investigate whether there are additional relevant studies available, as more recent work may not have been included or thoroughly reviewed in this report.

Broad definitions of "fish and shellfish" will be adopted in this report, in an attempt to be all-inclusive and encompass whatever organisms may have been included in any particular study. "Fish" includes any of various aquatic animals (belonging to the subphylum Vertebrata) having gills, commonly fins, and bodies usually but not always covered by scales, including the bony fishes (those having bony skeletons) and more primitive forms with cartilaginous skeletons (*i.e.*, lampreys; hagfishes; and sharks, skates, and rays). The term "sport fish" will be used throughout this report to denote fish that are caught by a sport fisher as opposed to purchased or caught commercially. Synonymous terms (*e.g.*, sport-caught, self-caught, recreationally-caught, noncommercial, and game fish) may be used in some cases, such as when a report or study is

reviewed and the authors have used one of these terms. "Shellfish" includes any edible invertebrate animal usually belonging to one of the following taxonomic categories: 1) mollusks, including bivalves (*e.g.*, clams, oysters, mussels, scallops), gastropods (*e.g.*, snails, limpets, abalone), and cephalopods (*e.g.*, squid and octopods); 2) crustaceans (*e.g.*, crabs, shrimps, lobsters); and 3) echinoderms (*e.g.*, sea urchins and sea cucumbers). The term "seafood" in its broadest sense could include any edible organism from any water body. However, it generally is used synonymously with the phrase "fish and shellfish" which would exclude marine mammals and edible marine plants. The studies included in this report all pertain to fish and shellfish, and do not include marine mammals or aquatic plants, and thus, the narrower interpretation is applicable here. It should be noted that consistency among studies is lacking in terms of how fish and shellfish were defined and which types of seafood were actually included in a given study. Therefore, estimates of consumption of fish and shellfish across studies may not (and likely will not) include the same types of organisms. It should also be noted that although this report does not do so, in some situations it would be appropriate to consider consumption of other aquatic vertebrates or "wildlife" (*e.g.*, turtles, alligators, and waterfowl). In addition, none of the studies reviewed in this report indicated that amphibians were included in the study.^a

As discussed in further detail throughout this report, consumption rates have been determined for different segments of the population. "General population" refers to the national population as a whole, and includes both consumers and nonconsumers. Estimates of consumption rates for the general population are derived on a "per capita" basis. Consumption rates can also be determined for subpopulations such as "consumers only" or groups of people with particular demographic traits in common. Consumption rates determined for actual consumers may include consumption of either commercial species, sport-caught fish and shellfish, or a combination of fish and shellfish from multiple sources.

In addition to providing a general review and evaluation of the literature pertaining to fish and shellfish consumption, this report will address more specific objectives. The overall objectives are as follows:

- 1) Describe fish and shellfish consumption rates and studies that are appropriate for use in describing the general population, fish and/or shellfish consumers, and those people who catch and/or consume sport fish and/or shellfish.
- 2) Describe consumption rates and whether they differ among ethnic groups. Determine whether the available data support using different consumption rates for specific ethnic populations. If there are differences, evaluate whether they are consistent across studies and how different various subgroups might be.
- 3) Describe fish and shellfish consumption rates and characteristics of the population of fishers referred to as "subsistence" fishers.

^a The California Fish and Game Code includes amphibians in the definition of "fish."

4) Evaluate whether the available data indicate differences in rates or patterns of fish and shellfish consumption for groups that differ by age, sex, or geographic location.

5) Compare the available data on rates of consumption for fish and shellfish obtained from different types of water bodies. Determine whether the available data indicate that a population of fishers using a freshwater source has a significantly different distribution of consumption rates than a population using a marine water body.

In addition to meeting the specific objectives listed above, which may apply to populations across the U.S., this report will also focus on consumption of fish and shellfish by populations in California, as follows:

6) Describe the consumption of locally caught sport fish and shellfish in California. This description will principally cover the population of sport fishers who catch and consume fish and shellfish, but may also include people who receive and eat locally caught sport fish, such as family members.

7) Describe the consumption of commercial fish and shellfish for sport fishers and for people in California who consume only commercial species.

8) Describe the portion of the population in California that consumes shellfish and estimates of the rates of consumption of commercial and noncommercial shellfish by this population.

In order to address each of the objectives described above, consumption studies that were applicable and relevant to the question(s) at hand were considered, and conclusions were drawn based on the available information.

The following section of this report briefly reviews factors to consider when comparing results from different studies and surveys. Subsequent sections of the document describe and present findings from various fish and shellfish consumption studies. A discussion section follows in which the issues identified in the stated objectives of the report will be addressed. And finally, the recommendations and conclusions of the report will be presented. A glossary of terms is provided in Appendix I. If the author(s) of a specific paper or report used a term to mean something different than what is noted in the glossary, the author's terminology and definition will be provided as part of the description of the study.

III. SOURCES OF VARIABILITY IN FISH AND SHELLFISH CONSUMPTION ESTIMATES

Different fish consumption rates have been reported and used by numerous researchers and agencies. Differences in reported rates may result from a variety of factors including both major and minor differences in study design and in the analysis of the data collected in various surveys. When information for a specific local population is not readily available, the exposure assessor must choose reasonable surrogate populations and default values from applicable studies (if available) that include information on the parameters or variables of interest. Thus, the exposure assessor must be able to discern which studies are most applicable and representative and provide the most reliable and accurate information. The results of a given survey are most accurate when the calculated mean is close to the true value and most precise when the variance is small (Anderson, 1988).

Numerous types of surveys and methods for collecting data have been used to estimate fish consumption rates. Each survey methodology has certain inherent biases that can contribute to the variable results seen among surveys. Each survey that has been conducted has strengths and limitations that must be considered when evaluating the rates derived by the study (Ebert *et al.*, 1994; U.S. EPA, 1992). Decisions that are made in the initial stages of planning a study will influence the nature of the findings of the study. The choices that independent researchers and various agencies make about the structure of the planned study are rarely consistent and may be heavily influenced by available resources. Limited resources and differences in objectives among studies are likely to influence the methods chosen and how well they are applied, and a variety of other factors may also influence decisions about study design. When reviewing the various studies and their results, one must evaluate how a given study approached study design and data analysis, and determine whether the approach chosen is applicable to the questions being addressed. Knowledge of the purposes of a study, how the study was conducted, and how the data were evaluated can be used to assess the reliability of the results, as well as to determine how the information provided by the study can be used and whether the results are applicable to a particular scenario of interest. Often, however, it is difficult to obtain access to all the pertinent and detailed information about how a study was performed and/or analyzed, and therefore, caution regarding one's confidence in the results is warranted. The following discussion describes some of the major factors that can and do vary among fish and shellfish consumption surveys.

A. Target populations and characteristics of populations

Different rates of fish consumption have been reported for different population groups. One must first define exactly which group is intended as the target population and then evaluate whether the sample population defined by the study adequately represents the target population (Anderson, 1986). A random probability sample can be used to sample a portion of the target population in a way that the results are applicable to the entire population(s) of interest.

However, not all studies have used random sampling methods and in some cases, the sample design does not allow for statistical evaluation of the data.

Rates reported for the general national population, usually referred to as per capita rates, differ from those reported for subpopulations such as individuals who catch and consume their own catch of fish and shellfish. It is essential to consider whether rates that apply on a per capita basis are appropriate to the study question or whether rates specific to particular subpopulations are needed. For example, some consumption rates have been derived by averaging over both consumers and nonconsumers, as compared to consumers only. These per capita estimates would not be representative of consumption by actual consumers or other specific subpopulations. Thus, exposure assessments and evaluation of potential risks to consumers must consider consumption rates appropriate for actual consumers.

For groups of individuals who consume sport fish and/or shellfish, there is a continuum ranging from intermittent fishers, who may eat fish only occasionally, to those who fish regularly and/or heavily and consume large quantities of the fish that they catch. These "high-end consumers" could include recreational fishers with high rates of success and subsistence fishers who rely on their catch to feed themselves and their families. Therefore, within the subset of the population that fishes (*i.e.*, fishers) there is likely to be a wide range of fishing effort and success, and a single value is unlikely to adequately describe consumption by the entire fishing population.

It is important to recognize the difference between characterizing the whole population and estimating exposure to contaminants in sport fish and shellfish to actual consumers. Often the portion of a population that consumes sport fish is relatively small, and these consumers are represented by the upper percentiles in a full distribution. As a result, using either per capita estimates or a consumption rate derived from a low percentile of the consumption distribution would not accurately estimate exposure to consumers from contaminants in sport fish. Therefore, it is important to understand how the distribution of consumption rates for a given population has been constructed, and whether nonconsumers of fish and/or shellfish have been included. Consumption rates that pertain specifically to consumers must be used in exposure assessments and consequent management actions in order to describe exposure to the subpopulation of consumers (as opposed to the general population) accurately, and to provide for adequate protection of public health including the subpopulation(s) most at risk.

To obtain estimates of consumption rates for specific subpopulations, such as particular ethnic groups or women of reproductive age, the sample population must include sufficient numbers of people that represent the subpopulation. Often, however, sample sizes have been too small to adequately represent these subpopulations and/or to allow statistical comparisons of the data.

U.S. EPA (1996b) suggested that, ideally, fish consumption information that is collected should include descriptive demographic information on the size and location of fishing populations using specific water bodies; the age and sex of those consuming the fish; the size and frequency of meals; and the types of fish caught, portions consumed, and methods of preparation and preservation. Most studies, however, do not characterize the fishing population in the detail suggested.

B. Definitions and terminology

Definitions of relevant terms, *i.e.*, "seafood," "shellfish," and sometimes even "fish," can be highly variable, making comparisons of the results of consumption studies difficult. Many studies have been conducted on seafood consumption; however, each one is likely to define "seafood" differently and to include measures of different types of organisms. Therefore, estimates of consumption of fish and particularly shellfish across studies may not (and likely will not) include the same types of organisms.

The term "seafood" can specifically refer only to organisms from saltwater bodies or can include edible items from any type of water body. The term "fish" is usually used to represent finfish only; however, it is used in some cases as a general term that also includes shellfish and/or other types of edible seafood. The definitions of "shellfish" are particularly problematic. The term generally refers to aquatic invertebrate organisms that have a shell. Although certain organisms such as clams and oysters are easily identified as having a shell, other aquatic animals have evolved such that the shell has become internal and/or reduced (*e.g.*, squid), or has disappeared entirely (*e.g.*, octopus). Crustaceans, including several types that are commonly consumed (*e.g.*, crab, shrimps, and lobster), have exoskeletons, which serve as a shell or protective covering. Definitions of shellfish in the literature may be limited to only a few types of edible species or may be more comprehensive. A few studies of consumption of "fish and shellfish" have included species that are less commonly recognized as "shellfish" (*e.g.*, squid, octopus, and sea urchins).

In addition, some consumers obtain and eat other types of aquatic products such as roe (eggs from fish or urchins) and seaweed (plants). Some populations in the world also consume certain types of marine mammals. Some of these less common types of seafood may be important in the diet of certain fishing communities and/or ethnic groups. Clearly there is a need to increase consistency in defining terms and, at the same time, definitions need to adequately distinguish which organisms are included. Additionally, definitions are needed which are comprehensive enough to include all types of aquatic organisms that are consumed.

Total seafood consumption by individuals is likely to include fish and/or shellfish obtained from a variety of sources. However, rates may or may not be based on fish and shellfish obtained from all sources including sport-caught, commercial, gift, and fish and shellfish consumed in restaurants. Additionally, studies that derive rates based on all potential sources of fish and/or shellfish may or may not differentiate the sources. Many studies have not included sport fish and of those studies that did evaluate consumption of sport fish, some may have only considered consumption of fish caught from a specific single water body whereas other studies determined rates for fish from multiple water bodies. Ebert *et al.* (1994) summarized these differences and the contribution they can make to variability in reported rates, as follows. "Because total consumption by an individual is comprised of the sum of the rates of consumption for each of these components, estimates may vary substantially, depending upon which components have been evaluated."

Consumption rates reported in different studies may or may not differentiate between consumption of marine, estuarine, and freshwater fish and shellfish. Additionally, researchers typically define and use these terms in different ways, resulting in different interpretations of datasets and variations in estimated rates of consumption (Stephan, 1980). Studies may differentiate between marine and freshwater species, but the differentiation between marine and estuarine species is often not clear. Some studies combine estuarine with freshwater species whereas other studies combine estuarine with marine species. Further problems can arise in the analysis of data because distinctions between marine and freshwater species of fish are not always clearly documented in the datasets.

Surveys vary with respect to the number of types of fish or fish products included and how each fish item is defined. Differences in definitions, the way fish items are grouped, omission of certain types of fish products, and how portion sizes are measured or estimated can influence estimates of the amounts and type of fish consumed and, therefore, can impact the calculated population mean and variance used to estimate consumption rates. Additionally, quantities of fish and shellfish items consumed in food mixtures ("mixed dishes") such as casseroles or soups and chowders are often difficult to estimate and may not be included in the overall derived rates (USDA, 1983). One further complicating factor is the difference between raw or "fresh weight" and cooked weight of the fish and/or shellfish consumed. Cooking procedures will result in weight loss of the fish tissue and may also affect the concentration of chemical contaminants. Surveys can vary in terms of whether raw or cooked weight is used, and often the differences are not considered and/or reported. These differences may result in decreased accuracy of estimates of consumption rates that are used in the development of advisories or water quality criteria.

C. Types of data and methods of collection

Approaches to collecting data on fish consumption include both indirect and direct measures. Indirect measures primarily rely on data pertaining to food supply availability or food disappearance into marketing channels or households, and are best regarded as a measure of food availability into commercial markets and only a rough indicator of consumption. Data from studies on food availability generally have been collected for purposes other than to estimate consumption rates, and data gaps are most serious at the level of the individual consumer; therefore, these types of data are inappropriate for estimating consumption rates for consumers (Anderson, 1986; U.S. EPA, 1992). Additionally, food availability data do not account for waste or spoilage, and interpretation of the results is highly specialized; however, the results from these types of surveys can be useful to assess trends over time (Anderson, 1986).

Direct measures refer to data collected by a variety of methods to quantify actual food use or food consumed by individuals and/or households. These surveys include food recalls and/or food diaries, and data can be collected through the mail, telephone, or personal interview. There are two types of data that are obtained from these methods: quantitative data and food frequency data (Anderson, 1986). Quantitative data are derived from measures that attempt to obtain exact quantities of food consumed per unit time. However, accuracy in estimating consumed portions varies among studies. Quantitative data obtained over short time periods are not considered

the best measure of usual intake for the individual consumer over long periods of time (Anderson, 1986; U.S. EPA, 1989a).

Food frequency data are obtained from questionnaires about typical patterns of food intake and, thus, are thought to represent usual intake over time. However, food frequency questionnaires are designed to rank or categorize food items rather than to obtain actual measures of intake. Therefore, these data may be less accurate (and less precise) depending on how the amount of food consumed is quantified. This type of survey is also subject to errors in under- or over-reporting, and food frequency questionnaires tend to suffer from loss of exactness in the identification of specific food items in order to achieve improved estimates of usual consumption patterns of foods (Anderson, 1986, 1988).

Fish consumption rates have also been derived based on data obtained through creel surveys. These surveys usually involve interviewing fishers at fishing locations to provide water body-specific data about fishing frequency, and fish species and sizes caught and/or consumed. Thus, the catch data may only be representative of specific seasons or targeted species. Information derived from creel surveys is often used for fisheries management development purposes such as to determine fishing activity patterns or demands on specific water bodies, or to evaluate stocking programs for specified lakes and streams. Consumption rates are often estimated from catch data using assumptions of total edible weight represented by the catch, based on the length of the fish, divided by the number of household consumers expected to share the catch (Landolt, 1985, 1987; SDCDHS, 1990; Puffer *et al.*, 1982). Additional assumptions may be made. For example, the amount of fish caught may be estimated when actual measurements of fish catch lengths have not been made or recorded, and estimates of fishing success at nonsurvey times are often incorporated into the calculations of consumption rates (*e.g.*, Puffer *et al.*, 1982; SDCDHS, 1990; ChemRisk, 1992). Intercept surveys also involve interviews with fishers at fishing locations but include the collection of consumption data based on recall and/or catch. Price *et al.* (1994) suggested that creel surveys might oversample frequent fishers and produce a distribution that overestimates intake rates of the total fishing population using surveyed water bodies. This premise is discussed further in a subsequent section. Creel surveys also may be subject to reporting biases in that poor catches or catches below legal size limits or above total allowable limits may not be reported.

U.S. EPA (1998) evaluated the principal survey methods used in obtaining consumption rate information for fishing populations, including telephone and mail surveys, diary, personal interview, and creel surveys, and provided guidelines for selecting (and/or critiquing) a survey approach. The guidance document, which addresses key components in survey design and methods, including quality control and data analysis and interpretation, should be consulted by anyone planning to conduct a consumption survey, and can provide valuable information for comparing and evaluating studies that have been conducted. Advantages and disadvantages of each approach are described, as are specific issues pertinent to each method. Selection of an appropriate survey methodology depends on a number of considerations. The U.S. EPA guidance elaborates on each selection criterion, including characteristics of the target population and water body of interest, the degree of accuracy needed, and available resources.

U.S. EPA (1998) emphasizes the significance of the survey objectives in guiding the choice of methodology and in designing a survey. The criteria that U.S. EPA delineated for selecting a

survey approach, and which can be used to compare and evaluate studies, are summarized here; for further detail, the reader is referred to the U.S. EPA guidance.

One of the most critical elements to evaluate is whether a study adequately represents its target population. A number of factors can affect the ability of a study design to reach the target population and represent it accurately. The various survey approaches will differ in the degree to which target populations must be identified prior to the survey, and the degree to which specific subpopulations are likely to be reached. When planning a survey, one must consider the accessibility of target populations and subpopulations, and whether literacy, language, and cultural sensitivities may affect communications with the target population. Characteristics of the fishery that can influence the choice of methodology and the success of the survey include the number of access points, fishing pressure, whether fishing is seasonal, and other characteristics of the geographic area. Survey approaches vary in the amount of resources (labor and cost) needed, and geographic considerations can also affect the costs. The level of effort required of respondents also varies by survey type. Consideration of the time period to be covered by the survey and the amount of time needed to complete the survey (and analyses) will also bear on the choice of survey methodology. Comprehensive surveys can provide more accurate and complete results, but the time to completion is delayed.

Another critical, and often the most important criterion to consider, is the accuracy of the survey. Many factors contribute to the accuracy of the results of a survey, and selection of survey methodology should consider the desired level (and types) of accuracy. Accuracy can affect not only consumption estimates, but other aspects of the survey as well, such as species identification. The reliability and the validity of the responses will depend on many components of the survey and the survey instrument, including understanding, familiarity, and interest on the part of respondents and interviewers, the specificity of the questions, and interpretation of questions. Underestimates or overestimates of consumption can result from different types of bias including recall bias, prestige bias, or bias in the sample selection or in survey participation (as discussed further in the subsequent section). Measurement error can also occur and can be attributable to the interviewer, respondent, questionnaire, or the mode of data collection. Evaluation of surveys should consider the quality assurance and quality control measures that have been implemented in the study.

While these criteria should be kept in mind when reviewing consumption studies, it is difficult to identify discrete and objective measures to use to evaluate surveys. It is usually necessary to consider the importance of each of the various issues identified in these "selection criteria" in the context of the specific study, and make a subjective determination of how well a survey has succeeded in addressing the issues. Ultimately, one should assess the extent to which the survey has met its objectives, and then whether the objectives (and the results) of a given survey are relevant to the reviewers' questions and needs.

D. Time factors

Food intake surveys may only cover specific time periods or seasons. U.S. EPA (1997a) distinguished surveys that use "longitudinal methods" to derive long-term patterns and estimates

of "usual" consumption for individuals or groups from "cross-sectional studies." The latter are used to give a "snap shot" in time, and provide information on the distribution of intakes for groups based on short time periods (typically 24-hour or 3-day sampling periods). Short-term quantitative recall methods (e.g., a 24-hour food recall to gather information on foods consumed by individuals in the prior 24 hours) can be useful in providing information on total consumption over the specified recall period. However, extrapolation of this information to derive long-term intake rates will contribute uncertainty given the inherent intra-individual variation of intake from day to day.

To reduce intra-individual variability and derive more accurate estimates of individual consumption, use of multiple days of dietary intake data is generally more desirable (Anderson, 1986; Popkin *et al.*, 1989). Data collected on multiple days for the same individual do not represent independent events but can be used to assess the amount of intra-individual variation. Additionally, estimates of consumption rates based on multiple days are preferable to estimates based on too few days (Anderson, 1988). Alternatively, data from one-day surveys can be used to estimate population averages if the sample size is large (Anderson, 1986).

Data obtained from single days are subject to potential biases from the effects of the day of the week or the season. Consumption data obtained on consecutive days may also be biased due to autocorrelation of food items consumed on adjacent days. The timing of the study period may or may not account for seasonal differences. The length of the study period also appears to have a large effect on the percent of the population determined to be consumers of fish and shellfish. Hu (1985) noted that the percent of the total population reporting consumption of fish was greater in studies in which the length of the study period was longer and vice versa. For example, Hu observed that in a three-day U.S. Department of Agriculture (USDA) survey, 8.5 percent of the individuals reported using tuna, whereas in a one-week USDA survey, 27 percent of households used tuna, and in the National Purchase Diary one-month survey, 67.8 percent of households used tuna.

Surveys that rely on recall, which generally pertain to longer periods of time, may suffer from recall bias. Recall errors can result in either overestimates or underestimates of consumption depending on many factors such as how commonly or frequently the activity occurs; actual time frames covered; survey methods, including provisions to enhance memory; and social desirability, prestige, or other psychological factors. Recall error generally increases as the length of the recall period increases, and long-term recall periods such as one year are likely to result in the least reliable estimates (Chu *et al.*, 1992). The optimal recall period will be long enough to capture typical habits and patterns of fish consumption without impairing the ability of respondents to accurately recollect their fish consumption. Food diaries where individuals are asked to record daily food consumption can cover different time periods ranging from several days during a particular season to more than a year. However, consideration must be given to participants' ability and willingness to follow directions in accurately recording numbers, types, and quantity of fish and/or shellfish consumed.

E. Regional considerations

Fish consumption and/or purchasing studies conducted across the U.S. have shown regional variation including differences for coastal areas compared with inland areas, seasonal differences in available species, and regional preferences for certain types of fish and/or shellfish (Javitz, 1980; Miller and Nash, 1971; Rupp *et al.*, 1980).

Ebert *et al.* (1994) proposed that regional or local differences in climate, fishing regulations, accessibility to good fisheries, and availability of desirable target species may contribute to the variability in reported fish consumption rates. The productivity of specific water bodies may also have a bearing on survey results. Depending on the time period or season covered by different surveys, these factors may affect estimates of consumption rates of sport-caught fish. The occurrence of health advisories recommending limited consumption of fish and/or shellfish may also influence consumption rates and survey results. Thus, when comparing the results of studies conducted in different locations, in which the methodologies, time frames, or other parameters are not comparable, it is likely to be difficult to interpret apparent differences in consumption.

F. Data analysis and statistical considerations

Researchers reporting fish consumption rates differ in their approaches to data analysis and the presentation of results. Data gathered from the same study may be analyzed in different ways by the same or other researchers thereby yielding different results. The methods used to analyze data are not always consistent, and frequently, data tapes and analytical procedures, including data-cleaning decisions, have been lost, preventing researchers from checking and comparing analyses. Different ways of treating missing data or nonresponse bias can occur. Data may be stratified^b differently and stratification can affect the results, particularly for subgroups. Adjustments of the data such as log transformations or the application of weighting factors may also be inconsistent across studies and may result in different interpretations. Small sample sizes or low response rates may result in less reliable estimates, especially for subsets of the population. When sample size is small and the variance is large, the ability to compare groups is limited. If data are derived from household surveys rather than from individual data, calculations of consumption rates can not be made for age groups or by gender and should not be used to estimate percentiles of fish consumption (Javitz, 1980). Biases in datasets can be random across individuals or days, associated with a subset of the population, or systematic across the entire population (Anderson, 1986).

Fish intakes may be reported as distributions or as point estimates, usually a mean. When information about the distribution of values obtained is available, values derived for the tails of the distribution may be based on only a few individuals. Some studies considered the median value to represent the "average" consumption rate and may not have reported the mean (average) value. Other studies may have reported only the mean value and not provided information on other statistics of dispersion (*e.g.*, the median and other percentiles). When the variable of interest is normally distributed in a population, the mean and median values will be close

^b Stratification involves defining subgroups within a population, such as by age, race, or geographic location, and then making random selections from each subgroup or stratum.

(approximately equivalent). When a distribution is skewed (e.g., lognormal), the mean and median can be substantially different. The mean represents the average value for the sampled population and in a skewed distribution it will either be a higher or lower value than the median value and reflect a consumption rate for a different percentile of the population distribution than the 50th percentile. The median value represents the 50th percentile (or midpoint) of the distribution where half of the sampled population consume more, and half consume less, than the median value.

Measures of central tendency such as the mean and the median are typically used to represent a sample of observations more concisely than the full dataset. However, no single value will adequately represent a distribution that is highly skewed. The mean and median values each represent different points within the distribution, neither of which provides sufficient information to describe the full dataset unless some information about the shape of the distribution (such as the range or standard deviation) is also provided.

As an example, in a hypothetical population in which 75 percent of the people did not eat fish, even if the 25 percent that were consumers ate very large quantities, the median would be zero. The median value would thus indicate that based on the *number* of consumers, the population on average did not eat any fish. In this case, the mean value would not represent actual average consumption for most of the people because most are nonconsumers.

On the other hand, in the above hypothetical example, using the median value to estimate risks from exposure to contaminants in fish would ignore the real consumption by consumers and result in a determination of zero risk. This conclusion would not protect 25 percent of the population. In this case, the mean would provide more information about the actual average *amount* of fish consumed, and would be more useful and more protective than the median value would be.

Although the hypothetical example chosen to illustrate the difference between the median and mean values may be extreme, it demonstrates the difficulty in characterizing the "average" in a population with a skewed distribution. This example indicates that for populations in which the variable of interest (consumption rate) is not normally distributed, neither the mean nor the median represent actual average consumption rates, and neither value in itself is adequate to describe central tendency. In these cases, more information about the distribution is needed than a single value can provide.

Most populations display considerable variability in fish and shellfish consumption rates, and lognormal distributions of fish and shellfish consumption rates have been described for several populations (Ruffle *et al.*, 1994; Murray and Burmaster, 1994). Thus, no single point estimate can describe the entire population, or the "average." To adequately represent the population as a whole, it is preferable to perform a distributional analysis that will reflect the range and the distribution of consumption rates in the population.

The median will always represent the midpoint in the distribution, and for distributions based on consumption of fish and shellfish, the mean will typically represent a higher percentile than the median. Consumers with the highest levels of intake are represented in the upper tail of the

distribution, traditionally defined as those represented between the 90th and the 99.9th percentiles (U.S. EPA, 1997c). This range represents plausible estimates of individual exposures at the upper end of the exposure distribution (U.S. EPA, 1996b). Upper level intake rates of fish and shellfish can be represented by any one of the upper percentile values, such as the 90th, 95th, or 99th percentile. Some studies report only one of the upper percentile rates of intake, usually either the 90th or 95th percentile, and thus, it is difficult to select one of these values to represent "high-end" intake in all cases. In addition, as discussed further below, a specific percentile will represent a different point in the actual distribution depending upon how the sample distribution has been constructed. U.S. EPA (1996b) considered exposure above the 99.9th percentile to be the bounding estimate for a population. U.S. EPA further stated that this value is expected to be greater than any actual exposure by an individual and thus can be used as a maximum upper bound or worst-case estimate that should encompass the entire population. However, estimates of extreme percentiles, including the maximum intake rate, can be unstable and highly uncertain when only limited data are available. As a result, for some distributions, the 95th or 99th percentile may provide a reasonable maximum or upper bound estimate of intake (Finley *et al.*, 1994).

U.S. EPA (1997a) noted that sample distributions can be constructed from consumption surveys that have used different methods to collect data and that some distributions, particularly those derived from creel survey data, may describe the "resource utilization distribution"^o and may not be appropriate for generalizing to the general population. U.S. EPA (1997a) claimed that the probability of being sampled in a creel survey is highly dependent on fishing frequency. They proposed that sampling weights (*i.e.*, inverse fishing frequency) be applied to the data obtained from creel surveys in order to extrapolate the results to the "target" population, defined as the entire fishing population, inclusive of infrequent consumers and nonconsumers. This adjustment may create a distribution that is more representative of a target population that includes the general population of fishers. If the population of concern is indeed the entire fishing population, then data obtained for frequent fishers only likely will not describe the full distribution for the population inclusive of nonconsumers and infrequent fishers. Consequently, it is always important to clearly define the target population and to assess how adequately the sample population represents the target population.

The U.S. EPA method of applying the inverse fishing frequency was based on a proposal by Price *et al.* (1994) to adjust data derived from creel and/or intercept surveys to statistically "correct" for the increased probability of encountering frequent fishers (relative to infrequent fishers) in these surveys. Price *et al.* (1994) proposed using the inverse frequency of fishing, multiplying the number of anglers encountered with fishing frequency F by the inverse of the number of days that they fish per year (365/F), to construct a distribution of fishing frequency for the entire fishing population. They then constructed consumption distributions in a similar manner, either weighting the reported consumption rates in a survey by the angler's fishing

^o U.S. EPA (1997a) did not define the "resource utilization distribution" but distinguished it from the "standard distribution" for a population in the following way. U.S. EPA claimed that the 50th percentile in the resource utilization distribution reflects that "50 percent of the overall consumption in the population is done by individuals consuming below it," whereas the 50th percentile in the standard distribution reflects the "level such that 50 percent of individuals consume below it." Therefore, it appears that the resource utilization distribution more closely represents the consumption distribution. Furthermore, it could be assumed that the "standard distribution" would include fishers that do not consume, and/or consume infrequently.

frequency or by calculating an average amount of fish consumed per fishing trip and applying it to a fishing frequency distribution they constructed.

The fishing frequency distribution is constructed on the basis of the assumption that the probability of encountering an individual fisher is completely proportional to the frequency of fishing. However, many factors can affect the relationship between fishing frequency and the probability of encounter, including the actual timing and frequency of sampling, the methods for selecting respondents, and whether repeat interviews occur. Differences in the probability of encounter also depend on whether all fishers encountered are included in a sample and, if only a portion is selected, how respondents are chosen. Furthermore, a fisher's frequency of fishing may be correlated with the time of day, day of week, climate and seasonal factors, and other parameters that may not be equivalent across sampling days. The basic weighting adjustment used by Price and colleagues (and others adopting a similar methodology) does not account for these factors. Statistical treatments alone can not compensate *a posteriori* for study shortcomings, and should not be used without consideration of the true target populations. In addition, if a survey is not designed appropriately for the type of adjustments that are applied *a posteriori*, the resulting weighted distribution can introduce bias. Also, it is worth noting that as the frequency and number of sampling events increases, the number of fishers encountered increases and the probability of encountering fishers with a greater range of fishing frequency (including fishers that fish less frequently) also increases. Therefore, some surveys will be more representative than other surveys.

The Air Toxicology and Epidemiology Section (ATES) of OEHHA utilized a basic inverse-weighting scheme to adjust survey data (OEHHA, 2000). However, the weighted adjustments were based on fishing frequency during a one-month period rather than annual fishing frequency. Additionally, the analysis adjusted for four separate factors producing potential bias in the sampling procedure (*i.e.*, number of times fished, frequency of site selection, proportion of successful interviews, and week days versus weekend days sampled). This four-factor scheme was used to adjust the consumption distribution from the Santa Monica Bay creel/intercept study for use in multimedia risk assessments of airborne contaminants in the Air Toxic Hot Spots Program. The target population in assessments done under this program is the general fishing population including infrequent fishers. The adjusted mean consumption value using the four-factor scheme was 63 percent lower than the unadjusted mean value, and 70 percent lower when adjusted for fishing frequency alone. Accounting for additional factors yielded a slightly higher distribution and point estimates than using the inverse fishing frequency weighting alone.

Despite their selection of the general population as the target for certain applications, U.S. EPA (1997a) also noted that the approach of characterizing the resource utilization distribution is of particular interest when a relatively small percentage of the overall population consumes a large percentage of the resource, as is often the case for sport fish consumers within a local or regional population. Comprehensive creel or intercept surveys that address consumption by those fishers who consume fish most frequently from the water body of interest can provide representative information on consumption patterns when the population most at risk is the target population. Data obtained in such surveys may be useful for exposure assessments conducted to describe fish consumption behavior and the potential risks for frequent fishers. U.S. EPA (2000c) identified sport (recreational) and subsistence fishers as more highly exposed individuals separate from the

general population. Therefore, these survey data are preferred for evaluations that are focused on fish consumption as a major exposure pathway for frequent fishers and other frequent consumers.

Keill and Kissinger (1997) noted that multiplying the number of infrequent anglers by the inverse of the number of days that they fish per year results in greater weight being given to the infrequent angler. For example, an individual who fishes once a year would be assigned a weight 365 times an individual who fishes daily. Keill and Kissinger (1997) maintained that this adjustment obscures and negates the importance of the subpopulation most likely to incur exposure to contaminated fish. They noted that some researchers have specifically excluded infrequent anglers from surveys, and/or nonconsumers from analyses, in order to avoid characterizing consumption for a population that is not at risk. Thus, careful definition of the population of concern, and use of the appropriate consumption distribution, is fundamental.

Use of the inverse frequency of fishing as a weighting factor in consumption distributions as described by Price *et al.* (1994) tends to shift frequent consumers in a fishing population to the upper percentiles of the distribution, often above the 95th percentile. For example, in the reanalysis by Price *et al.* (1994) of data from two consumption studies, the median consumption rates reported for the studies were near the 95th percentile in the adjusted distributions. Therefore, because the 95th percentile is typically considered to be a reasonable representation of maximum levels of intake, the population of concern (frequent consumers) may be excluded in summaries of weighted representations of the consumption distribution. Furthermore, the subpopulation of frequent consumers would not likely be represented by statistics of dispersion used to reflect the average (either the mean or the median) consumption rate. Therefore, the application of inverse frequency weighting factors may result in construction of distributions that do not reflect frequent fish and shellfish consumers, and in some cases, the resource utilization distribution may be a better representation of the population of concern.

The use of estimates of consumption that are based on the resource utilization distribution, or the subpopulation consuming sport fish more regularly or frequently, will provide estimates of consumption that are health protective (*i.e.*, that err on the side of caution). Such estimates may be appropriate in a number of exposure assessment scenarios.

In summary, careful definition of the target population is essential. In addition, it is important to evaluate how well the survey (*i.e.*, sample population) represents the selected target population or population of concern. If weighting factors are applied to survey data, the statistical adjustments of the data must be appropriate for describing the population of interest, appropriate for the study design that was used, and applied correctly so that the weighted sample does not result in introduced error or loss of power in the dataset. Survey data should be weighted only when there is a scientific basis and justification for doing so. In addition, the statistical methods used should consider sampling rate, differences in sampling days, and other factors likely to influence the results.

Finally, for risk assessment purposes, it is important to characterize a population as a whole in order to evaluate risks to individuals within that population. A distributional analysis will provide a description of the population and the variability within it. If a probabilistic

determination of exposure is not done, reference points in the population distribution can be represented by use of several values from the distribution, such as the median (50th percentile), mean, and an upper percentile (90th, 95th, or 99th) or the bounding estimate (95th, 99th, or 99.9th percentile). Each of these values represents a different point in the distribution and, therefore, a different proportion of the population. It is also essential to understand how given distributions (or point estimates from the distribution, such as the mean) have been derived, and how survey data were used to construct the distribution. In particular, the inclusion or exclusion of nonconsumers and the application of sampling weights can have significant effects. As a result, point estimates or percentile rates of consumption derived from distributions constructed differently can have vastly different meanings and applications, and thus, it is important to be aware of and understand these differences.

G. Summary of potential sources of bias

Food intake surveys rely on food recalls, food diaries, or food frequency questionnaires obtained through the mail, telephone, or personal interview. Response rates, literacy, and language barriers may affect the quality of data collected in surveys. Other sources of bias in a survey include coding errors, interviewer bias, differential effort by interviewers or respondents, cultural differences in interpretation, recall bias or memory problems, and over- or under-reporting. Reporting errors may be inadvertent or intentional, and can relate to attitudes or perceptions held by the respondent. The wording and sequencing of questions can also affect the responses. As mentioned previously, sampling bias can result when the sample design is nonrandom and does not accurately represent the target population. Additionally, correlations among subgroups can exist and become exaggerated when repeated samples (such as the collection of data on consecutive days) or clustered^d samples are used (Anderson, 1986). Assumptions about unknown factors, such as the number of consumers in a household or the amount of fish obtained and eaten, that are used to calculate rates of consumption may not be accurate and may not be consistent among studies. Different methods of analysis can yield very different estimates of consumption from the same dataset. Finally, whether or not statistical tests have been performed on the data, one must evaluate the biological meaning and relevance of the results. An understanding of the overall survey design and data analyses procedures is essential when reviewing studies reporting fish consumption rates.

IV. REVIEW OF STUDIES USED TO DERIVE FISH AND/OR SHELLFISH CONSUMPTION RATES

The following section of this report provides an overview of consumption rates that have been presented in the literature and a listing of the studies and analyses conducted, categorized by their applicability to identified populations and circumstances (e.g., general population, consumers, fishers, geographic region). An evaluation of the strengths and weaknesses of key studies is included.

^d Clustering involves defining subgroups within a population, such as by household or ethnicity, selecting subgroups randomly, and then making observations or collecting data only within the subgroups.

A. Per Capita Estimates for Fishery Products - Disappearance into Commercial Marketing System

The Economic Research Service of USDA annually calculates the amount of food available for human consumption in the U.S., and provides time-series data on food and nutrient availability (Putnam and Allshouse, 1994, 1999). The availability of food is measured and/or estimated from supply and utilization balance sheets, considering production, import, and disappearance of food into the marketing system. Per capita estimates of consumption are derived by dividing total food disappearance by the U.S. population.

1. National Marine Fisheries Service

The National Marine Fisheries Service (NMFS) within the United States Department of Commerce (USDC) annually prepares a publication entitled *Fisheries of the United States*. This publication contains information pertaining to commercially caught or processed seafood (fish and shellfish) entering commercial markets. Consumption rates in the annual publications are expressed as per capita rates for the civilian resident population, in pounds of edible weight for fresh, frozen, canned, and cured fishery commodities, and are presented for every year beginning with 1909. Although rates have shown some fluctuations, including a peak in 1987, the values presented by NMFS show an overall increase in consumption of fishery products over time. Table 1 presents commercial marine fish and shellfish per capita consumption rates for selected years between 1970 and 1993 as presented in the NMFS (1994) publication.

To derive the per capita rates, NMFS (1994) conducted balance sheet calculations based on a "disappearance model." Quantities of commercial seafood available for consumption were derived by deducting exports, inventory changes, and nonfood use from data on production, imports, and beginning inventories for fresh, frozen, canned, and cured commercial fishery products. Civilian population size was estimated at the middle of the census period. Calculated per capita rates were based on an "edible weight basis." No adjustments were made for spoilage or waste or for nonconsumers. The per capita rates derived by NMFS do not include sport-caught freshwater and saltwater fish, nor commercial fish or shellfish sold from "roadside" stands. NMFS (1987) reported that in addition to the consumption of commercially caught fish and shellfish, "recreational fishermen caught and consumed an estimated 3 to 4 pounds of edible meat per person."⁶ As shown in Table 1, per capita consumption estimates increased from 11.8 pounds per year in 1970 to 15.0 pounds per year in 1993. These annual estimates correspond to 14.7 grams per day and 18.7 grams per day, respectively.

⁶ No explanation for the derivation of this value was given. However, NMFS initiated a series of surveys in 1979 to estimate the amounts of participation, catch, and effort by recreational fishers in marine waters of the U.S. (NMFS, 1992). Although estimates of fish consumption were not determined, data from these surveys may have been used to estimate the amount of (marine) fish obtained from recreational fishing.

2. United States Department of Agriculture

USDA utilized the data gathered by NMFS to present similar per capita fish and shellfish consumption rates, based on disappearance estimates, in their publication *Food Consumption, Prices and Expenditures, 1970-93* (Putnam and Allshouse, 1994). Data maintained by the USDA for this series publication serve to document trends in food and nutrient availability for the U.S. The yearly per capita food consumption values provided in USDA's publication were derived by dividing total food disappearance by the total U.S. population on July 1 of the noted year. USDA estimated that annual per capita consumption of fish increased 3.2 pounds from 1970 to 1993 representing a 27 percent increase in average seafood consumption. Fresh and frozen fish and shellfish accounted for most of the growth. USDA also stated that "the lack of reliable estimates of game fish supplies means that fish consumption is likely understated" (Putnam and Allshouse, 1994). Putnam and Allshouse (1999) reported that consumption of fish in the U.S. increased by 24 percent between 1970 and 1997.

3. Summary of Per Capita Consumption Rates Based on Market Disappearance Data

The results of studies of the disappearance of food products into commercial markets are used to evaluate trends in food and nutrient availability. Although food disappearance has been used as a proxy to estimate human consumption, and NMFS has used the data to calculate per capita consumption rates of fishery products, these rates have limited use for estimating consumption of fish and shellfish for several reasons. Disappearance data do not represent direct measures or provide accurate estimates of per capita consumption in the U.S. These studies do not account for what happens to the food when it "disappears." As with any per capita estimate, no differences in distribution are considered. Although edible portions are estimated and used in the calculations, there are no measures of how much is eaten and how much of the food is wasted or spoiled. Assumptions about the relationship between disappearance and consumption are based on the premise that potential changes in food production and marketing practices over time do not alter the relative difference between food disappearance and food actually consumed. Most importantly, the data do not include noncommercial (sport-caught) fish or shellfish or any commercial fish or shellfish sold outside of commercial markets. However, the data can be used to evaluate whether the U.S. population consumes more or less of certain foods over time. Generally, the data have shown an increase in the availability (and disappearance) of commercial fishery products, and thus, it is assumed that consumption of fish and shellfish in the U.S. has increased over time.

B. Per Capita Consumption Estimates from National Consumption Surveys

Per capita consumption estimates for the overall U.S. population have been derived from national food consumption surveys and national surveys specifically targeting fish and shellfish consumption. Rates for combined fish and shellfish consumption have been derived from these

surveys. Rates differentiated by age, sex, race, and region, as well as rates differentiated by fish and shellfish have also been defined in some studies (discussed in further detail in the Discussion section). Different time periods and survey methodologies are reflected in the different studies. Because many of the studies presented here were conducted a number of years ago, they can provide a historical perspective or framework that reflects the development of these types of studies over the years. In addition, information about more recently conducted national surveys of food intake that were not reviewed in detail in this report can be accessed electronically (on the Internet), such as through the National Center for Health Statistics at <http://www.cdc.gov/nchs/data/nutrimon.pdf>. The per capita estimates average consumption for both consumers and nonconsumers of fish and shellfish, however, and thus tend to underrepresent consumption rates for consumers. Furthermore, it is difficult to distinguish consumption of noncommercial (sport) fish or shellfish in the national consumption surveys.

Various researchers have utilized the databases from national surveys and presented estimates of fish and shellfish consumption rates. In some cases, multiple analyses have been conducted on data derived from the same survey. However, the data tapes that each of the researchers received may not have been identical and the analyses that were performed were not exactly the same. These differences could account for the variation in results reported for the same study.

1. 1969-1970 Market Facts Consumer Panel Survey

The National Marine Fisheries Service contracted with Market Facts, Inc. to conduct a consumer panel survey from February 1969 through January 1970 to determine consumption of major species of fish and shellfish at home and away from home, mainly for marketing purposes. A stratified sample of households was selected from a national panel designed to parallel U.S. census data. Pacific households (from California, Oregon, and Washington) represented 13.1 percent of the total sampled population. Heads of approximately 1500 households were asked to use a diary to record purchases twice per month of the types of fish and shellfish meals eaten at home and away from home for the entire household. No individual consumption data were collected; individual consumption values were derived by dividing total household consumption (as represented by purchases) by the number of household members.

Javitz (1980) stated that the results of the Market Facts survey were useful for estimating mean consumption, although it was unclear whether the survey included game fish. Javitz also claimed that unsophisticated methods may have been used to account for meals eaten away from home, and that the household-based data could not be used to derive percentiles or consumption rates by age or sex.

Finch (1973) used the data from the Market Facts Survey to develop a Model for the Estimation of the Consumption of Contaminants from Aquatic Foods (MECCA). The MECCA project estimated levels of mercury in 52 kinds of fish and shellfish and computed a frequency distribution of human ingestion of mercury from the fish and shellfish. Finch reported the mean per capita intake of fish and shellfish for the U.S. to be 14 grams per day (Table 2). Values for the 99th percentile and the 99.9th percentile of fish and shellfish consumption were reported as 77 grams per day and 165 grams per day, respectively. The estimates of fish and shellfish

consumption were based on records selected from families that reported for at least six months of the survey. The amounts of fish and shellfish reported as purchased in the Market Facts survey diary entries were converted to estimates of edible portions based on data on the yield of edible portions from purchased forms and from recipes. For restaurant meals, data on the amounts of fish and shellfish served by major institutional caterers were used to estimate portion size.

Hu (1985) included the findings of the Market Facts survey in his report comparing several seafood consumption studies. His analyses of the Market Facts data were based on the seafood consumption information reported by Nash (1971) and Miller and Nash (1971) because the data tapes Hu received were incomplete for certain types of fish and shellfish and could not be reconstructed. Hu claimed that the Market Facts dataset did not include "at-home" and "away-from-home" consumption information. Hu reported (based on data obtained from Nash, 1971) that the overall average annual per capita consumption of seafood at home was 13.5 pounds, which corresponds to 16.8 grams per day (Table 2).

Nash (1971) reported annual per capita consumption in pounds, based on the Market Facts survey data, by a number of demographic variables including race, religion, income, geographic region, age, occupation, and education (of the head of household). Annual per capita consumption of total fish and shellfish was highest for Blacks (23.0 pounds per year) and Jews (27.3 pounds per year). Per capita consumption decreased as level of education increased, being highest among families in which the head of household had less than four years of high school. However, the relationship between income and per capita consumption was not linear and did not follow a consistent pattern.

Miller and Nash (1971) used the data provided by the Market Facts survey to evaluate consumption patterns of shellfish by demographic variables. They documented regional preferences for individual shellfish items as well as seasonal differences related to availability, and reported positive associations between high-income households and consumption of all types of shellfish except oysters. Pacific coast households showed the highest consumption rate of crabs, compared to other regions, and also ranked among the highest-consuming regions for clams and oysters. Out of nine regional rankings for total at-home consumption of fish and shellfish, the Pacific region ranked fifth, preceded by the Mid-Atlantic, South-Atlantic, West-South-Central, and East-North-Central regions.

2. 1973-1974 National Purchase Diary (NPD) Survey

Under contract to the Tuna Research Institute, the National Purchase Diary Research, Inc. (NPD) conducted a fish and shellfish consumption survey from September 1973 through August 1974. The firm used a syndicated national purchase diary panel representative of the U.S. population (weighted sample) and additional families selected from specific subgroups. The overall sample frame consisted of approximately 9,600 households (approximately 7,000 households from the national panel, plus 2,400 households with a female head >35 years, and 200 Black families). The survey achieved an 80 percent response rate. The survey was administered to 1/12 of the total sample during each of twelve months of the survey (*i.e.*, respondents reported on fish and shellfish consumption for one month). Each participating household recorded the date of fish

and shellfish purchase, the type of fish, whether fresh fish was recreationally caught or commercially purchased, the amount prepared per meal, the quantity consumed by each family member and guest (as opposed to per household), the amount of fish not consumed during the meal, and fish and shellfish meals eaten away and at home. Information was obtained on approximately 135 fish and shellfish items. Consumption information for 25,165 individuals from 7,662 households was gathered. Actual fish and shellfish consumption was reported for 24,652 individuals; this sample was estimated to represent, on a weighted basis, 94 percent of all U.S. residents (Javitz, 1980). Survey respondents were weighted on the basis of age, income, household size (but not less than two), census region, and market size.

Although the survey was planned to obtain comprehensive information about seafood consumption, there was incomplete documentation for the NPD dataset (Javitz, 1980). Additionally, various researchers made assumptions in their respective data analyses that likely led to different derived per capita consumption rates. For example, population weighting factors, representational weights for mixed dishes containing fish or shellfish, and whether fish and shellfish consumed away from home were included were likely to contribute to variability in rates derived from the NPD dataset. Although questions regarding consumption of game fish were included in the questionnaire, the distinction between sport-caught and purchased fish and shellfish was not maintained in the original compilation of data (U.S. EPA, 1989a), and consumption rates for commercial and noncommercial fish and shellfish could not be differentiated. Presumably, derived rates were inclusive of both commercial and noncommercial fish. However, in its Exposure Factors Handbook, U.S. EPA (1989a) stated that the per capita values derived from the NPD survey underestimated actual consumption rates for recreational fishers.

Cordle *et al.* (1978) analyzed the NPD dataset and reported a consumption rate of 18.7 grams per day for the average U.S. resident (Table 2). U.S. EPA cited this value in the March 15, 1979 Federal Register in their "Water Quality Criteria Request for Comments." However, errors in the database were later discovered that invalidated consumption values derived by Cordle and colleagues (Javitz, 1980).

Javitz (1980) conducted an in-depth analysis of the NPD dataset for U.S. EPA, after errors in the dataset were identified and corrected. The corrected data tape contained consumption and demographic data for consumers only; this sample was estimated to represent 94 percent of the U.S. population. The overall average rate of fish consumption reported by Javitz was 14.3 grams per day (Table 2).

Hu (1985) also carried out an analysis of the NPD dataset. The data tape he received apparently did not contain information about away-from-home consumption. Hu reported that the overall average amount of seafood consumed was 12.3 pounds per year (corresponding to 15.3 grams per day), which he identified as "at-home" consumption (Table 2).

Rupp *et al.* (1980) used the NPD survey dataset to derive percentile distributions of consumption for three age groups (1-11 years, 12-18 years, and 19-98 years), and by nine census (geographic) regions for freshwater finfish, saltwater finfish (no differentiation for estuarine was made), and shellfish. In general, their analyses showed that consumption increased with age. Per capita fish

consumption was reported in kilograms per year for each region and for the entire U.S. population. They reported the average per capita consumption rate for freshwater finfish as 0.43 kilograms per year, saltwater finfish as 3.20 kilograms per year, and shellfish as 1.01 kilograms per year for the U.S. (Table 3a). However, the number of people actually consuming freshwater fish, saltwater fish, and shellfish differed substantially (as discussed below). In addition, it is not possible to determine the percentage of individuals included in more than one category. Regional differences in annual per capita consumption were also summarized. Mean per capita consumption by people living in coastal regions exceeded the national average for shellfish and marine finfish whereas residents of central (primarily inland) regions consumed more than the national average of freshwater fish (Table 3b).

Ruffle *et al.* (1994) developed a lognormal distribution based on the results of the NPD survey as reported by Rupp *et al.* (1980). Ruffle and colleagues indicated that the "results can not necessarily be used to model the consumption of fish by sport or subsistence anglers from specific sites or from single water bodies." The authors reviewed information provided by USDA and USDC and concluded that consumption values had shifted upward by about 25 percent (between 16 and 27 percent) since the NPD survey was conducted in 1973-74. They recommended that adjustments be made to account for this increase in fish consumption, but also indicated that the data derived from the survey should still be useful in carrying out distributional risk analyses for the general population. Ruffle *et al.* (1994) presented distributions of fish and shellfish consumption rates and reported mean daily consumption rates of 10.68 grams per day for saltwater finfish, 1.48 grams per day for freshwater finfish, and 3.59 grams per day for shellfish on a national per capita basis (Table 3c). Although these values are slightly higher than the rates presented by Rupp *et al.* (1980), they did not include an upward adjustment for trends in increased consumption over time. The mean per capita values reported by Ruffle *et al.* (1994) for the Pacific region were slightly higher than the overall U.S. rates for saltwater finfish and shellfish (11.37 grams per day and 4.05 grams per day, respectively), and slightly lower for freshwater finfish (1.07 grams per day; Table 3c).

3. 1981 Market Research Corporation of America (MRCA) Survey

The National Marine Fisheries Services contracted with the Market Research Corporation of America (MRCA) to collect 48 weeks of weekly purchase data and 14 months of monthly household fish and shellfish consumption data from December 1980 through January 1982. MRCA utilized their national consumer panel consisting of 7,500 households and 12,000 individuals. More than 500 detailed seafood items were included in the survey, and Hu (1985) called it "the most comprehensive seafood consumption survey ever pursued." However, Hu reported that errors were found in both data processing and reporting, and that despite substantial efforts to correct them, unreliable rates of consumption (Table 2) resulted from conversion errors as well as from definitional problems and the high level of detail required for record keeping and reporting. Nevertheless, Hu indicated that the relative ranking of seafood products and the distribution of users by sociodemographic categories were similar to the patterns found in the other surveys he reviewed. One exception, reported by Hu, was a reversal in later studies, including the 1981 MRCA and the 1977-78 Nationwide Food Consumption Survey, of the inverse relationship between level of education and consumption of fish found by Nash (1971) in

the Market Facts survey. Hu also used the data from the MRCA survey to compare at-home versus away-from-home consumption and concluded that at-home consumption constituted about 70 percent for fish and about 50 percent for shellfish of the total amount of fish and shellfish consumed.

4. 1977-1978 and 1987-1988 USDA Nationwide Food Consumption Surveys (NFCS)

The Consumer Nutrition Division of USDA conducted surveys on general food intake to describe food consumption behavior and to assess the nutritional content of diets. Information obtained through these surveys supported policy decisions related to food production and marketing, food safety, food assistance, and nutrition education (IBNMRR, 1992). The NFCS date back to 1936 and were carried out every 10 years. The NFCS generally targeted households in the 48 conterminous states and individuals residing in the households. The surveys used a multistage stratified area probability sample^f taking into account geographic location, degree of urbanization, and socioeconomic considerations. Information on food intake over a three-day period was gathered. Individuals within each sampled household were asked to recall the kinds and amounts of foods eaten at home and away during the previous day and to keep a record of the foods eaten on the day of the interview and the following day (1-day recall and 2-day record). Overall, data reports for both surveys (1977-78 and 1987-88) provided information on food intake in grams per day from 64 food groups and subgroups. Mean per capita rates were derived for fish and shellfish combined, but these values did not include fish and shellfish in mixed dishes. The surveys conducted by USDA measured consumption of fish and shellfish in mixed dishes but reported the amounts for mixtures inclusive of all types of meat. Therefore, the amount of fish and shellfish consumed in mixtures could not be differentiated.

The 1977-78 NFCS obtained dietary intake records from 36,142 individuals (about 90 percent response rate) in 14,930 households (USDA, 1983). USDA derived an overall mean per capita rate for fish and shellfish of 12 grams per day from the survey results (Table 2). At-home consumption represented about two-thirds of the average rate, or 9 grams per day. Differences in food intakes calculated from one-day as opposed to three-day records were evaluated in 1977. The results showed a 9 percent difference in the reported average fish intake, 11 grams per day compared to 12 grams per day based on data from one and three days, respectively.

Hu (1985) conducted an analysis of the 1977-78 NFCS data, including fish and shellfish in mixed dishes, and derived a mean rate of 17.9 grams per day for at-home consumption. Popkin *et al.* (1989) also included fish and shellfish in mixed dishes in their analysis of this survey, and derived a mean per capita rate for women aged 19-50 years of 18.3 grams per day, as discussed below.

^f Each successive sampling stage selected increasingly smaller and more specific locations. The 48 states were grouped into nine census geographic divisions; then all land areas within the divisions were stratified into three urbanization classifications - central city, suburban, and nonmetropolitan. The final number of total strata corresponded to the geographic distribution, urbanization, and density of the population within the conterminous United States as defined by the Bureau of the Census.

USDA (1993a) derived an overall mean per capita rate of 11 grams per day from the 1987-88 NFCS. However, the 1987-88 NFCS only achieved a 31 percent response rate for individuals. The General Accounting Office (GAO, 1991) issued a report citing poor survey methodology and quality control problems that "raise doubts about the integrity of the data" and, therefore, limit the usefulness of the 1987-88 survey findings.

5. 1985-1986 and 1989-1991 USDA Continuing Survey of Food Intake by Individuals (CSFII)

For time periods in-between the nationwide food consumption surveys, and subsequent to the 1987-88 NFCS, which was the last one conducted, the Human Nutrition Information Service of USDA conducted the Continuing Survey of Food Intakes by Individuals (CSFII). These surveys serve to provide "timely information on U.S. diets and diets of population groups of concern and indicate changes in diets from previous surveys" (IBNMRR, 1992). The surveys utilize a multistage stratified area probability sample. Some changes in methodology were made for the 1985-86 CSFII compared to the 1977-78 NFCS (USDA, 1985). For example, participants were notified of the 1977-78 survey in advance and were asked to prepare notes on the foods used in the household in the week prior to the interview. These notes were expected to improve recall abilities. However, participants in the 1985-86 study were not contacted in advance of the survey. The later survey included additional questions and interviewers received additional training to probe for more detailed information. Also, participants in the later survey were asked about their racial identity whereas racial designations were previously based on observations by the interviewer of whether the household respondent was Black, White, or other.

The 1985-86 CSFII specifically targeted women 19-50 years of age and their children aged 1-5 years in the 48 conterminous states. Although the CSFII studies may include additional population groups each year, this "core monitoring group" of women and children was selected because previous surveys showed that women of reproductive age and young children were more likely than other population groups to have diets low in certain nutrients (USDA, 1985). The 1985-86 survey included the collection of up to six one-day recalls at about two-month intervals during a one-year period from both a basic sample and a low income sample (at or below 130 percent of the poverty guideline). Response rates ranged from 57 percent to 75 percent. Not all participants provided six separate days of dietary data. As shown in Table 4a, mean per capita rates for women aged 19-50 years were found to be 11, 12, or 13 grams per day, varying by year and/or the number of days of data. The percentage of the surveyed population reporting consumption of fish and shellfish ranged from approximately 10 percent from one-day data to 33 percent from four-day (nonconsecutive) data (USDA, 1985, 1987a, 1987b, 1988b).

Mean per capita consumption rates for low-income women were 9 or 11 grams per day, also varying by year and/or the number of days of data. The percentage of women reporting consumption of fish and shellfish among the low-income group ranged from 7.5 percent from one-day data to 26 percent from four-day (nonconsecutive) data (USDA, 1986a, 1987c, 1988a, 1989).

Information on men aged 19-50 years was gathered in 1985 based on one-day dietary recalls obtained through personal interviews. The mean per capita rate reported for men was 21 grams per day (Table 4a), representing a 50 percent increase from the mean rate of 14 grams per day reported for men aged 19-50 years in the 1977 NFCS (USDA, 1986b).

Popkin *et al.* (1989) compared food group consumption trends between the 1977-78 NFCS and the 1985-86 CSFII for women aged 19-50 years and identified personal and household characteristics associated with food group trends. They found that changes in consumption behavior pertaining to various aspects of dietary intake were associated with demographic and socioeconomic variables, particularly the level of education of the female head of household. By using an average of three days of dietary intake of fish, shellfish, and mixed fish dishes from each survey^g, a mean per capita rate of 20.4 grams per day was defined from the 1985-86 CSFII (Table 4a), compared with 18.3 grams per day from the 1977-78 NFCS for women aged 19-50 years. The data from the 1985-86 CSFII were collected on three nonconsecutive days whereas the data from 1977-78 NFCS were collected on three consecutive days.

The 1989-91 CSFII also included a general sample population and a low-income sample from individuals in households in the 48 conterminous states. The survey included the collection of three consecutive days of intake data (1-day recall and 2-day record). Descriptive variables for households included income, size, cash assets, region, urbanization, tenancy, and participation in Food Stamp and WIC programs. Individual data included sex; age; race; ethnicity (Hispanic or non-Hispanic); education; employment (for persons 15 years of age and over); pregnancy, lactation, and nursing status; height; and weight. Response rates for individuals with at least one-day intake records ranged from 54 percent to 65 percent. USDA derived mean per capita rates for men and women (≥ 20 years) of 17 grams per day and 14 grams per day, respectively, and an overall mean per capita rate of 13 grams per day, based on one-day data (Table 4b). U.S. EPA also conducted an analysis of the 1989-91 CSFII, inclusive of fish and shellfish from mixed dishes. Results from this analysis included an estimated mean per capita rate of 15.65 grams per person per day (Jacobs *et al.*, 1998; Table 4b). These results were projected from a sample of 11,912 individuals to the U.S. population of 242,707,000 based on three-day data and using three-year combined survey weights.

6. 1994-1996 USDA Continuing Survey of Food Intake by Individuals (CSFII)

More recently, USDA conducted the 1994-96 CSFII^h. For each survey year, a nationally representative sample of individuals was asked to provide, through in-person interviews, food intake on two nonconsecutive days. A total of 16,103 individuals responded with one-day data over the three-year period, and 15,303 provided two days of data. The response rates were 81 percent and 76 percent for one and two days, respectively. Major differences in the

^g Although data were available for six days for some of the respondents in the 1985-86 CSFII, for comparative purposes, Popkin *et al.* (1989) used the 24-h food-recall data and two randomly selected days from the CSFII to obtain a sample comparable in number of days to the 1977-78 NFCS data.

^h The 1994-96 CSFII was planned by the Human Nutrition Information Service, USDA. On February 20, 1994, legislation passed by Congress moved the functions of Human Nutrition Information Service to the Agricultural Research Service, USDA.

1994-96 CSFII compared to previous ones are food consumption data collected for two rather than three days, sampling to cover all 50 states, oversampling of low income populations, larger samples in selected age-sex categories (especially young children and the elderly), and subsampling within households rather than collection of information from all household members (USDA, 1993b). Descriptive variables for households included income (in dollars and as a percent of poverty), size, region, urbanization, tenancy, participation in Food Stamp and WIC programs, food expenditures, and shopping practices. Individuals were asked about sex; age; race; ethnicity (Hispanic or non-Hispanic); education; employment status (for respondents aged 15 years and over); pregnancy, lactation, and nursing status; height; and weight. Each respondent was asked to recall the kinds and amounts of foods eaten at home and away from home during the previous day. Analyses were conducted and reported first by U.S. EPA (1997b) in the *Mercury Study Report to Congress* (December 1997) based on data on consumption of fish and shellfish from years 1994 and 1995 of the CSFII. Some of these results are presented in the subsequent section on national consumption rates for consumers.

The reported mean quantities of fish and shellfish consumed per individual calculated by sex and age using one-day data included 3 grams per day for children aged 5 and under, 14 grams per day for males aged 20 and over, and 10 grams per day for females aged 20 and over. The overall mean per capita rate reported for all individuals was 10 grams per day (USDA, 1997). Other analyses included averages over the two-day reporting period, and grouped respondents by different age categories, and by ethnicity, income, and region (USDA, 1997).

In 1998, a survey of food intake by children was conducted and the results were added to the CSFII data from 1994-96.

7. The National Health and Nutrition Examination Survey (NHANES)

The National Health and Nutrition Examination Survey (NHANES) is a survey conducted by the National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention, U.S. Department of Health and Human Services. The survey has been designed to collect information about the health, diet, and nutritional status of the population of the U.S. through interviews and physical examinations. NHANES combines home interviews with health tests administered at mobile examination centers at selected locations in the U.S. NHANES was created as a result of the National Health Survey Act of 1956, which provided the legislation authorizing a continuing survey to provide statistical data on the amount, distribution, and effects of illness and disability in the U.S. The current NHANES (1999-2001) is the eighth in a series of national examination studies conducted in the U.S. since 1960. The first NHANES (NHANES I) was conducted in 1971-74, and included a sample size of 28,043; of these, 27,753 (99 percent) were interviewed and 20,749 (74 percent) were examined. An augmented sample of 4,288 was conducted in 1974-75.

The second National Health and Nutrition Examination Survey, NHANES II, included a nationwide probability sample of 27,801 persons from 6 months to 74 years of age; 25,286 people were interviewed and 20,322 people were examined, and the overall response rate was 73 percent. Children and persons classified as living at or below the poverty level were assumed

to be at special risk of having nutritional problems, and therefore were sampled at rates substantially higher than their proportions in the general population. Adjusted sampling weights were computed within 76 age-sex income groups in order to inflate the sample to closely reflect the target population at the midpoint of the survey.

NHANES III was conducted from 1988 to 1994, and also included a nationwide multistage, stratified, probability cluster sample of households in the U.S. The sample size of 39,695 included 33,994 (86 percent) that were interviewed and 31,311 (79 percent) that were examined. Certain subgroups in the population that were of special nutritional interest (*i.e.*, preschool children aged 2 months to 5 years, persons aged 60 to 74 years, Non-Hispanic blacks, and Mexican Americans) were oversampled. As with other national surveys, the geographic coverage included the civilian noninstitutionalized population of the conterminous U.S., and the data were weighted accordingly.¹ Some of the 30 topics investigated through this survey included medical conditions (*e.g.*, high blood pressure, high blood cholesterol, lung disease, diabetes, osteoporosis, hepatitis, and HIV, among others), food and nutrient intake, and dietary practices. Normative health-related measurement data were collected to describe health characteristics for the total population. A 24-hour recall and one-month food frequency questionnaire were used to obtain dietary data.

NCHS also sponsored a survey in 1982-84 designed to obtain data on the health and nutritional status of the three largest Hispanic subgroups in the U.S. because the sample size for Hispanics was insufficient in the NHANES to adequately estimate the nutritional and health status of this subpopulation. The goals of the Hispanic Health and Nutrition Examination Survey (HHANES) were similar to the NHANES, to obtain national population reference distributions, national prevalences of diseases and risk factors, and to monitor trends in nutritional and health status over time. The design for this survey also placed an emphasis on identifying unmet health care needs among Hispanics. The survey design was a stratified, multistage, probability cluster sample of the target populations. Civilian, noninstitutionalized, Hispanics aged 6 months to 74 years residing in households in three defined geographic areas of the U.S. were targeted. These regions included Mexican Americans residing in five Southwestern States (Arizona, California, Colorado, New Mexico, and Texas), Cubans residing in Dade County, Florida, and Puerto Ricans residing in the New York City area (parts of New York, New Jersey, and Connecticut). The sample was comprised of 9,894 Mexican Americans (87 percent interviewed and 75 percent examined), 2,244 Cuban Americans (79 percent interviewed and 61 percent examined), and 3,786 Puerto Ricans (89 percent interviewed and 75 percent examined). Although HHANES was not designed as a national Hispanic survey, it was the first health examination survey to cover the health and nutritional status of Hispanic subgroups, and the three HHANES universes included approximately 76 percent of the 1980 Hispanic origin population in the U.S. As with NHANES, data were obtained by interview and examination and included a 24-hour dietary recall, a food frequency questionnaire, physical examinations, anthropometric measurements, and laboratory analyses of blood and urine specimens. Descriptive variables included age, gender, ethnicity, income, education, and marital status.

¹ U.S. EPA (1997b) reported that the "findings for each person in the sample were inflated by the reciprocal of selection probabilities, adjusted to account for persons who were not examined, and stratified afterward according to race, sex and age."

A current NHANES began in April 1999. Also beginning in 1999, NHANES became a continuous annual survey that will visit fifteen U.S. locations a year and survey approximately 5,000 people annually. The new design (continuous annual sampling) is intended to provide more timely results, will allow increased flexibility in survey content, and can be linked to other related federal government surveys of the general U.S. population, specifically, the National Health Interview Survey and, in the future, the CSFII (NCHS, 2001). Beginning in January 2002, the USDA CSFII study will merge with NHANES. The merged survey sample will include the NHANES examination sample and an additional sample whose characteristics have not yet been defined (NCHS, 2001). The integrated survey will be called the National Food and Nutrition Survey (NFNS) and will provide comprehensive information on health and nutrition characteristics of the U.S. population. Detailed information on consumption rates of specific food items, such as fish, is not emphasized in data analyses as the data are used more broadly to evaluate the health status of the U.S. population. NCHS and USDA are working to finalize the NFNS sample design, core questionnaires, dietary interview protocol, and data processing and reporting plans (NCHS, 2001).

8. 1992 National Health Interview Survey

The National Health Interview Survey was conducted in 1992 using a multistage stratified random sample representative of the noninstitutionalized population of the U.S. aged 18 years and older (Block, 1994). A food frequency questionnaire was used to gather information from respondents who reported their frequency of consumption of food items over approximately the prior year. Records of fish intake were limited to two categories, "fried" or "not fried" and information on shellfish intake presumably was not collected. A published report was not available for this study. Additionally, because the results were based on one-year recall and fish items were not adequately characterized, the potential use of these data to evaluate fish and shellfish consumption is likely to be extremely limited.

According to The Directory of Federal and State Nutrition Monitoring Activities (IBNMRR, 1998), the NHIS is a continuing, nationwide, household interview survey that has been conducted annually since 1957. However, the purpose of the survey is to monitor health and demographic characteristics of the civilian, noninstitutionalized population residing in the U.S. National data on the incidence of acute conditions, injuries, disability days, physician contacts, prevalence of chronic conditions, limitations of activity, hospitalizations, assessed health status, and other health-related topics are provided by the survey. Therefore, this survey is not appropriate for monitoring consumption of foods, including fish and shellfish.

9. Summary of Per Capita Consumption Rates

The national consumption surveys varied in their purposes, methodology, and time frames. Overall national mean per capita consumption values for fish and shellfish combined ranged

from 10 to 17.9 grams per day^j, excluding rates that were reported to be unreliable (Table 2). Many of the earlier national studies may be useful primarily for a historical perspective.

The earlier USDA studies and more recently conducted national surveys rely on short-term recall and diary records (1-6 days). Although more recent studies have included analysis of fish and shellfish consumed in mixed dishes, only limited information is available from the national surveys to differentiate consumption rates between fish and shellfish (see Discussion on shellfish). Furthermore, data from the national surveys were not usually differentiated for commercial and sport fish and shellfish^k, and typically can be used only to derive total consumption for both of these categories combined or for commercial species alone. Trends in fish and shellfish consumption related to demographic variables will be discussed in more detail in the Discussion section.

It should be noted that updated information is available electronically on national studies of food consumption and monitoring of health and nutrition in the U.S. For example, in October 1998, the Interagency Board for Nutrition Monitoring and Related Research (IBNMRR) released its first Internet-only publication of *The Directory of Federal and State Nutrition Monitoring Activities* (IBNMRR, 1998). The first Directory was published in 1989, and the 1998 Directory represents an update and expansion of the second Directory, published in 1992. The Directory provides summaries of national surveys, lists of related publications, and contact information for obtaining results and further information on particular surveys. The national health and nutrition studies conducted most recently were only briefly summarized here to update the report. Further information can be accessed through the 1998 Directory, which can be found at the following Web site: <http://www.cdc.gov/nchs/data/nutrimon.pdf> or can be downloaded from: <http://www.cdc.gov/nchswww/about/otheract/nutrishn/nutrishn.htm>.

Estimates of per capita fish and shellfish consumption have limitations in their applicability. National studies with large sample sizes have been used to depict food consumption patterns for the U.S. population as a whole. Because per capita estimates average consumption rates for consumers and nonconsumers, the results from national per capita studies underestimate actual rates of consumption for consumers. This is most likely to be true for food items such as fish and shellfish that are not regularly consumed by all individuals in the population. In addition, the results from national per capita studies only provide information for foods consumed on the few days on which respondents are queried. Hu (1985) stated that "all of the survey estimates of per capita consumption are only point estimates; they are subject to spatial or temporal distribution error." As one example, differences in the reported percentage of users based upon the number of days that data were collected reflect the inadequacy of short-term surveys (covering a few days) for detecting all people who consume fish and/or shellfish, since fish and shellfish are not typically consumed on a daily basis. Hu (1985) further noted that national survey data were useful for examining how sociodemographic and economic factors related to seafood consumption over time and that this information was applicable to the marketing and

^j The upper end of this range reflects the 17.9 grams per day rate reported by Hu (1985) that was calculated for meals eaten at home only. These values do not reflect estimates calculated for women only or men only.

^k The survey questionnaire used in the 1994-96 CSFII was modified to ask about the source of the food consumed. However, it is unclear whether the results allow for quantification of fish from different sources.

development of fishery products. Finally, short-term recall (or diary) data do not address usual (long-term) patterns of consumption of fish and shellfish.

Per capita consumption rates generally are useful as a measure of trends or changes in demand for the entire population or when the whole U.S. population is the target population. A comparison of per capita rates from sequentially conducted national studies can indicate whether, on average, the entire population is consuming more or less of a specific food group, although differences in methodology should be considered when making comparisons. Changes in per capita rates do not indicate specifically whether more or fewer people are eating the food or whether those eating it are eating more or less. National per capita studies have not adequately addressed or distinguished consumption of sport fish and shellfish. Therefore, the results from these studies may include consumption of sport fish and shellfish but are less useful for deriving estimates of consumption of sport fish and shellfish by the general population. In summary, per capita rates are not truly representative of fish and shellfish consumption rates, particularly for subpopulations in the U.S. that actually consume fish and/or shellfish, and especially for consumption of sport fish and shellfish.

C. Consumption Rates for Consumers Derived from National Surveys

Per capita rates, by definition, reflect consumption averaged over the general U.S. population, and thus do not necessarily describe actual rates of consumption by consumers of fish and shellfish. Estimates of consumption for "consumers only" (*i.e.*, respondents that consumed fish or shellfish during the reporting period of the survey) have been derived from several nationally based surveys, including the 1973-74 NPD survey, the 1977-78 NFCS, and the 1985-86 CSFII. A review of rates derived for "consumers only" from these national studies is presented in this section and in Table 5. Some of the results that have been reported from more recent surveys such as the 1989-91 CSFII, the 1994-96 CSFII, and the Third National Health and Nutrition Examination Survey (NHANES III), are also summarized below. Although consumption rates derived for consumers would be preferable to per capita rates for use in describing actual consumption of fish and shellfish in the U.S., there are limitations to the data available from national surveys for "consumers only" as discussed below.

1. 1973-1974 National Purchase Diary (NPD) Survey

Rupp *et al.* (1980) suggested that differences in rates of consumption for "consumers only" compared to national per capita rates were greatest for freshwater fish and shellfish consumption. In their analysis of the NPD dataset, there was not much difference between per capita estimates and actual consumption of saltwater fish. These differences (or lack thereof) would be expected because a large percentage of the population reported consumption of saltwater fish, but fewer people ate freshwater and shellfish species. Rupp and colleagues reported that about 94 percent of children and 96 to 100 percent of adults in the U.S. ate some kind of fish and/or shellfish, and that about 90 percent of the total population reported consumption of saltwater finfish. However, only 26 to 42 percent of the population ate shellfish and only 12 to 16 percent ate freshwater finfish. Although Rupp *et al.* (1980) focused on per capita consumption in the U.S.

and in specific geographic regions, they reported annual "per capita" estimates of consumption for "consumers only" as well as for the entire U.S. population¹ (Table 3a). Annual per capita consumption of saltwater finfish by consumers was 1.1 times that of national per capita consumption (3.52 kilograms per year compared to 3.2 kilograms per year). Annual per capita consumption of freshwater finfish by consumers was 5.7 times the estimate for the general population (2.43 kilograms per year compared to 0.43 kilograms per year), and annual per capita consumption of shellfish by consumers was 2.9 times the national per capita consumption (2.91 kilograms per year compared to 1.01 kilograms per year).

Rupp *et al.* (1980) reported that the percentage of the population consuming each type of fish or shellfish varied on a regional basis (Table 3b). Among adults, the percent of people consuming saltwater species ranged from 31 percent (in the West-North-Central region) to 93 percent (in New England). The percent of adults consuming freshwater fish ranged from 5 percent (New England) to 25 percent (West-South-Central), and shellfish consumers ranged from 30 percent (East-North-Central) to 60 percent (New England).

2. 1977-1978 USDA Nationwide Food Consumption Survey and 1985-1986 Continuing Survey of Food Intake by Individuals (CSFII)

Using data from the 1977-78 Nationwide Food Consumption Survey, Pao *et al.* (1982) derived frequency distributions for rates of consumption of different foods by actual consumers, *i.e.*, individuals who reported consuming specific food items at least once during the three-day (consecutive) study period. Pao *et al.* reported average quantities of fish and shellfish consumed per day and per meal (at specified percentiles) for ten age groups and by sex for six of the age groups. They also reported the percentage of users. Out of 37,874 individuals with three-day diet records, 24.5 percent reported eating fish and shellfish at least once in the three days; 20.5 percent reported eating fish and shellfish consumption for only one of three days, 3.6 percent for two out of three days, and 0.4 percent reported eating fish and shellfish on all three days. However, these summary statistics, which were based on data obtained from three reporting days, can not be used to determine actual frequencies of consumption.

Pao *et al.* (1982) reported an overall mean rate for fish and shellfish combined of 48 grams per day (Table 5) for "consumers only" compared to the per capita rate of 12 grams per day. Fish and shellfish mixtures were not included in the analysis. The average consumption rate for finfish was slightly higher at 54 grams per day. Finfish did not include canned, dried, or raw fish. (This rate can not be compared to per capita consumption of finfish because USDA reports only provided values for fish and shellfish consumption combined.) Pao *et al.* (1982) also indicated which food items and food groups were most frequently reported to be consumed by survey participants. The most frequently reported finfish included fishsticks, flounder, haddock, and perch. Canned tuna and shrimp were reported as frequently consumed seafood items.

¹Note that "per capita" consumption rates typically refer to the national population and thus would include both consumers and nonconsumers. However, Rupp *et al.* (1980) also provided annual "per capita" estimates for "consumers only" as well as for the entire U.S. population.

Popkin *et al.* (1989) included fish and shellfish in mixed dishes in their analysis of consumption behavior for women aged 19-50 who reported consuming fish and shellfish in the 1977-78 NFCS and 1985-86 CSFII. They derived a mean intake of 111.0 grams per day compared to a per capita rate of 18.3 grams per day which they determined from the 1977-78 NFCS, and 88.2 grams per day compared to their per capita estimate of 20.4 grams per day from the 1985-86 CSFII (Table 5). Their analysis also showed a higher percentage of consumers in the 1985-86 CSFII (44.7 percent) compared to the 1977-78 NFCS (36.7 percent).

In comparison, Pao *et al.* (1982) derived mean rates of 44 grams per day and 49 grams per day for women consumers only, aged 19-34 and 35-64 years, respectively, from the 1977-78 NFCS. However, Pao *et al.* (1982) did not include fish and shellfish in mixed dishes in their report. Whether this difference in methodology accounts for most of the disparity in results is difficult to ascertain. Estimates of consumption that include fish and shellfish consumed in mixed dishes are likely to be more realistic than estimates which do not include this source, although the reliability of the results depends on how accurately the portions of fish and/or shellfish consumed in mixed dishes are estimated.

3. 1989-1991 and 1994-1996 USDA Continuing Survey of Food Intake by Individuals (CSFII)

U.S. EPA performed an analysis^m of the 1989-91 CSFII dataset that included fish and shellfish consumed in mixed dishes and used a database that provided actual proportions of fish, shellfish, and other ingredients in mixed dishes (e.g., breading on fishsticks) based on USDA recipe files. Therefore, the results were expected to be more accurate than estimates based on assumptions about the proportions of ingredients (e.g., the assumption that 50 percent of a mixed dish is fish and/or shellfish) (U.S. EPA, personal communication, Helen Jacobs, 2/96). A mean rate of 100.63 grams per person per day for "acute consumers" of fish and shellfish, including fish and shellfish consumed in mixed dishes, was estimated from a sample size of 3,927 projected to a population size of 89,800,000 using three-year combined survey weights (U.S. EPA, personal communication, Helen Jacobs, 6/97; Table 5). An estimated rate of 253.38 grams per person per day was determined for the 95th percentile. "Acute consumers" were defined as individuals who consumed fish at least once during the three-day reporting period; if a respondent consumed fish and/or shellfish more than one time during the three-day period, their daily average was calculated. These estimates were determined for fish and shellfish "as consumed;" estimates for uncooked fish and shellfish were higher (e.g., 129.00 grams per person per day and 326.00 grams per person per day of uncooked fish and shellfish at the mean and 95th percentile, respectively).

The U.S. EPA Office of Air Quality Planning and Standards and the Office of Research and Development conducted a separate analysis of the 1989-91, 1994, and 1995 CSFII surveys and used the data to estimate fish intake for the purpose of estimating exposure to methylmercury; these results were reported in the *Mercury Study Report to Congress* (U.S. EPA, 1997b).

^m This analysis was conducted by the U.S. EPA Office of Water, Office of Science and Technology.

U.S. EPA (1997b) applied a two phase reweighting of the USDA weighted dataⁿ; characteristics used by U.S. EPA in weight construction included day of the week, month of the year, region, urbanization, income, food stamp use, home ownership, household composition, race, ethnicity, and age. U.S. EPA (1997b) summarized the number and percentage of respondents from each of these surveys that had indicated consumption of fish or shellfish during the reporting periods of the surveys. In the analysis, consumption of fish was summed across the days of dietary intake data provided by the respondent and divided by the number of reporting days. As a result, for respondents that consumed fish or shellfish on only one of the reporting days, their "usual" daily intake was estimated as a fraction (one-half or one-third, depending on the survey year) of what they reported for that day.

U.S. EPA (1997b) used the results from an analysis of the 1989-91 CSFII dataset to estimate fish intake by the general U.S. population and a subpopulation of women of childbearing age, and to estimate the size of the population consisting of pregnant women (who were of particular interest because of the potential developmental toxicity to the fetus from ingestion of methylmercury by the mother). In addition, data were obtained for 3614 individuals (30.9 percent of the 11,706 respondents reporting three days of dietary intake) who reported consumption of fish or shellfish. Fish consumption data included approximately 250 individual "fish only" and 165 "mixed dish" fish items. Additionally, fish were divided into six categories: marine finfish; marine shellfish; freshwater fish; tuna; shark, barracuda, and swordfish; and all fish and shellfish. Consumption patterns were determined on a "per capita" and a "per user" (*i.e.*, those respondents that reported consumption of fish or shellfish during one of the reporting days) basis. U.S. EPA (1997b) reported overall mean consumption rates for "users" of 49 grams per day for males and 40 grams per day for females. This estimate is notably lower than the estimate provided by U.S. EPA, Office of Water (as discussed above). However, as also noted, the methods of data analysis were considerably different.

U.S. EPA (1997b) also reported the number of consumers of fish and shellfish by age and gender from an analysis of the 1994 CSFII data. Overall, 11.3 percent of respondents reported consumption of fish or shellfish, 598 individuals on day 1 and 596 individuals on day 2. U.S. EPA (1997b) noted that the 1994 CSFII questionnaire included one question on the frequency of consumption of fish and shellfish over the past 12 months. However, the question was worded to exclude consumption of canned fish, making it difficult to estimate overall fish consumption. The CSFII survey also included a question on whether fish consumed were caught by the respondent or someone known to the respondent. U.S. EPA (1997b) reported that among respondents who ate non-canned fish (84.1 percent) during the past 12 months, 37.5 percent indicated that they ate sport fish (caught by themselves or a person known to them). Shellfish consumption was reported by 62.2 percent of respondents.

4. Third National Health and Nutrition Examination Survey (NHANES III)

ⁿ U.S. EPA (1997b) reported that in the first phase, the inverse of the probability of selection was computed for each household and the sampling weight was adjusted to account for nonresponse; in the second phase, first phase weights were used as the starting point for a reweighting process that used regression techniques to calibrate the sample to match characteristics thought to be correlated with eating behavior.

Data from the NHANES III, conducted from 1988 to 1994, were used by U.S. EPA in an analysis presented in the *Mercury Study Report to Congress* (U.S. EPA, 1997b). U.S. EPA reported that 3864 individuals (12.9 percent of 29,973 respondents) indicated consumption of fish or shellfish in their 24-hour dietary recall record ("users"). NHANES III included two questions on the frequency of consumption of fish and shellfish (as part of the household interview portion of the survey) in which respondents were prompted to report the number of times per day, week, or month that they ate certain types of fish or shellfish^o. U.S. EPA (1997b) reported that 88 percent of all adults consume fish and/or shellfish at least once a month, 58 percent of adults consume at least once a week, between 13 percent and 23 percent consume two or three times a week, an estimated 3 percent indicated that they eat fish and shellfish six times a week, and 1 percent of all respondents reported consuming fish and shellfish daily. U.S. EPA (1997b) also reported weighted mean estimates and percentile rates of consumption for "users" by sex and age category and by habitat of species consumed. However, it is not clear whether the results (which are reported in "grams") represent what was recorded for the 24-hour recall period, or whether the reported frequency of consumption was factored in to derive daily estimates.

5. Summary of Consumption Rates for "Consumers Only"

Only a few national surveys have provided estimates of fish and shellfish consumption rates for "consumers only." Rupp *et al.* (1980) provided annual values of per capita consumption of freshwater fish, saltwater fish, and shellfish for consumers as well as for the overall U.S. population, but did not report consumption rates for total fish and shellfish consumed. Rupp and colleagues analyzed data from the NPD survey, which was conducted in the early 1970's, and thus, the results may not be applicable to current rates of consumption. Pao *et al.* (1982) reported a mean rate for "consumers only" of 48 grams per day based on their analysis of the 1977-78 NFCS data. The analysis performed by Pao and colleagues did not include fish and shellfish consumed in mixed dishes, and therefore, is likely to underrepresent actual consumption as reported by consumers in the survey. Popkin *et al.* (1989) derived mean rates for women consumers only, aged 19-50 years, inclusive of fish and shellfish in mixed dishes, of 111.0 grams per day from the 1977-78 NFCS survey and 88.2 grams per day from the 1985-86 CSFII. Although it is difficult to compare their results with those reported by Pao and colleagues because the target populations evaluated were not equivalent (in age), the consumption rates reported by Popkin *et al.* suggest that fish and shellfish consumed in mixed dishes contribute significantly to the overall consumption rate for consumers. Estimates from the 1989-91 CSFII support this assumption, as the estimated mean rate for consumers of all fish and shellfish including mixed dishes was 100.6 grams per day. However, it is also possible that the higher estimates of consumption rates in the more recent survey may reflect changes in consumption patterns for fish and shellfish over time. Comparison of the results of analyses that have been reported is difficult due to differences in methods used for data analysis.

^o The questions were worded to ascertain the frequency of consumption of shellfish as "shrimp, clams, oysters, crabs, and lobster" and fish as "fish including fillets, fish sticks, fish sandwiches, and tuna fish."

U.S. EPA (1989a) indicated that data from the USDA studies using one to three-day records for "consumers only" might not reflect long-term intake patterns, and thus, are more appropriate for assessing acute exposures than chronic exposures. However, the values reported for "acute" consumption, which represent the amount of fish and/or shellfish that a respondent ate on a given day would not be equivalent to meal size when the amount reported as consumed is divided by the number of survey-period days. Although the methodology was changed in more recent surveys to incorporate questions about the frequency of consumption, limitations in the wording of the new questions are likely to preclude the ability to derive accurate estimates of "usual" intake of fish and shellfish from the short-term data. Therefore, although estimates of consumption based on "consumers only" may be reported as "grams per day," the values are not actually representative of long-term consumption rates that have been averaged over time and presented as a daily rate. In addition, U.S. EPA (1997b) noted that because fish is not a frequently consumed food for the majority of individuals, short-term recall/record assessment methods would likely underestimate the extent of fish consumption. People who typically consume fish and shellfish, but did not do so during the reporting periods of the surveys, were not captured and thus did not contribute to the national estimates derived. It is not possible to determine the percentage of the fish and shellfish consuming population that was missed or whether the respondents who did consume fish or shellfish during the survey-reporting period adequately represented the total fish and shellfish consuming population. Mean estimates of consumption are considered to be more reliable when sample sizes are very large. Although overall sample sizes in the national surveys were large, sample sizes for "consumers only" (or "users") represented a relatively small percentage of all respondents, and thus, the results for consumers may be less accurate and precise.

As mentioned previously, the national surveys have not adequately addressed consumption of sport fish and shellfish. Fish and shellfish from commercial and noncommercial sources have typically not been distinguished. Questions on consumption of sport fish that have been used in some of the more recent national surveys can provide estimates of the percentage of respondents consuming sport fish. However, all sport fish and shellfish consumers may not be captured in the short-term survey periods and actual consumption rates for sport fish and shellfish may not be quantifiable^p.

In summary, the available data from national surveys for "consumers only" are limited and it is difficult to determine an overall average rate for "usual intake" for consumers of fish and shellfish in the U.S. from these studies. Furthermore, in their guidance series for the assessment of chemical contamination in fish and development of fish consumption advisories, U.S. EPA (1996b) recommended that exposure values designed to address consumers of commercial fish not be used for characterizing consumers of sport fish and shellfish. A review of studies pertaining to consumption rates and patterns for people who catch and consume their own fish and shellfish is presented in the following section.

^p The 1994-96 CSFII survey questionnaire asked about the source of fish or seafood consumed (e.g., freshwater lake, pond, or river, ocean, bay, sound, estuary, or gift). Only certain types of fish were considered in the question.

D. Consumption Rates Reported for Consumers of Sport (Noncommercial) Fish and Shellfish

Consumption values for populations who consume sport fish and/or shellfish can range widely from those who fish intermittently to those who fish regularly for recreation or sport, or to those who fish mainly to provide a dietary staple (subsistence fishers). These fishing populations are poorly represented in the national studies discussed previously, which did not fully distinguish between consumption of commercially harvested and noncommercial or sport-caught fish and/or shellfish. U.S. EPA (1994) suggested that recreational and subsistence fishers represent subgroups that are likely to consume higher average rates of fish and shellfish than those reflected in national consumption surveys of the general population.

Various regional studies have been done to define consumption rates relevant to people who consume sport fish and/or shellfish. Some of these studies have looked at total consumption (sport and commercial) and others have looked only at fish caught and consumed from specific water bodies during certain seasons. Studies that have derived consumption rates for sport fish are summarized below. The methodologies used in these studies of fishing populations differ from the methods used in the national studies, and include mail surveys, diaries, creel surveys, and personal interviews with fishers and/or consumers of noncommercial sport fish and shellfish.

1. Combined Commercial and Sport Fish Consumption Studies

Many of the regional studies that targeted sport-fishing populations asked about consumption of all fish and shellfish inclusive of species caught and/or purchased. Some of these studies distinguished the source of fish and shellfish whereas other studies did not. A review of studies that covered consumption of sport and commercial fish and shellfish follows.

a. 1988 Michigan Statewide Survey

From January to June 1988, West *et al.* (1989a) conducted a mail survey of a sample of 2,600 Michigan sport fish license holders, stratified by license type and geographic residence. The study population excluded nonresident Michigan fishing license holders as well as individuals that purchased one-day licenses only. Fish consumption information was gathered from all members of the household for a seven-day recall period. Fish meals included self-caught, market, restaurant, and gift fish. Respondents estimated fish meal size by using a picture of "about 1/2 pound" and were asked to judge whether each fish meal was "about the same, less, or more" than the pictured fish meal. Meal size was recorded as 8 ounces, 5 ounces, or 10 ounces, accordingly.

West *et al.* (1992) applied statistical tests to the results of the survey to compare rates of consumption among different subpopulations and to test for the interaction of demographic factors such as race, income, age, level of education, and residence (including size of town). Their main objective was to identify subgroups, especially minorities, with especially high rates of consumption who would thus be potentially at greater risk of exposure to chemical

contaminants. They surveyed all members of households that consumed fish in order to assess potential risks to family members as well as anglers, and then adjusted for the lack of independence among household members by reducing the acceptable error rate. (An alpha level of $p = 0.05$ was considered marginally nonsignificant.) They noted that the sampled population may not have represented subsistence fishers because it was selected from licensed anglers only.

West *et al.* (1992) reported an overall mean rate for fish consumption of 18.3 grams per person per day (GPD) for the winter-spring period for sport fishermen and their family members who ate fish. West and colleagues indicated that data from the summer-fall months would be expected to yield higher rates of consumption due to an expected increase in fishing effort during these seasons. Because the overall response rate was only 47.3 percent, the authors adjusted the population mean value downward by 2.2 grams to account for nonresponse bias, thus deriving a mean rate of 16.1 GPD (Table 6). Derivation of the adjustment factor was based on a follow-up telephone survey of respondents and nonrespondents and is explained fully in West *et al.* (1989b). Nonresponse bias was not measured for subgroups. Therefore, the mean rates of consumption reported for subgroups were unadjusted, as were the variance calculations (such as the rate reported for the 80th percentile). For comparative purposes, the unadjusted overall mean rate is presented in Table 7a.

West *et al.* (1992) examined the effects of age, race, income, education, and residence on consumption. Differences by age were found to be statistically significant, with older anglers (over 65 years) having the highest average fish consumption rate (25.2 GPD). West *et al.* (1992) found that minority subgroups combined (Black, Native American, and Other) had higher mean rates of consumption compared to Whites (21.7 compared to 17.9 GPD), but the difference was "marginally nonsignificant." Most other trends related to demographic variables (as described below) were also marginally nonsignificant or nonsignificant, although the highest consuming subgroups (e.g., low income Native Americans) had consumption rates nearly twice the overall average. Although the results did not show statistical significance, they may indicate patterns and trends in consumption, as described below.

Native Americans and Blacks had the highest mean rates of consumption, 24.3 and 20.3 GPD, respectively (Table 7a). Patterns between these two highest-consuming groups differed considerably. Middle-income (\$15,000-\$29,000) Black anglers had higher consumption rates than lower and higher income Black anglers. Native American anglers with either low or high income had higher mean rates of consumption than did middle-income Native Americans. Older (51-91 years) Black anglers and low income (<\$15,000/year) Native Americans were the highest consuming subgroups, 31.9 and 33.7 GPD, respectively. White anglers demonstrated little difference by income level, and for the surveyed population as a whole, the relationship between consumption and income was nonsignificant. The relationship between consumption and level of education was marginally nonsignificant.

West *et al.* (1992) found a significant, but nonlinear, relationship between fish consumption and place of residence (degree of urbanization). Consumption (mean intake) was highest for Native Americans living in rural areas and small towns (32.1 and 29.9 GPD, respectively) and among Blacks, the highest mean rate was for those living in cities (23.9 GPD). The number of years of residence in Michigan also had a significant positive (linear) relationship with fish consumption;

the highest mean rate (30.3 GPD) was for Black anglers who had lived in the state more than thirty years.

Murray and Burmaster (1994) used the data from the 1988 Michigan Statewide Survey to derive distributions of fish consumption rates for survey respondents. They defined categories (not mutually exclusive) of consumers as those who ate fish, those who ate self-caught fish, and those who ate Great Lakes fish. For each category, they evaluated rates of consumption of both sport fish and total fish for all adults, men, women, and anglers, and presented empirical (Table 8) and parametric distributions for 12 of these population subgroups. The data analyses performed by Murray and Burmaster differed from those conducted by West and colleagues in several ways. Murray and Burmaster used the raw data without applying weighting factors to data obtained for different time periods and analyzed consumption data for all adults, whereas West and colleagues reported that they evaluated consumers only and included all ages. However, the estimated mean consumption rates calculated by West and colleagues for "consumers only" included a relatively large percentage (56.6 percent) of anglers and household members who had not eaten any fish during the seven-day recall period. In contrast, the distribution of consumption rates reported by Murray and Burmaster applied only to those (adult) respondents who had eaten fish during the recall period. Murray and Burmaster (1994) demonstrated that the distributions for fish consumers were lognormally shaped and proposed that the distributions could be used in Monte Carlo simulations.

Murray and Burmaster calculated a mean intake of 45.3 grams per day for total fish consumption for all adult respondents that ate fish (Table 8). For anglers who reported eating self-caught fish, the mean intake rates were 45.0 grams per day for sport fish, and 55.1 grams per day for total fish (from all sources). In general, the mean intake rates for anglers were slightly higher than the mean intake rates for other consumers in the same category, suggesting that the angler eats only slightly more than (adult) family members and other adults who share the catch. Anglers who reported eating Great Lakes fish had the highest mean intake of fish from all sources, 61.3 grams per day, which included an average of 20.4 grams per day of fish from other sources in addition to 40.9 grams per day of Great Lakes fish. Murray and Burmaster (1994) reported that the category of anglers reporting consumption of Great Lakes fish consisted of 89 people or four percent of all adult respondents, and 2.6 percent of all respondents.

Anglers who ate Great Lakes fish also had the highest median intake (53.1 grams per day) and the highest intake rate at the 95th percentile (123.9 grams per day) for total fish consumed. The median rates for the other population subgroups ranged from 32.7 to 40.8 grams per day, including both sport fish and total fish consumption (Table 8).

b. 1991-1992 Michigan Sport Anglers Fish Consumption Study

With additional funding from the Michigan Great Lakes Protection Fund, West *et al.* (1993) conducted a yearlong study in order to evaluate more thoroughly fish consumption rates in Michigan. Previous funding had only allowed for a six-month study to be conducted, which did not include the seasons considered to be important fishing seasons (summer and fall). The objectives of the 1991-92 study were similar to the previous survey: to test assumptions about

fish consumption rates used to establish water quality criteria, to determine angler compliance with consumption advisories, and to determine which subpopulations might be at greatest risk of exposure to chemical contaminants as a result of consuming fish at higher than average rates.

A random sample of 7,000 licensed anglers, stratified for geographic residence and type of license, was selected to receive a mail survey covering fish consumption over a seven-day period. Twenty-five cohorts were staggered throughout the year to capture a full year cycle of consumption behavior. As in the previous study, the data were weighted to equalize the frequency of responses in each two-week period. In contrast to the earlier study, the sampling unit was the license holder only rather than all household members that consumed fish. The rationale for this change was that statistical interdependence of consumption by household members could be avoided, and additionally, the previous study had already addressed the question of whether family members consumed equivalent amounts of fish. (They were found to consume proportionately less corresponding to body weight.) The survey found that about 93 percent of licensed fishers ate fish (and 94 percent of those that did not eat fish had eaten fish in the past). All anglers who indicated that they were fish consumers were included in the estimates of consumption rates although approximately 70 percent of them had not eaten fish during the recall period. Because the mail survey return rate was 46.8 percent, and funding did not allow for follow-up calls to nonrespondents, West *et al.* (1993) used the same downward adjustment of 2.2 grams (applied to the overall average rate of consumption) that was determined and applied in the earlier 1988 study. Data analysis in the final report delineated consumption for sport fish only as well as for total fish (Table 6), and also provided frequency distributions for sport fish and total fish. Sport fish included any fish from Michigan waters including the Great Lakes and Michigan rivers that flow into the Great Lakes. Total fish included both sport fish and commercial (restaurant and market) fish. The authors noted that a "sizable (but unknown) amount of commercial fish come from Michigan surface waters."

Sport fish consumption averaged 14.5 GPD and total fish consumption averaged 24.3 GPD (both rates adjusted for nonresponse bias, Table 6). West *et al.* (1993) tested whether mean fish consumption rates differed in the winter-spring period compared to the summer-fall period in the 1991-92 study and found no significant differences. Therefore, seasonality did not appear to affect consumption rates. The difference in rates derived from the two studies may have resulted from differences in methodology, including a larger sample size (nearly three times) in the later study. In addition, the percentage of "nonconsumers" (those respondents reporting zero consumption of sport fish during the seven-day reporting period of the survey) differed between the two studies; the adjusted average estimate of 16.1 GPD in the 1988 survey included 57 percent "nonconsumers" whereas the adjusted average estimate of 14.5 GPD in the 1991-92 survey included 70 percent "nonconsumers."

West *et al.* (1993) also evaluated the relationships between education, income, residence, race or ethnicity and sport fish and total fish consumption, respectively. They demonstrated statistically significant relationships between sport fish consumption and income. In the bivariate analyses, the two lowest income groups (<\$14,999/year and \$15,000-24,999) had the highest mean rates of sport fish consumption (21.0 and 20.6 GPD, respectively). For total fish consumption, however, consumption rates did not vary with income level. Minority anglers had significantly higher mean rates of consumption than White anglers for both sport fish (23.2 compared to 16.3 GPD)

and total fish (35.9 compared to 25.9 GPD) consumption (Table 7b). Racial and ethnic variables were not broken down into individual minority subgroups due to low sub-sample sizes, but the two main groups included in the "minority" category were Black anglers and nonreservation Native American anglers. In contrast to the earlier 1988 study, no significant relationship between age and consumption was evident. Males ate significantly more sport fish than females. However, gender differences were nonsignificant for total fish consumption. The relationships between education and fish consumption were not significant, although the patterns differed for sport fish and total fish consumption. For example, anglers with post-graduate education tended to consume less sport fish but more total fish relative to anglers with less education. Mean consumption rates differed significantly for sport fish only by place of residence (size of town); the highest mean rate (22.8 GPD) was for small towns (population size 100 to 2,000). In the multivariate analyses, the authors documented a significant combined and interactive effect between race/ethnicity, income, and fish consumption such that lower income minorities ($\leq \$24,999$) had the highest mean sport fish consumption level of 43.1 GPD and the highest mean total fish consumption of 57.9 GPD.

In the earlier study, West and colleagues evaluated the stability of fish consumption data over time by comparing the results reported by a subset of the sample population who responded to both the initial mail survey and a follow-up telephone survey conducted one year after the initial study. West *et al.* (1989c) suggested that a decline in fish consumption between 1988 and 1989 may have reflected a "suppression effect" due to consumption advisories and/or increased awareness of potential risks as a result of participation in the survey. In the later study, West and colleagues did not find a significant suppression effect, although they reported that 46.8 percent of anglers who were aware of advisories had decreased the amount of fish they consumed. They also documented some changes in methods of preparation or cooking and choice of location or species, particularly for anglers fishing in the Great Lakes (compared to those fishing rivers, inland lakes, and river mouth lakes).

c. 1988 New York Statewide Angler Survey

Under contract with the New York State Department of Environmental Conservation, Connelly *et al.* (1990) conducted a statewide mail survey to estimate the amount of effort and expenditure by fishers on certain waterways and for certain species, and to identify fishing patterns, preferences, and attitudes of anglers during 1988. Surveys were sent to 17,000 fishing license holders and a response rate of 62.4 percent was obtained. Two questionnaires were used, with one of the questionnaires being sent to roughly half of the selected sample. Consumption of fish was addressed by only one of the questionnaires which included one question regarding all fish meals (sport-caught or purchased fresh, canned, or frozen) consumed by the responding angler in 1988 and one question regarding the number of meals of sport-caught fish from Lakes Erie and Ontario consumed by the angler's household in 1988. The number of respondents reporting on consumption was 1,190 (7 percent) and only limited results concerning consumption were included in the final report. An overall average fish consumption rate for statewide anglers of 45.2 meals per year was reported. Connelly *et al.* (1990) assumed a half-pound portion of fish per meal to derive a mean consumption rate of 10.1 kilograms per year or 28.1 grams per day (Table 6). Sport fish consumption was also reported for Lake Ontario only (an average of 6.9

meals per year). The authors stated that consumption appeared to increase with increasing age, income, and education. Although the study included a comprehensive survey of many waterways used for fishing throughout the state, estimating fish consumption rates was not a stated objective of the study, and the information provided on consumption, particularly for sport fish, was limited.

d. 1992 Lake Ontario Angler Survey: Estimating Sportfishing Participation and Consumption of Fish in the Great Lakes

Continuing studies of anglers fishing the Great Lakes were conducted in the early 1990's by Connelly, Knuth, Brown, and colleagues at the Human Dimensions Research Unit of the Department of Natural Resources at Cornell University. A yearlong diary survey, funded by Sea Grant, was administered in 1992 to anglers who fished Lake Ontario. The objectives of the study were to provide accurate estimates of fish consumption among Lake Ontario anglers, including both sport fish and fish from all sources; to evaluate adherence to health advisory recommendations; and to assess the use of risk-reducing procedures in the preparation and cooking of sport fish.

Personalized letters were mailed to a sample of 2,500 anglers whose names were drawn systematically from New York fishing license records and included resident, nonresident, and short-term license holders in six counties bordering Lake Ontario. The initial diary participant sample consisted of 1,202 anglers who were successfully reached, willing to participate, and "eligible" in that they intended to fish Lake Ontario in 1992. In an attempt to reduce bias associated with greater response from avid anglers, phone calls were made to nonrespondents who were encouraged to participate even if they fished or consumed sport fish infrequently. In addition to diaries, a mail questionnaire was sent to all participants asking for 12-month recall of their 1991 fish consumption, including seasonal variation, demographic information, and preparation and cooking habits for sport fish. Up to three follow-up mailings were sent to nonrespondents to encourage return of the mail questionnaire. Although the information recorded in the diaries was considered the primary database for the study, comparisons were made of the results from the recall and diary portions of the study. Participants were asked to record in the diary all fishing trips to Lake Ontario and to other New York state waters, and all fish consumption. For each meal consumed, they were asked to record the species, source, meal size, method of preparation and cooking, and the number of household members consuming the fish. Pictures of eight-ounce (227 grams) fish steaks or fillets were used to assist respondents in estimating meal size (after West *et al.*, 1989); "smaller" portions were assumed to be four ounces (114 grams), and "larger" portions were assumed to be twelve ounces (343 grams). Shellfish meals were not included in the survey. Of the initial diary participants, 516 (43 percent) participated for the full year, 906 provided some information that could be used, and 372 actually returned their diaries. Telephone calls were placed every three months throughout the year to encourage continued participation and to gather information that was recorded in the diaries; as a result, data were available from participants even when they did not return their diary.

The mean number of fish meals consumed by Lake Ontario anglers in 1992 was 30.3 meals, with 28 percent, on average, being sport-caught fish. Overall average meal size was 216 grams per meal (just under eight ounces). The average sport-caught meal size was larger (232 grams per meal) than fish meals from other sources, so that sport fish comprised 30 percent, on average, of grams consumed. Nearly all of the respondents (95 percent) reported awareness of health advisories. Half of the respondents reported no consumption of sport fish from Lake Ontario, 14 percent ate amounts of sport fish from Lake Ontario that were within the recommended limits, and 36 percent exceeded advisory recommendations for Lake Ontario (although 90 percent of these people believed they were in compliance). Connelly *et al.* (1996) reported that advisories have been in place for Lake Ontario since 1978 and that the 1992 advisory recommended either no consumption or no more than one meal per month of Lake Ontario fish, depending on the species, and recommended no consumption for women of childbearing age and children under the age of 15. There was also a general advisory in place for New York State that recommended fish consumers limit total sport fish consumption to 52 meals per year.

The results from this study were used to estimate a mean consumption rate for total fish (from all sources) consumed by Lake Ontario anglers of 17.9 grams per day (Table 6). Although the median rate of consumption, 14.1 grams per day, was close to the mean, the authors reported that individual average daily fish consumption varied considerably, with ten percent of anglers (90th percentile) having consumed more than 34.2 grams per day, five percent (95th percentile) exceeding 42.3 grams per day, and one percent (99th percentile) consuming more than 56.6 grams per day. The authors reported that sport fish consumption from all sources (not just Lake Ontario) also varied. The use of risk-reducing cleaning methods (*i.e.*, trimming fat and removing skin) was high among Lake Ontario anglers. However, risk-reducing cooking methods were used less frequently, although health advisories also include recommendations for baking, broiling, and grilling as risk-reducing techniques.

The results of the 12-month recall questionnaire provided an estimated mean of 41.6 meals per year of fish from all sources. The authors reported that diary surveys are generally considered more accurate than recall methods. However, they also noted that consumption estimates for nonsport-caught meals were similar in the 1991 recall and 1992 diary portions of the study, and suggested that the lower estimate from the diary survey (30.3 meals per year) compared to the recall results (41.6 meals per year) for all fish meals may have resulted from a decrease in fishing Lake Ontario in 1992.

The diary survey also revealed monthly variation in consumption of fish from all sources, with highest consumption in the spring. Sociodemographic differences included higher rates of consumption of fish from all sources by older anglers, women, and out-of-state anglers. Residence was also a significant sociodemographic factor for consumption of sport fish, but consumption rates for sport fish did not differ significantly by age or sex.

The results from this study suggest that fish consumption behavior of Lake Ontario anglers has been affected by health advisories. Only 16 percent of anglers reported no consumption of sport fish, but approximately 50 percent did not eat fish from Lake Ontario. In addition, the number of meals of sport fish consumed appeared to decrease between 1991 and 1992, whereas the number of meals of commercial fish remained the same. Respondents were asked to estimate their

“desired” consumption (if there were no advisories), and 32 percent said they would eat more fish. However, it is difficult to quantify “true” consumption rates and the degree to which individual consumption patterns have changed (e.g., substitution of commercial fish meals for sport-caught fish; consumption of less fish overall). The authors concluded that current estimates of fish consumption may not reflect the desired or potential fish consumption that would occur if fish were not contaminated with chemicals. They further point out that regulatory decisions (i.e., discharge requirements for chemical contaminants) that are based on current suppressed rates of consumption will serve to reinforce and sustain the problem that resulted in the need for health advisories.

e. 1985 Wisconsin Angler Study

The Wisconsin Division of Health conducted a cross-sectional study of licensed Wisconsin anglers to assess sport fishing and fish consumption habits and to evaluate comprehension and compliance with the state’s fish consumption advisory (Fiore *et al.*, 1989). Questionnaires were mailed to 1600 licensed anglers, containing questions regarding fish consumption in 1984, targeted species, kilograms caught and kept for eating by family members, fish preparation, cooking methods, demographic characteristics, and knowledge of and compliance with the Wisconsin fish consumption advisory. The study also measured body burden of PCBs and DDE (in 200 respondents) to determine possible correlations between sport-caught fish and body burden of PCBs and DDE. Fifty percent of anglers returned survey questionnaires.

The mean number of sport-caught fish meals reported for 1984 was 18 and the mean number of commercial fish meals was 24. The mean number of all fish meals reported was 41. For anglers only who reported eating fish in 1984, the mean number of fish meals was 42. Although the survey was not specifically designed to obtain respondents’ daily fish consumption, the authors derived an estimated daily fish intake from both sport-caught and commercial sources by assuming an average meal size of 227 grams (8 ounces). They estimated a mean daily intake of 26.1 grams per day, and 63.4 grams per day at the 95th percentile, from all fish meal sources (sport-caught and commercial). The mean daily sport-caught fish intake was estimated at 12.3 grams per day, and at the 95th percentile, 37.3 grams per day (Table 6).

f. 1991-1992 Columbia River Basin Fish Consumption Survey

The Columbia River Inter-Tribal Fish Commission (CRITFC) entered into a Cooperative Agreement with U.S. EPA to conduct a fish consumption survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin (CRITFC, 1994). The objective of the survey was to identify individual tribal members’ consumption rates, patterns, habits, and preparation methods of anadromous and resident fish species caught from the Columbia River Basin. Concerns regarding exposure to dioxins and other waterborne toxins through ingestion of contaminated fish prompted the survey. Personal interviews conducted on the four tribal reservations resulted in achieving the targeted 500 interviews (69 percent response rate from 744 total individuals randomly selected from health records to achieve representation from four tribal lists). A total of 513 tribal members 18 years and older were surveyed over a

three-week period in November 1991; respondents also provided information for 204 children aged five and younger. The survey questionnaire included a 24-hour diet recall and questions regarding seasonal and annual fish consumption (e.g., average number of fish meals weekly). Foam sponge food models approximating 4, 8, and 12-ounce fish fillets were used to help respondents estimate the amounts of fish consumed.

Although tribal members were randomly selected to participate, respondents were subsequently self-selected in that they chose to appear at the interviews held in a centralized location on each reservation. People living farther from this center may not have been as well represented, and more females than males chose to participate in the study. The interviews took place in November, which was one of the designated months of lower consumption. The authors also noted that consumption rates may have decreased relative to consumption by tribal members in the past as a result of diminished supplies (availability of fish) over time. The data on consumption were weighted to account for differences in population size among tribes in order to obtain an unbiased population mean from the pooled (four tribes) dataset.

CRITFC (1994) presented consumption rates that were derived by averaging consumption for both consumers and nonconsumers (i.e., based on a population sample that included both fish consumers and non-fish consumers) in order to be more representative of the tribal population as a whole, although they indicated that this rate would not be appropriate for risk assessment. The mean rate of consumption for all surveyed adults (consumers and nonconsumers) throughout the year was determined to be 58.7 grams per day (Table 6). Seven percent of respondents indicated they did not consume fish. Excluding nonconsumers, the mean rate of fish consumption for consumers was 63.2 grams per day (Table 9). Most fish were consumed during the months of April through July, resulting in a mean rate of 108 grams per day during May and June, the two months most frequently indicated to be high fish consumption months. November through February represented months where fish were consumed the least. In January and December, the two most frequently chosen months of low fish consumption, survey respondents consumed, on average, 30.7 grams per day. Overall, the researchers reported the mean rate of consumption during the high months (April-July) as being three times higher than the mean rate of consumption in low months (November-February).

Approximately 83 percent of the 204 tribal children five years of age or younger were reported to eat fish. The mean rate of consumption for children who consumed fish was 19.6 grams per day. The calculated mean consumption rate for nursing mothers or mothers who had nursed was 59.1 grams per day, nearly the same amount of fish as the general tribal population. Female tribal members had a mean intake of approximately 56 grams per day, significantly different from the mean of 63 grams per day for males. Respondents reported consuming the fillet, skin, head, eggs, bones, and other organs. Baking and pan-frying were the most commonly reported cooking methods. Canning and smoking were also reported as common methods for preserving fish. The species most commonly consumed were salmon, lamprey, and smelt, of the anadromous species, and trout, of the resident species; salmon was consumed in the greatest quantity. Estimates of consumption rates included commercially obtained fish and/or shellfish. However, CRITFC (1994) reported that approximately 88 percent of the fish that tribal members consume originates from the Columbia River system. In addition, 70 percent of respondents

reported that none of the fish they consumed was obtained from stores, and only seven percent of respondents reported obtaining half or more of their fish from grocery stores.

g. 1994 Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region

A survey of fish and shellfish consumption by two of the fourteen Puget Sound Indian tribes was conducted in 1994 (Toy *et al.*, 1996). The objectives of the study included description of preparation methods and sources of acquisition in addition to determining rates of consumption of anadromous, pelagic, bottom fish, and shellfish in grams per kilogram of body weight per day for the participating tribes. The Tulalip tribes (a conglomeration of tribes) and the Squaxin Island tribe were selected nonrandomly to represent "the expected range of fishing and fish consumption activities of tribes in the region." The target population included adult enrolled tribal members who lived on or within a fifty mile radius of the reservation and children aged five or younger who lived in the enrolled member's household. In total, 190 successful interviews were completed with adult respondents during March through mid May. A parent or guardian from the same household answered questions about consumption by children. Only one child per household, selected randomly, was included in the survey, for a total of 69 children. Participants were selected randomly from tribal enrollment lists and were mailed introductory letters followed by phone calls to schedule interview appointments. Target sample sizes were calculated on the basis of standard deviations determined in other surveys in the region with the intention of achieving confidence intervals in which the upper and lower bounds of confidence would lie within 20 percent of the estimated mean consumption rate. The intended sample size was also increased to account for an expected refusal rate of 20 percent and an additional five percent of unusable interviews. The actual number of interviews conducted closely approximated the planned target number. However, results from half (73) of the adult respondents in the Tulalip tribe were dropped because it was discovered after the interviews were completed that one of the interviewers did not follow survey procedures. Repeat interviews were conducted by telephone as a follow-up with ten percent of the survey respondents, using five key questions from the survey instrument to check the reliability of responses. Adults who did not consume fish (less than one percent of those contacted) were excluded from the survey; respondents not consuming fish or shellfish within any of the specific groups (*e.g.*, anadromous; pelagic) were included and a value of zero was assigned for that species group and used in calculating descriptive statistics for the survey population. Models of most of the fish and shellfish species were constructed and used to estimate portion sizes; surrogate models or estimates (in ounces) without a model were used for a few of the species. Preparation methods were categorized as either those that allow toxins to leach out (*e.g.*, baking or broiling) or those that tend to seal in toxins (*e.g.*, canned, fried, or raw). Sources of fish and shellfish consumed were queried and mean percentages of sources were reported by tribe and species groups; consumption rates were not determined separately for sport and commercial sources.

Weight-adjusted consumption rates were calculated by tribe, age, gender, income, and species group. The authors reported the median, mean, and 50th, 90th, and 95th percentile rates of consumption for adults in each tribal community separately and combined (in grams per

kilogram of body weight per day) for each of the categories of fish and shellfish and for total (all forms of) fish and shellfish combined. They also provided detailed descriptive characteristics of the respondents in each tribe and reported median and 90th percentile rates of consumption for children. Overall, the median consumption rate for adults for total fish and shellfish was 0.55 grams per kilogram of body weight per day for the Tulalip tribes and 0.52 grams per kilogram of body weight per day for the Squaxin Island tribe (Table 9). Anadromous fish and shellfish were the groups of fish most frequently consumed. The difference in average (both mean and median) total fish consumption by each tribe was not statistically significant, however, adult consumption rates differed substantially between tribes for subgroups of fish. For example, the Tulalip tribal members consumed substantially more shellfish than did respondents from the Squaxin Island tribe. The 95th percentiles of total fish and shellfish consumption (2.9 to 3.0 grams per kilogram of body weight per day) were reported to be at least five times as large as the median consumption rate (Toy *et al.*, 1996).

Median consumption rates were also reported in grams per day (unadjusted for weight) by sex and by tribe. The median rates for the Tulalip tribes were 53 grams per day for males and 34 grams per day for females. Median rates for the Squaxin Island tribe were 66 grams per day for males and 25 grams per day for females. These rates reflect differences in body weight by sex and by tribe.

The median consumption rates for children between birth and five years were 0.08 grams per kilogram of body weight per day for the Tulalip tribes and 0.51 grams per kilogram of body weight per day for the Squaxin Island tribe. The average age and weight of children surveyed from each tribal community were similar (approximately 30 months and 15 kilograms) although the gender composition differed (57 percent Tulalip boys versus 40 percent Squaxin Island boys). The results for children from both tribes included nonconsumers (29 percent for the Tulalip and 25 percent for the Squaxin Island children) and some of the percentiles were based on very few numbers of children.

The resemblance between results from in-person interviews and follow-up phone re-interviews varied considerably across respondents, fish species, and tribes. The authors suggested that the telephone re-interviews were less accurate than the in-person interviews and cited timing, questions out of context, distractions in the home, lack of prescheduled time, and lack of models as contributing factors to the differences in responses from the telephone re-interviews. Toy *et al.* (1996) also indicated that, in general, long-term recall bias would be expected to be minimized in their study because recall is more accurate for foods eaten habitually, and fish and shellfish are an integral part of Native American diet and culture.

The authors reported that both tribes prepared fish using methods that may allow for reduction in chemical concentration more often than those methods that tend to seal in toxins. However, a substantial percentage of fish was prepared using methods from the latter category. The main source for the most heavily consumed fish group (anadromous fish) was Puget Sound, supplying 72 to 80 percent, on average, of anadromous species consumed by each tribe. Sources for other types of fish and shellfish were more variable; commercial sources (grocery stores and restaurants) represented larger percentages (ranging from 43 to 69 mean percent) of pelagic and bottom fish whereas anadromous fish and shellfish (which represented most of the seafood

consumed) were usually obtained from local water bodies (ranging from 69 to 91 mean percent). The majority of fish consumed was comprised of fillets without skin. However, fillets with skin were consumed by up to 40 percent of respondents, on average, and mean percent consumption of other fish parts including head, bones, eggs, organs, and skin, ranged up to 11 percent of respondents eating anadromous fish⁹. Roughly one third of the respondents from each tribe reported that their consumption of fish or shellfish had changed in the last twenty years, one third reported no change, and one third reported that they didn't know whether their consumption had changed.

h. 1992 Sulphur Bank Mercury Mine/Clear Lake, California - Biological Testing

Harnly *et al.* (1997) collected and analyzed blood, hair, and urine samples for mercury from 68 individuals living near an inactive mercury mine bordering Clear Lake, a large recreational lake. Interviewers personally administered a questionnaire covering fish consumption (sport fish caught from Clear Lake and commercial fish) over the six-month period prior to the interview, as well as potential inorganic mercury exposures to participants. Respondents included 63 members of the Elem Native American community bordering the old mine site and five additional nearby residents. For the 23 individuals reporting consumption of Clear Lake fish, the average amount consumed was 60 grams per day (Table 6). The report also indicated that 32 individuals reported consuming commercial fish (canned tuna was the most common type) at an average rate of 24 grams per day. The authors did not indicate what portion of the population ate both sport fish and commercial fish, and did not estimate consumption rates inclusive of both sport-caught and commercial fish. It should be noted that health advisories recommending limited consumption of fish from Clear Lake were in effect during the survey.

i. 1994 Urban Fishers and Crabbers in New York/New Jersey Harbor Estuary

May and Burger (1996) reported on fishing and consumption behavior and risk perception by fishers and crabbers using one of three regions along the New Jersey shore where fish and shellfish consumption advisories had been issued. Interviews were conducted with a total of 318 fishers or crabbers from the three regions, including 46 crabbers, 221 fishers on shore and 100 fishers on party boats, from May through September 1994. Data on location, activity, weather, residence, age, and occupation were recorded and the interviews included questions on the frequency of fishing, catching and eating fish; cooking methods; and awareness and understanding of advisories. Estimates of the average serving size and frequency of consumption were calculated for each region as well as average and "worst case" rates of consumption in the most heavily fished region, Arthur Kill. All fishers and crabbers at a location were approached for interviews and most agreed to participate (although only one person per group of fishers was interviewed and individuals were not interviewed more than one time). May and Burger (1996) reported on the percentages of people eating their catch and the percentages purchasing commercial species. However, their estimates of consumption did not distinguish between commercial and sport-caught fish and shellfish.

⁹ Mean percentages varied by tribe and by fish species group.

Most fishers and crabbers were male, and age varied among regions, ranging from 36 to 48 years on average. Most fishers (85 percent) and crabbers (91 percent) at Arthur Kill were local residents whereas the percentages of residents fishing in the other two regions were considerably lower (27 percent and 25 percent). At least 70 percent of fishers in all regions indicated that they consume their catch. The overall average number of times fish were eaten was 4.6 times per month. The average serving size ranged among regions from 10.3 to 11.5 ounces. Over 40 percent of the fishers reported that more than half of the fish consumed was self-caught, and 20 percent ate only self-caught fish. Most fishers (78 percent) also indicated that they buy commercial fish, and 58 percent indicated that more than half of the fish they eat are purchased in the store. Most fishers said they did not fish during winter, however, some reported freezing their catch for consumption at other times of the year. May and Burger (1996) also noted that sixty percent of those interviewed at Arthur Kill, and 28 percent and 30 percent of fishers in the other two regions, had heard warnings about consuming fish from the area.

In the Arthur Kill region, more than 75 percent of crabbers ate their catch and more than 65 percent indicated that at least three-fourths of the crabs they ate were self-caught. Forty-six percent reported eating only self-caught species. An average of 9.5 crabs was eaten per meal at an average frequency of 3.7 times per month; the maximum frequency was 16 times per month. Most crabbers reported cleaning the crabs to remove the hepatopancreas; fewer than three percent said they ate whole crabs.

May and Burger (1996) multiplied the average (4.8) and maximum (20) number of fish meals eaten per month by average serving size to calculate estimates of average and "worst case" consumption rates for fishers in the Arthur Kill. They determined average and worst case consumption rates for fish of 52.8 grams per day and 220 grams per day, respectively (Table 6). These rates included both sport-caught and commercial fish. They similarly determined average and worst-case consumption rates for crabs, using 160 grams of muscle per crab, of 187 grams per day and 810 grams per day, respectively.

j. Per Capita Fish and Shellfish Consumption in Florida

A comprehensive survey of per capita consumption of seafood including commercially and recreationally obtained species, and both at-home and away-from-home consumption was conducted in Florida using telephone interviews for a one-year period from March 1993 through March 1994 (Degner *et al.*, 1994). A smaller number of personal interviews were also conducted with food stamp recipients in several counties. Extensive statistical analyses of the data were also performed and reported by Portier *et al.* (1995). A thorough review of this study is not included here, as the methodology differed from other regional studies and the results are likely to be applicable mainly to "per capita consumption" by populations in this particular region of the U.S. (Florida). However, references are provided to facilitate access to the results from this study for situations in which the data may be appropriate and/or useful.

2. Fish Consumption Rates for Sport Fish from Marine and/or Estuarine Water Bodies

Fish consumption surveys of sport fishers using marine and/or estuarine water bodies are presented in the following section and summarized in Table 10.

a. 1991-1992 Santa Monica Bay Seafood Consumption Study

The Santa Monica Bay Restoration Project contracted with the Southern California Coastal Water Research Project (SCCWRP) and MBC Applied Environmental Sciences to conduct a seafood consumption study from September 1991 to August 1992 (SCCWRP and MBC, 1994; Allen *et al.*, 1996). The objectives of the study were to describe the demographic characteristics of "recreational anglers" fishing in Santa Monica Bay, California, to assess their seafood consumption patterns, to identify ethnic subgroups of the population with high consumption rates, and to determine species being caught and consumed at the highest rates. The survey form included a census and a questionnaire. The census served to collect information about site characteristics such as location and weather conditions, and to record the number of anglers at specific survey sites and some basic demographic characteristics (*e.g.*, ethnicity, gender, and age) of the observed fishing population. The questionnaire was administered to randomly selected anglers fishing from piers and jetties, private boats, party boats, beaches, and rocky intertidal zones. It consisted of a series of questions personally administered by interviewers to individual anglers to obtain information on site characteristics and the angler's fishing history, consumption patterns, age, gender, ethnic background, and household income.

During the summer months (September 1991 and June through August 1992) interviews were conducted during two weekday/weekend sets (a set consisted of one weekday plus one weekend

¹ The fishers interviewed in this study were referred to as "recreational anglers" although they included people fishing for shellfish and thus were not necessarily limited to anglers using the hook-and-line method to obtain their catch.

day) per month for each of the three major fishing modes⁵, for a total of 12 surveys per month. During nonsummer months (October 1991 through May 1992) interviews took place on one weekday and one weekend day per month for each of the three fishing modes, for a total of six surveys per month. Fishing modes, geographical regions, and specific sites were selected prior to the study to maximize spatial coverage. Sampling times and sequence were randomly selected each month. Late-night fishers who fished only during the night would have been excluded from the sample population.

Twenty-nine sites were surveyed on 99 days of sampling for a total of 113 surveys, with 2,376 anglers included in the census (41 percent on party boats, 37 percent on piers, 20 percent on private boats, 1 percent on beaches, and 0.5 percent at rocky intertidal sites). Over 1,200 interviews (71 percent) took place out of 1,740 attempted interviews (571 anglers in nonsummer months and 672 anglers in summer months). Of the successful interviews, 555 anglers (45 percent) provided information used to derive consumption rates. Interviewers encountered the lowest success rate (66 percent) on piers. Interviewees were asked whether they had been interviewed previously; the number of repeated interviews was seven. For those who completed interviews, 93 percent were male and 7 percent were female, with the majority (54 percent) between the ages of 21 and 40 years. The results of the census showed that about one-third of the respondents had not fished in the bay during the four weeks prior to the interview, and that a small population, 2 percent of the respondents, appeared to fish every day. Thus, this study targeted fishers exhibiting a broad range of fishing effort, and may have included some subsistence fishers. However, only respondents who consumed fish at least one time during the one-month survey period were included in estimates of consumption and thus, the distribution of consumption rates generally represents consumers with a minimum sport fish consumption frequency of once a month.

SCCWRP and MBC (1994) identified ethnic groups among those interviewed and reported the composition of the subpopulation used to derive consumption rates as being approximately 40 percent Whites, 10 percent Blacks, 25 percent Hispanics, 22 percent Asians (consisting of Filipinos, Japanese, Koreans, Chinese, and Vietnamese), and 3 percent Other (consisting of one Thailander, one East Indian, three Samoans, three Hawaiians, three Indonesians, one Guamanian, and one Malaysian). Interviewers were able to administer the questionnaire in English, Spanish, Vietnamese, Chinese, and Tagalog. Of the successfully completed non-English speaking interviews, 95 were conducted in Spanish and four in Vietnamese. Language barriers (Korean, Armenian, and a few others) prevented interviews with 149 (9 percent) of the anglers that were approached (Allen *et al.*, 1996). In comparison to the ethnic composition of Los Angeles County in 1990, SCCWRP and MBC indicated that the surveyed population of Santa Monica Bay anglers had a greater proportion of Asians, Whites, and other ethnic groups, a much lower proportion of Hispanics, and a similar proportion of Blacks.

Annual household income information was not available for 27 percent of responding anglers. Of those providing information on income, about one-third (32 percent) reported incomes greater than \$50,000, 39 percent reported incomes between \$25,000 and \$50,000, and 19 percent

⁵ Fishing mode refers to the type of place or platform from which fishing occurred. NMFS identified three fishing modes: 1) shore, including piers, jetties, breakwaters, bridges, beaches, etc., 2) party or charter boats, and 3) private or rental boats.

reported incomes between \$10,000 and \$25,000. About 6 percent reported incomes between \$5,000 and \$10,000, and 5 percent reported annual incomes less than \$5,000. The majority of Hispanic anglers reported annual household income in the lower income brackets (<\$25,000) whereas the majority of all other ethnic groups reported annual household incomes exceeding \$25,000, and the majority of Korean and Chinese anglers reported incomes greater than \$50,000.

A larger proportion of respondents who reported on consumption was encountered on boats (61 percent) than on land (39 percent). With respect to ethnicity and fishing mode, Hispanics fished most often on piers and jetties, and Whites were most represented on party and private boats. Asians (mainly Koreans and Chinese) ranked second for fishing on party boats. With respect to household income and fishing mode, respondents with annual incomes less than \$25,000 tended to fish on piers and jetties, while those with incomes greater than \$25,000 tended to fish from party boats and private boats.

Anglers were questioned about consumption of eight commonly consumed species of fish as well as about fish they had in hand. Consumption rates were calculated by multiplying the angler's estimate of his/her typical meal size of a species relative to a balsa wood fillet model representing 150 grams (*e.g.*, twice as much, three times as much, half as much, etc.) by the frequency of consumption of that species in the four weeks (28 days) prior to the interview. For fishers with fish in hand, the frequency of consumption was increased by one to account for consumption of the catch present at the time of the interview. For fishers without fish in hand, photographs were used to identify species, and only those anglers that had eaten the species in the prior four weeks were included in the estimates of consumption rates.

A second method of calculating consumption rates based on fish in hand and estimates of the amounts available for consumption ("consumable portions") was also employed. However, because the "fillet model" method was based on specific information provided by the anglers and utilized fewer assumptions, it was considered more appropriate to use than the "consumable portions" method. A comparison of the results using each method showed no significant differences in median consumption rates for all species combined although the rates derived for individual species were more variable (Allen *et al.*, 1996). Consumable-portion method estimates were generally higher than fillet-model estimates for larger-sized species and lower for smaller-sized species.

SCCWRP and MBC (1994) reported the overall mean consumption rate for Santa Monica Bay anglers as 49.6 grams per day. Respondents in the Other group (represented by 14 individuals mainly of Pacific Island origin) had the highest mean consumption rate (137.3 grams per day) compared to the White, Hispanic, Black, and Asian groups (Table 11a). SCCWRP and MBC (1994) reported using a one-way analysis of variance (ANOVA) to compare consumption rates by ethnicity and found significant differences. Pairwise comparisons showed that Whites had a significantly higher rate of consumption than Hispanics, and individuals in the Other group had a significantly higher consumption rate than Filipinos, Hispanics, Japanese, and Whites.

The frequency distribution of consumption rates was found to be highly skewed (to the right), and thus, the use of medians and upper percentiles for describing central tendency and variation was recommended (SCCWRP and MBC, 1994; Allen *et al.*, 1996). (The mean rate of

49.6 grams per day roughly corresponded to the 75th percentile of the frequency distribution for consumption by the respondents.) The median consumption rate for the overall surveyed population was 21.4 grams per day. Median consumption rates for the various ethnic groups ranged from 16.1 to 85.7 grams per day, with Hispanics having the lowest median rate, followed by Whites and Asians (both 21.4 grams per day), Blacks (24.1 grams per day), and those in the Other group having the highest median rate (Table 11a). SCCWRP and MBC (1994) selected the 90th percentile to represent upper level consumption rates. Among ethnic groups, these values ranged from 64.3 to 173.6 grams per day, again with Hispanics having the lowest and Other having the highest rates.

With respect to income, SCCWRP and MBC (1994) found that the lowest income group (<\$5,000/year, reported by 20 respondents) had the highest median consumption rate (32.1 grams per day) of all income groups. However, the highest income group (>\$50,000/year, reported by 130 respondents) had the highest mean consumption rate (58.9 grams per day) and the highest consumption at the 90th percentile (128.6 grams per day). Mean and upper level (90th percentile) consumption rates increased as income increased, with the exception of the lowest income group (<\$5,000), which had mean and upper percentile rates in the mid-range. It should be noted that a larger percentage (two-thirds) of the population of consumers was comprised of higher income anglers (>\$25,000 per year).

SCCWRP and MBC (1994) also demonstrated that median consumption rates differed by fishing mode, with party boat anglers (21.4 grams per day) consuming more than pier and jetty or private boat anglers (16.1 grams per day). Hispanics, who predominated in the lower income brackets, accounted for almost 39 percent of the pier and jetty anglers. The ethnic groups having the greatest annual household income were most abundant on party and/or private boats, and included Whites, Koreans, and Chinese. These results suggest the possibility that those who could afford to fish from boats, had greater fishing success, and thus consumed more fish.

Consumption data for the Santa Monica Seafood Consumption Study have principally been presented as consumption rates, *i.e.*, grams per day or kilograms per individual per month (SCCWRP and MBC, 1994; Allen *et al.*, 1996). Although information on meal size was obtained in the survey, data have not been presented to summarize information regarding usual or typical meal size or meal frequency. With respect to preparation and cooking methods, about 65 percent of the anglers reported consuming steaks/fillets, 33 percent consumed fish whole/gutted, and 1 percent reported eating whole fish with intestines. Among the ethnic groups, Asians were more likely to eat fish whole/gutted than other ethnic groups. White anglers were more likely to eat fish steaks/fillets and least likely to consume fish whole/gutted. Frying was the most common cooking method for each ethnic group.

Allen *et al.* (1996) combined individuals in SCCWRP and MBC's original Other group with the Asian subgroup to form a larger Asian subgroup (similar to what Puffer *et al.*, 1982, described below, did to define their Oriental/Samoan group) with a mean consumption rate of 60 grams per day. Their analysis demonstrated that Whites and Asians, inclusive of Pacific Islanders, had significantly greater consumption rates than Hispanics.

b. 1980 Los Angeles Metropolitan Area Survey

In an earlier (1980) survey of the Los Angeles metropolitan area represented by the Santa Monica Bay, Puffer *et al.* (1982) assessed consumption rates of potentially hazardous marine fish and shellfish by local nonprofessional (noncommercial) fishermen. In total, 1,059 fishers were interviewed at twelve sites, including people fishing from piers, shore, and breakwater areas, as well as party boats, but not private boats. No fisher was interviewed more than once during the yearlong study period. Surveys were conducted approximately three times per month on different days and at different times. Surveyors recorded the number of fishers at a site, and their sex, race, and approximate age. Interviews were conducted only with successful fishers (those with fish in hand). Ethnic groups in the survey population included Caucasian (42 percent), Black (24 percent), Mexican-American (16 percent), and Oriental/Samoan (13 percent), but interviews were only carried out in English.

Daily consumption for each species caught was based on fish in hand and was calculated using an equation that factored in the number of fish or shellfish in the catch, the average weight in the catch, the edible portion by weight of the species, the number of fish eaters in the family/living group, and the frequency of fishing per year. It was assumed that the number of family fish eaters was constant over the study period and that the catch was shared equally among family members. Additionally, assumptions about the number and average weight of the fish representing a typical catch for a given fisher were used to estimate consumption. The authors noted that the survey may have been biased toward the most frequent fishers and underrepresented youths (≤ 17 years) who fished with older family members.

Puffer *et al.* (1982) estimated the median amount of sport fish and/or shellfish consumed to be 36.9 grams per day and the 90th percentile to be 224.8 grams per day (Table 12a). Significant differences in consumption rates were found by age and by ethnicity. Individuals over 65 years had the highest median rate of consumption (113.0 grams per day). Among ethnic groups, Puffer *et al.* (1982) found that the Oriental/Samoan group had the highest median consumption rate (70.6 grams per day), followed by Whites (46.0 grams per day), Mexican-Americans (33.0 grams per day), and Blacks (24.2 grams per day). Consumption by fishing mode or by income was not reported. About half of the respondents reported eating fish one to two times per week, and about 20 percent reported eating fish greater than, or equal to, three times per week. The authors also found that 71 percent of the respondents reported freezing fish for later consumption.

Puffer *et al.* (1982) reported that shellfish, primarily crabs and mussels, comprised three percent of the catch, although they did not indicate whether this percentage was based on edible weight, amount consumed, or some other factor. They also reported that shellfish (including crabs, mussels, and abalone, collectively) were among the 12 primary types of "fish" kept by sport fishers, that three percent of the fishers interviewed obtained shellfish, and that 97 percent of them consumed the catch. They estimated the median rate of consumption of shellfish at 10.0 grams per day per person.

c. 1988-1989 San Diego Bay Health Risk Study

The San Diego County Department of Health Services (SDCDHS, 1990) conducted a study to estimate the potential health risks associated with consuming fish from San Diego Bay. Certified SCUBA (self-contained underwater breathing apparatus) instructors interviewed 369 anglers using a survey questionnaire at popular fishing locations (boat launch areas, piers, and shorelines) over a one-year period to identify fish species most commonly caught in the bay, to identify demographic characteristics of anglers, and to characterize fish consumption patterns. Consumption rates were derived assuming the catch was evenly distributed among consumers within a household and that 30 percent of the measured catch was edible. Fishing frequency was also factored into the equation. "Individual" rates (per interview) were calculated and used to derive a bay-wide consumption average that applied weighting factors for the number of consumers per "individual" consumption rate. For example, a rate that applied to six consumers would count six times as heavily as one that applied to a single consumer. Average rates based upon the subset of the population that caught and ate fish were then adjusted to account for the percentage of interviewed anglers who had not caught fish at the time of the interview. Only 59 anglers indicated that they fish year-round and provided all the necessary data for calculating individual fish consumption rates.

The authors derived an overall bay-wide fishing population mean of 31.2 grams per day (Table 12b). Five ethnic subpopulations were identified (White, Filipino, Hispanic, Asian, and Other). Although the authors suggested that Filipinos and Asians consumed fish at higher rates than Whites and Hispanics, consumption rates for ethnic groups could not be reliably estimated because sample sizes were inadequate. Sample size for the overall survey of anglers was also small. Therefore, the results provide only limited information about consumption rates among San Diego Bay fishers.

d. 1993 San Francisco Bay Seafood Consumption and Information Project

The Save San Francisco Bay Association (SSFBA) released a report *Fishing for Food in San Francisco Bay: Part II*, that described a study they conducted from September to November 1996 to obtain information about demographic traits and fish consumption habits of people fishing from ten San Francisco Bay public piers (Wong, 1997). Surveyors conducted personal interviews with approximately 200 people fishing or crabbing, using a questionnaire and fish fillet model (representing 150 grams) to assist with estimating the amount of fish eaten at a meal.

Ninety-one respondents (42 percent) reported having eaten fish from the bay in the prior 30 days. These respondents were then asked to recall for the prior seven days the amount of bay-caught fish consumed by himself/herself only. Sixty-two respondents (29 percent) reported consumption of bay-caught fish in the seven-day period preceding the interview; the information provided by these people was used to estimate median consumption by ethnic group and overall. However, sample sizes for each ethnic category were small and the differences reported were not compared statistically. Overall, SSFBA calculated a median consumption rate of 32 grams per day and reported that of those people that ate fish and/or shellfish from the bay, 90 percent

exceeded health advisory recommendations (which were in effect during the survey). The ethnicities of the 62 respondents reporting consumption of fish or shellfish from the bay during the prior seven-day period were African American (10 percent), Asian/Pacific Islander (60 percent), Caucasian (13 percent), Latino (11 percent), and Mixed Race (6 percent). This study was one of the first surveys of fish consumption behavior for fishers in San Francisco Bay⁴, however, the selection of survey sites was nonrandom and sample sizes were small. Therefore, this study provided some limited information on consumption rates and demographic characteristics for San Francisco Bay fishers. However, the study also obtained supplemental information on fishing and consumption behavior including the consumption of organs and tissues other than muscle fillets.

e. 1980 Commencement Bay Seafood Consumption Study

Pierce *et al.* (1981) interviewed about 500 fishermen from July through November 1980 for the Tacoma-Pierce County Health Department in Washington to identify fish and shellfish consumption habits and demographic characteristics of noncommercial fishermen fishing in four subareas of Commencement Bay. The objectives of the survey were to determine the extent to which local species of fish and shellfish (specifically crustacea) were used as food and which species were most commonly consumed, to assess methods of preparation of the catch, and to develop a health risk model. Only successful fishermen were interviewed, and salmon caught by interviewed fishermen were not included in the study because they were considered to have minimal contact with Commencement Bay pollutants due to their migratory behavior. Surveys were conducted in the mornings and evenings. Each subarea was sampled five times during the first half of the survey (summer) and four times during the second half (fall), except for one area that was sampled only twice during the second half. The boat fishing area was sampled four times during the second half of the survey only. Although sampling periods sometimes lasted as late as 1:00 a.m., the authors noted that a considerable portion of total catch was suspected to have been obtained during all-night fishing. The racial composition of the surveyed population was reported as White (60 percent), Black (23 percent), Oriental (15 percent), and Mexican (2 percent).

In the first half of the survey, which did not include boat fishing, the authors derived a mean daily catch of 208 pounds, and estimated that approximately 95 percent of the catch, representing 197 pounds of fish or seafood, would be taken home by fishermen for personal consumption. This amount corresponds to about 3.5 pounds of fish per fisherman, representing 1.7 pounds of edible tissue. The average size living group (household) for the surveyed population was determined to be 3.74 persons. Thus, dividing 1.7 pounds by 3.74 persons results in nearly one half pound (0.45) per person per day. The addition of boat fishing during the second half of the survey increased the average daily catch to 409 pounds, representing about one pound of edible fish tissue per person per day.

⁴ A report by the Asian Pacific Environmental Network (APEN) entitled *A Seafood Consumption Survey of the Laotian Community of West Contra Costa County, California* was released in March 1998. This survey used a community-based approach to target and examine the seafood consumption practices of a San Francisco Bay area Southeast Asian refugee community. In addition, a study of San Francisco Bay fishers was completed in 2001 by the San Francisco Estuary Institute.

U.S. EPA (1989a) used the estimated daily consumption rates derived from this study^u of 23 grams per day at the 50th percentile and 54 grams per day at the 90th percentile, in combination with the consumption rates reported by Puffer *et al.* (1982), to derive recommended default values for recreational fishers (as discussed below). However, because salmon catch was excluded from the study, the actual consumption of fish and shellfish could have been considerably higher than what was calculated. On the other hand, the study did not address consumption rates for fishers who did not have fish or shellfish at the time of the interview. Additionally, sampling did not include the winter or spring periods. Therefore, the results of this study provide only a crude estimate of the amount of catch available for consumption by fishers in Commencement Bay.

f. 1983-1984 Puget Sound Survey

Landolt *et al.* (1985, 1987) conducted a two-year study of recreational anglers' fish and shellfish catch and consumption from four urban embayments of Puget Sound^v. The objectives of the study were to identify the most commonly consumed species, demographic characteristics of the fishing population, and patterns of consumption (including frequency, amount, and methods of preparation), and "to estimate the quantity of selected chemicals consumed by anglers and their families." Species-specific catch and consumption information was obtained through personal interviews. Over 4,000 shoreside anglers were interviewed the first year (November 1983 through November 1984). Initially, sampling times were selected at random and interviews were conducted at all times of the day, until the most preferred fishing times were identified. Subsequent sampling focused on those times when the most fishers were expected. Apparently no effort was made to avoid repeated sampling. The second year of the study focused primarily on chemical analyses of tissue specimens caught during the first year, but catch and consumption patterns for boating anglers at two of the embayments were also evaluated. During the second year, 437 boating anglers were interviewed from February to October 1985.

Calculations of consumption rates were based on estimates of the weight of the catch (fish in hand) divided by the number of consumers reported for the household, and by the number of days since fish caught at the same site were last eaten. This value was multiplied by a cleaning factor of 0.3 for fish and 0.49 for squid and crab to derive the mean daily grams of available edible portion consumed per person. Geometric means were then calculated for each embayment and ethnic group. Consumption rates were reported as geometric means for all non-U.S. born Asians, and subpopulations of Filipino, Southeast Asian, and Chinese-Japanese, and for U.S. born groups including Whites, Blacks, and Asians (Table 12c). Species-specific consumption was also characterized for the time period in which that species was present in the fishery.

^u It is not clear how the consumption rates reported by U.S. EPA were derived as they do not match the amounts of edible fish tissue reported by Pierce *et al.* (1981). In addition, Price *et al.* (1994) performed a re-analysis of the data from this study and their estimates of consumption were higher than what U.S. EPA (1989a) reported and what was reported in the original study. Price *et al.* (1994) suggested that U.S. EPA did not have access to the full raw dataset and that estimates of the 50th and 90th percentile rates were made by interpolation from a distribution U.S. EPA constructed using the average amount of fish consumed per fishing trip, as reported by the authors, rather than individual consumption data.

^v The authors used the term "angler" although this survey included squid and crab in the catch.

Landolt *et al.* (1985, 1987) derived an overall geometric mean daily fish consumption rate of 11 grams per day for all ethnic groups and species. Quantities consumed varied by site and by species, and ranged from 8 to 14 grams per person per day (geometric means) among embayments. Consumption rates for the most common species were considerably higher than the overall average. For example, the most common species, squid, was consumed at a rate of 39 grams per day (geometric mean). However, this rate was only applicable in the season (Fall) in which the species was obtained. Landolt *et al.* (1987) noted that boaters fished predominantly for salmon, and consumed 51.7 grams per person per day (geometric mean) of King salmon from the two bays where boating anglers were surveyed.

Landolt *et al.* (1985, 1987) reported that the "average" shoreside fisher in Puget Sound was employed (57 percent), male (92 percent), educated for at least 12 years (77 percent), and White (69 percent). Preferred fishing times varied by embayment but peaked at all locations between 6:00 p.m. and midnight. More fishing occurred during the fall, when squid was sought. The "average" boating angler was reported to be employed (69 percent), male (96 percent), educated at least 12 years (91 percent), and White (86 percent).

The following ethnic differences were reported as significant findings. Ethnicity was correlated with fishing mode, with Blacks fishing more from bridges and Whites fishing more from boats. Asians had larger numbers of fish eaters per household than other ethnic groups, were more likely to fish on weekdays or at night, and were more successful at catching fish. Asians were more likely to consume portions of the catch other than the fillet. Asians and Whites were more likely to be employed than other ethnic groups. Whites were more likely to be interviewed repeatedly. Seasonality was an important factor for Blacks who fished more during the spring and less during the winter than Whites or Asians.

3. Fish Consumption Rates for Sport Fish from Fresh Water Bodies

a. 1990 Consumption of Freshwater Fish by Maine Anglers

ChemRisk (1992) conducted a mail recall survey of licensed freshwater anglers in Maine in order to determine potential exposure to dioxins from certain water bodies. The population of interest was defined as all respondents who fished in either the 1989-1990 ice fishing or 1990 open-water fishing seasons (actual time frames not provided) and all respondents who did not fish but consumed Maine sport fish from the identified sources. Questionnaires were mailed to 2500 resident anglers holding inland (freshwater) licenses; 1612 anglers (64 percent) responded with usable data. Respondents reported the number of trips made or planned during the 1989-1990 ice fishing and 1990 open-water fishing seasons, the number of each of 15 species caught (14 species were identified and a line was provided for "other"), the number of fish consumed for each of the 15 groups of species, and the number of fish taken from flowing or standing water bodies. Anglers were also asked to estimate the average length of each species consumed. Estimates of the amounts consumed were calculated using equations that factored in species-specific length-mass relationships and edible percentages, number of household consumers, and time over which fish was consumed.

The authors reported that the mean rate of consumption for consumers of fish from all types of fresh water bodies (including lakes, ponds, rivers, and streams) was 6.5 grams per day (Table 13), assuming that the catch was shared equally among a mean household size of 2.5 persons. They also reported a mean rate of 3.7 grams per day for consumers of fish obtained only from rivers and streams.

ChemRisk (1992) suggested that their fish consumption estimates were likely to be conservative due to survey, recall, and self-reporting biases, and proposed that the median, or 50th percentile (reported as 2.0 grams per day for consuming anglers) is a better measure of central tendency. The authors also reported that a high percentage of the respondents practiced "catch and release" even on undesignated (unrestricted) water bodies. Ebert *et al.* (1993) noted that the results of this survey fell at the low end of the range of freshwater fish consumption estimates and suggested that a number of geographic differences were likely to have contributed to the findings of relatively low rates of consumption. Fishing in Maine, particularly in fresh water bodies, would be limited due to seasonal climatic effects on water bodies and thus, the availability or accessibility of fish. The actual length of time of legal fishing seasons was not defined in the report. Additionally, the survey covered a limited target population. Members of the Native American Penobscot population were only sampled if they obtained a complimentary license to fish waters outside of their land. Therefore, most of the fishing effort by this subpopulation would not have been included in the survey. Advisories were in place for some of the water bodies included in the survey. Finally, the authors (ChemRisk, 1992) suggested that the low rates of consumption of freshwater species in the state were not surprising given the greater availability of saltwater species (both recreationally and commercially).

b. 1992-1993 Freshwater Fish Consumption by Alabama Anglers

A statewide survey was conducted from August 1992 to July 1993 to estimate daily fish consumption of freshwater fish harvested by anglers fishing from 29 locations throughout Alabama, including 23 tailwater sites and six reservoir sites representing 11 river drainages. Sampling days were selected within each of four seasonal blocks and a clustered sampling approach was used in which each study site was surveyed once per season for two consecutive days, one weekend and one weekday. Surveys were conducted from sunrise to sunset and sampling days were randomly assigned to sites. Anglers were intercepted and interviewed at the completion of fishing activity. All anglers that reported consumption of fish from the study areas were included in the analysis. All anglers interviewed were asked to report the number of 113-gram (4-ounce) fish servings they typically eat in a meal and to recall the number of fish meals eaten in the last month. A serving was determined by equating the entire surface (palm side) of the flat open hand to a single 113-gram serving. An ancillary study was conducted to equate palm size to serving weight of fish; the mean weights for hand-sized fillets ranged from 85 grams (three ounces) to 156 grams (5.5 ounces). Two methods were used to estimate daily fish consumption rates and the results from each method were compared. The "serving method" (based on reported consumption) was applied to both the number of fish meals eaten in the past month consisting of fish from the study sites ("site meals") and the number of fish meals eaten in the past month consisting of fish caught at the study sites and those caught at other lakes and

rivers in Alabama, excluding farm ponds (“all meals”). The “harvest method” used anglers who had caught fish and planned to eat their fish. These fish were weighed and weights were adjusted for edible portion size and divided by the reported number of consumers as indicated by the respondent. Interviews were conducted with a total of 1,586 anglers; 1,303 anglers (83 percent) reported that they consumed fish from the study sites and thus were included in the serving method estimates and 563 anglers (33 percent) were included in the harvest method.

Meredith and Malvestuto (1996) calculated the sample sizes needed to produce 90 percent confidence intervals of ± 15 percent around the means for each method and determined that the number of interviews using the harvest method did not meet the criteria. However, the estimates derived from each method were similar and the differences (less than 3 grams per day) were not statistically significant. Mean annual consumption rates were 30.3 grams per day (serving method) and 32.6 grams per day (harvest method) for site meals and 45.8 grams per day (serving method) and 43.1 grams per day (harvest method) for all meals (Table 13). Estimates of seasonal consumption rates were consistently lowest in the spring and highest in the summer. However, statistically significant differences were found only for the estimates of mean daily consumption rate for spring and summer derived by the serving method. The average number of meals per month ranged from 3.9 in the spring to 4.8 in the summer; the same estimates of seasonal frequencies were used for both methods.

Meredith and Malvestuto (1996) reported that the serving method likely masked true variability in serving size (due to angler responses typically being given in whole numbers) while the harvest method likely magnified this variability. This study indicated that use of the serving method (based on recall) is likely to provide more reliable estimates because an adequate and more robust sample size can be achieved without increasing the costs of conducting the survey. The authors also noted that field procedures were simpler with the serving method but that the harvest method would be advantageous to document the species and sizes of fish consumed. The authors cautioned that when harvested fish are used to estimate consumption rates, accurate methods are needed for determining edible portions as well as meal sizes. Although the two methods provided similar estimates of consumption rates in this study, Meredith and Malvestuto (1996) suggested that selection of study methodology should include consideration of the objectives of the survey, the type of data needed, and the efficiency (including cost effectiveness) of various methods, and that, in some cases, use of multiple methods may be advisable.

4. U.S. EPA Derived Consumption Rates for Recreational and Subsistence Fishers

U.S. EPA used data from the 1973-74 NPD many years ago to derive a consumption rate of 6.5 grams per day that was based on an analysis of the NPD dataset by Stephan (1980). This value was promoted by U.S. EPA for the derivation of national and state water quality criteria. The 6.5 grams per day value became a “default” value for consumption of fish that had far-reaching effects. Other agencies adopted the 6.5 grams per day default value (see further discussion below) although, in many cases, there was little or no understanding of the origin or applicability of this value. U.S. EPA also continued to use and promulgate 6.5 grams per day to

represent a default consumption rate for fish consumption in the U.S. (U.S. EPA, 1995). For example, U.S. EPA proposed using it to derive screening values^w for target analytes in fish in the context of providing guidelines for developing consumption advisories for consumers of sport fish, an at-risk population (U.S. EPA, 1995) despite the claim that the value represented the general U.S. population, including both consumers and nonconsumers. Additionally, the 6.5 grams per day value was derived for per capita consumption of nonmarine (freshwater and estuarine) species only, and the percentage of users of nonmarine species in the NPD survey was determined to be only about 14 percent of the U.S. population. Furthermore, U.S. EPA recognized that the NPD survey did not adequately address consumption of fish and shellfish by recreational or noncommercial fishers.

The default value of 6.5 grams per day for consumption of fish and shellfish was applied in innumerable instances for many years regardless of the appropriateness of the value and/or without an adequate understanding of its derivation and applicability. As an example, West *et al.* (1993) reported that the State of Michigan used 6.5 grams per day to represent fish consumption by the general population in the state although no studies had been conducted to determine whether this rate was appropriate for the general population in Michigan. West and colleagues further explained that when questioned about the origins of the value 6.5 grams per day, the State of Michigan claimed that it was derived from Javitz (1980). West *et al.* (1980) pointed out that Javitz (1980) did not report an estimate of fish consumption at this rate (6.5 grams per day) but reported a mean consumption rate from the NPD survey of 14.3 grams per day and reported on several other national surveys that derived consumption rates similar to, or greater than, that derived from the NPD. Additionally, West and colleagues noted that the data from the NPD had been destroyed and that U.S. EPA had not been able to replicate the 6.5 grams per day value. Thus, West *et al.* (1993) proposed that the 6.5 grams per day value was derived from "unlocated and unreplicable origins." Hence, it seems evident that the widespread use of 6.5 grams per day, as a default value for fish consumption for sport fishers has been unjustified and inappropriate, especially when more appropriate values became available.

U.S. EPA has updated their default consumption values for water quality criteria and screening values. In the revised (second) edition of the first volume of their guidance series *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories*, U.S. EPA (1995) noted that the 6.5 grams per day consumption rate value was under review. Additionally, they recommended that States evaluate and use fish consumption rates that are appropriate for their region, and use local consumption rate data when available^x. In the latest (third) edition of the *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume I*, U.S. EPA (2000a) presented updated fish consumption rates for various fisher populations

^w U.S. EPA (1995) defined screening values as "concentrations of target analytes in fish or shellfish tissue that are of potential public health concern and that are used as standards against which levels of contaminants in similar tissue collected from the ambient environment can be compared. Exceedance of these screening values should be taken as an indication that more intensive site-specific monitoring and/or evaluation of human health risk should be conducted."

^x U.S. EPA published *Draft Water Quality Criteria Methodology Revisions: Human Health* in the Federal Register (August 1998). These Revisions included an updated evaluation of fish consumption surveys with recommendations for using local data in exposure assessments or proposed default values that were based on a comprehensive review of the consumption literature. These recommendations were finalized (U.S. EPA, 2000c) and superceded the "1980 Ambient Water Quality Criteria Guidelines" that included the 6.5 gram/day value.

including 17.5 grams per day for "recreational" use and 142.4 grams per day for "subsistence" use. These values are also recommended in *Methodology For Deriving Ambient Water Quality Criteria For The Protection Of Human Health (2000)* (U.S.EPA, 2000c). Consumption rates as well as discussion of special exposure issues for Native American subsistence fishers based on several surveys conducted in these subpopulations are also presented in the third edition of the fish advisory guidance series.

Historically, U.S. EPA has also proposed other values for fish consumption. In the Exposure Factors Handbook, U.S. EPA (1989a) reported that national per capita estimates of fish and shellfish consumption (*i.e.*, the rates derived by Javitz, 1980, from the 1973-74 NPD) underestimate actual consumption rates for recreational fishers, and recommended that values derived from two regional surveys of recreational fishers (*i.e.*, Puffer *et al.*, 1982, and Pierce *et al.*, 1981) be used to represent consumption rates for recreational fishers in any area where there is a large water body present and widespread contamination is evident. U.S. EPA (1989a) averaged the results derived from these two studies to provide recommended values of 30 grams per day at the 50th percentile, and 140 grams per day at the 90th percentile (Table 14). U.S. EPA indicated that no specific values could be recommended for small water bodies due to the lack of data, and suggested that local studies of recreational fishers would need to be conducted in order to estimate consumption rates for specific local areas of concern.

In U.S. EPA's 1989 Risk Assessment Guidance for Superfund (RAGS), recommended values for use in exposure calculations for ingestion of contaminated fish and shellfish were based on the analysis of meal size conducted by Pao *et al.* (1982) using data from USDA's 1977-78 NFCS (U.S. EPA, 1989b). The recommended values included an ingestion rate of 113 grams per meal (at the 50th percentile) and 284 grams per meal (at the 95th percentile). In the 1991 Supplemental Guidance to RAGS, U.S. EPA (1991) proposed using 54 grams per day (the mean rate for finfish consumption derived by Pao *et al.*, 1982) for recreational fishers and 132 grams per day (the rate at the 95th percentile) for subsistence fishers (Table 14).

U.S. EPA supplements to Volume II of their guidance series *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* included brief reviews of consumption studies on sport and subsistence fishers (U.S. EPA, 1996b). Many of the studies that have been completed on noncommercial fishers cited by U.S. EPA have been reviewed in this report. U.S. EPA also described several studies in progress to define consumption patterns and rates for various subgroups expected to be subsistence fishers. U.S. EPA did not derive recommended consumption values from the consumption studies reviewed, but suggested that the results of specific studies be selected for use on the basis of similarity in target populations.

U.S. EPA also published an update to the 1989 Exposure Factors Handbook. This version, dated August 1997, adopted a substantially different approach to estimating fish consumption rates, and the results and default consumption values presented differ considerably from the default numbers previously proposed by U.S. EPA for recreational and subsistence fishers (see Table 14). For recreational fishers on the Pacific coast, U.S. EPA (1997a) recommended default values of 2 grams per day and 6.8 grams per day at the mean and 95th percentile, respectively. U.S. EPA (1997a) derived these estimates of consumption rates from data obtained in a creel survey that also included telephone surveys designed to estimate the number of fishers and fishing trips

in the state^y. Estimates of intake of marine fish were provided for California, Oregon, and "All Pacific." Because this creel/telephone study did not address consumption, U.S. EPA (1997a) applied several assumptions in order to derive estimates of consumption rates from the creel data. In addition, the default consumption rates recommended by U.S. EPA (1997a) for Pacific coast recreational fishers were derived by applying weighting factors (the inverse frequency of fishing) to the data and adjusting the distributions of consumption rates to account for the entire fishing population.

U.S. EPA (1997a) did not provide recommended rates in the updated Exposure Factors Handbook for freshwater fishers on the Pacific coast. Multiple values were recommended for freshwater fishers based on studies that were conducted in three states, Maine, New York, and Michigan, and additional analyses of the data performed by U.S. EPA. The results were then averaged to provide overall recommended mean and 95th percentile values for recreational freshwater anglers of 8 grams per day and 25 grams per day, respectively. It should be noted that these values exceed the recommended values for marine (Pacific coast) recreational fishers (Table 14).

U.S. EPA (1997a) provided separate recommendations for default consumption rates for Native American subsistence populations. These values were derived by averaging the results from the CRITFC (1994) survey and an analysis performed on the data reported by Wolfe and Walker (1987). Inverse frequency weights were not applied to these data. The recommended values were 70 grams per day and 170 grams per day at the mean and 95th percentile, respectively.

5. Consumption Rates Used in California Regulatory and Fish Advisory Programs

In 1989, OEHHA (formerly the Hazard Evaluation Section of the California Department of Health Services) provided recommendations regarding estimates of fish and shellfish consumption. Based on a review of the literature available at the time, which was not considered comprehensive, a value of 23 grams per day was provided as an estimate of the minimum average consumption of sport fish and shellfish consumption (Kizer, 1989). This value, 23 grams per day, was selected from a range of values (23 to 40 grams per day) determined from the literature review. The 23 grams per day value was adopted and is used by the California State Water Resources Control Board for use in developing water quality criteria for marine waters, in *Water Quality Control Plan, Ocean Waters of California, California Ocean Plan* (SWRCB, 1997; 2001).

As mentioned previously, the Air Toxicology and Epidemiology Section of OEHHA (OEHHA, 2000) developed weighted estimates of fish and shellfish consumption based on the Santa Monica Bay dataset for use in multimedia risk assessments of semi-volatile airborne

^y This creel survey was considered by U.S. EPA to be the "key" study from which consumption rate estimates were derived for Pacific coast recreational fishers. Although U.S. EPA (1997a) reviewed (and re-analyzed) other "relevant" surveys, these other surveys were conducted in 1980 and were less comprehensive than the Santa Monica Bay Seafood Consumption Survey, which was not considered.

contaminants conducted under the Air Toxic Hot Spots Program. A distribution of fish consumption rates was presented on a body weight ("per kilogram") basis, and several values were developed for application to different exposure scenarios (*e.g.*, differences in age and duration of exposure). Default values for "fisher caught fish consumption" in grams per day were also presented as 30.5 grams per day for the "average" and 85.2 grams per day for "high end." The weighted values were derived to be more representative of the general fishing population for exposure assessments where fish is not a major pathway of exposure to chemical contaminants. For more detailed information, the reader is referred to OEHHA (2000).

The Pesticide and Environmental Toxicology Section of OEHHA is responsible for evaluating data on chemical concentrations in sport fish and issuing advisories for water bodies, where appropriate, in California. The goal of fish consumption advisories is to protect frequent fishers and sport fish consumers. These consumers eat fish at a greater rate than the general population. Fish advisories are presented as recommended amounts of fish or number of meals that can be eaten in a given time period based on the measured concentrations of chemicals of concern in fish tissues relative to reference doses and cancer potency factors for these chemicals. Therefore, advisories do not depend on estimated fish consumption rates. However, exposure assessments are also conducted to evaluate the degree to which local sport fish consuming populations may be exposed to the chemicals of concern. In these exposure assessments, several levels of consumption are considered, including a "low end," an "average," and a "high end" rate of consumption. For these three consumption levels, the median value of 21 grams per day, the mean value of 50 grams per day, and the 90th percentile of 107 grams per day from the consumption distribution OEHHA developed from the Santa Monica Bay study are used. In these cases, the unadjusted data from the consumption distribution (rounded to the nearest integer) are used to best represent the population at risk from consuming frequent meals of a single fish species.

6. Summary of Sport Fish Consumption Rates

The range of estimates of mean rates of consumption for consumers of noncommercial fish and shellfish derived from regional studies exceed mean per capita rates determined for the overall U.S. population. Per capita estimates, by definition, average consumption by consumers across the population and thus include nonconsumers, whereas many of the regional studies of sport fishers have focused only on actual consumers. Therefore, these comparisons are limited inasmuch as the target populations (and the study methodologies) differ. It is also difficult to compare consumption among fishers to national rates derived for "consumers only." National studies have been more focused on the general population and have evaluated short-term consumption rather than usual long-term consumption patterns. In addition, the national studies have not adequately addressed consumption of sport-caught fish and shellfish. For example, the estimate of finfish consumption derived by Pao *et al.* (1982) included consumption of mainly commercially purchased products (*e.g.*, fishsticks, flounder, haddock, and perch) rather than sport fish (although U.S. EPA used this estimate as a default value for recreational fishers in the 1991 Supplemental Guidance to RAGS). Comparisons of fish and shellfish consumption between sport fishers and the general population are also limited because of methodological differences in the surveys targeting these two groups. In addition, national studies are more

likely to mask individual variation, and thus, information pertaining to consumption by subpopulations of interest is likely to be lost. U.S. EPA (1996b) recommended that local data or regional studies with representative target populations (matched for specific characteristics that are likely to result in similar consumption patterns) are preferable to results from national studies for characterizing consumption by recreational and subsistence fishers.

A number of studies conducted on a regional basis provide information relevant to populations fishing in these regions. Whether any of these consumption values can be applied to other similar scenarios must be determined and justified on the basis of the characteristics of the population of interest and the particular uses for which the estimated rates are needed. It is important to note that many water bodies for which consumption surveys have been conducted have had health advisories in place. These advisories can influence actual and reported rates of consumption, and may affect other aspects of sport fish consumption behavior. (For more information on the process of developing advisories and the potential impacts of fish advisories, see Reinert *et al.*, 1996.) Among the studies conducted regionally on fishing populations, overall mean rates for sport fish consumption ranged from 12.3 to 63.2 grams per day (Tables 9, 10, and 13). Certain subgroups had substantially higher average rates of consumption, as reviewed in the Discussion section below. Full distributional analyses were not conducted in all of the studies and upper percentile rates of consumption, when provided, were reported either as the 90th, 95th, or 96th percentile, and in one case, as the maximum consumption rate, although most of the studies reported the 95th percentile. The values reported for upper percentile consumption rates ranged from 17.9 grams per day to 220 grams per day (and 810 grams per day for crabs). It should also be noted that the studies varied in terms of whether these values included sport fish or total fish consumed.

Several studies that reported on total consumption of fish and shellfish indicated that fishers and other consumers of sport fish and/or shellfish consumed commercial species in addition to sport-caught fish. However, only a few studies of fishing populations distinguished consumption rates for sport-caught and commercially available fish and/or shellfish. The overall mean rates for total fish consumption (from all sources) in the studies that reported consumption rates for both sport and commercially obtained fish ranged from 16.1 to 61.3 grams per day. It should be noted that the values representing both the lower and upper ends of this range were derived from different analyses performed on the same dataset.

Several studies in the Great Lakes region have provided estimates of fish consumption rates in that region. The surveys and analyses conducted on fishing populations using the Great Lakes and other Michigan waters (*e.g.*, West *et al.*, 1992, 1993; Murray and Burmaster, 1994) were the most comprehensive of the studies reviewed. Although the results of the Michigan Sport Anglers study were based on a mail survey that targeted licensed fishers only and relied on self-selected respondents, the authors also evaluated differences between respondents and nonrespondents and adjusted the estimated mean consumption rates accordingly. However, the estimates of consumption derived by West and colleagues included a large percentage of respondents (more than half) who had not eaten any fish during the study recall period. Murray and Burmaster (1994) provided estimates of consumption based upon actual consumers during the recall period and used the data obtained in the 1988 Michigan study to construct a

distributional analysis of fish consumption by anglers and other consumers of sport fish in Michigan.

The analyses performed by Murray and Burmaster (1994) on data from Michigan sport fishers provided results for both sport-caught and total fish consumption for anglers and other adult consumers. Murray and Burmaster (1994) calculated an overall mean consumption rate for adult consumers as well as for various groups of anglers and others that consumed sport fish (Table 8). A comparison of these rates shows that consumers of sport fish, and anglers in particular, had higher rates of consumption of fish, on average, compared to the general adult consumer population. A comparison of mean consumption rates of sport fish and total fish by anglers and other consumers of sport fish suggests that anglers and other consumers supplement sport-caught fish with consumption of fish obtained from other (commercial) sources.

The surveys reported by Fiore *et al.* (1989) and Connelly *et al.* (1990) used somewhat different methods, calculating the number of meals eaten per year and providing only crude estimates of actual consumption. The average number of total fish meals reported for anglers in each study was similar (42 and 45 meals per year, respectively). Evaluation of consumption of sport fish alone was notably incomplete, particularly in the New York Statewide survey. Therefore, the usefulness and applicability of the data from these studies for estimating consumption of sport fish are limited. However, additional studies in this region were conducted for Lake Ontario anglers (*e.g.*, Connelly *et al.*, 1996). Although the subsequent surveys were more comprehensive, and included more questions on sport fish consumption, the results indicated that fewer fish meals were consumed on average by anglers compared to the earlier studies. Results from these studies showed a decrease in fish consumption over time, particularly for consumption of sport fish from Lake Ontario, and Connelly *et al.* (1996) suggested that a suppression effect due to health advisories affected consumption rates.

The angler survey conducted by ChemRisk (1992) provided relatively low values for consumption of sport-caught fish from fresh water bodies in Maine. Given that consumption rates were calculated for selected species obtained from selected fresh water bodies, exclusive of any marine species, the results do not provide estimates of total sport fish consumption. The results indicate that relatively small quantities of freshwater species were caught and consumed by a select subpopulation of fishers in the state. These rates may be applicable in regions with similar conditions, (*i.e.*, populations fishing in fresh water bodies subject to consumption advisories, seasonal limitations in access and availability of fish, greater availability of saltwater species, absence of high-use populations such as Native American tribes, etc.). The estimates derived from this study are not likely to be representative of freshwater fishers in general. The survey of anglers in Alabama (Meredith and Malvestuto, 1996) determined estimates of freshwater fish consumption that were similar to the values determined by Murray and Burmaster for Michigan anglers, despite differences in the characteristics of the fresh water bodies fished by anglers in each of the studies.

The information derived from the CRITFC (1994) study provided comprehensive fish consumption data for four Native American tribes consuming fish from the Columbia River Basin, and documented fish consumption rates and patterns that may be generalized to similar Native American populations. Although the findings may only be applicable to select

subpopulations, the results are important in geographic areas where these groups comprise a significant portion of the fishing population. The results also demonstrate that fishers near a productive freshwater fishery can obtain and consume fish in amounts at least comparable to what is obtained from marine sources, although special fishing rights of Native American tribes may allow for greater catch. The results from a study of the Tulalip and Squaxin Island tribes of Puget Sound (Toy *et al.*, 1996) also showed relatively high rates of sport fish and shellfish consumption among Native American tribal members. In this survey, shellfish and anadromous fish from marine/estuarine sources were caught and consumed most commonly. Comparisons of actual rates of consumption are complicated, however, because Toy *et al.* (1996) determined and reported consumption rates by weight and by gender for each tribal community rather than reporting an overall mean rate.

Fish consumption data collected by Harnly *et al.* (1997) from residents near Clear Lake, California are pertinent to the small group of individuals surveyed (mostly members of a Native American tribe) and may not be applicable to the general California population or to all California fishers. However, no other study of consumption of sport fish from fresh water bodies in California is available. These data indicate that individuals in certain subpopulations in California consume sport-caught freshwater species at rates that are comparable to, or greater than, the average rates reported for consumption of marine sport fish in the state. The study results also suggested that some sport fishers might also consume commercially available species.

SCCWRP and MBC (1994) compared their results from Santa Monica Bay with those reported by Puffer *et al.* (1982) for the Los Angeles area, and stated that the consumption patterns of the ethnic groups were similar (as discussed in greater detail in the Discussion). Similarly, Allen *et al.* (1996) reported that gender, age, and ethnic characteristics of Santa Monica Bay anglers had not changed much since the 1980 study. Puffer *et al.* (1982) did not report mean consumption rates, and the overall median rate they reported (36.9 grams per day) was higher than the median rate (21.4 grams per day) reported by SCCWRP and MBC (1994). However, the methodologies in the two studies were different.

The Santa Monica Bay Seafood Consumption Study (1994) provides a large and comprehensive database applicable to a broad demographic of sport fishers in California, particularly those fishing in marine waters. Various fishing modes were included in the survey and all seasons were included in the yearlong study period. Because respondents reported consumption of fish for a one-month period of time, the variability in frequency of consumption among fishers would more likely be captured than in studies using shorter recall periods. Interviewers used a fillet model to help anglers describe his or her own consumption, in addition to methods similar to those used by Puffer *et al.* (1982) in deriving consumption rates based on estimates of the consumable portion weights divided by the number of consumers in a household. Interviewers also used pictures of fish when fish were not in hand to facilitate correct identification of species. The reported rates for fish consumption were derived from the amount of fish respondents reported to have consumed, and thus, it is possible that reports of fish consumption used to calculate the rates of consumption were inaccurate due to over- or under- reporting by respondents. However, a comparison of the results obtained from the two methods used for estimating fish consumption rates showed that the results were similar for most groups. Thus,

estimates based on recall were corroborated by estimates based on catch. Demographic characteristics of the population and the relationships of these factors to consumption were evaluated. Interviews were conducted in other languages (mainly Spanish) when appropriate in order to achieve greater representation from ethnic groups (although language barriers were still encountered in some cases). A stratified-random sampling design was employed to minimize bias, and a comprehensive survey resulted from the frequent sampling and extensive coverage (*e.g.*, geographic area, mode of fishing, and sample size) of fishers in Santa Monica Bay.

Creel surveys and other surveys conducted at fishing locations may oversample the most frequent fishers. While this may have occurred in the Santa Monica Bay study, the frequency of interviews conducted over a yearlong period (combined with the random sampling regime) was likely to have increased the representativeness of the sample population. As an example, one-third of the fishers interviewed had not fished during the previous four weeks. Eighty-one percent of those interviewed fished between once a month and one and one-half times per week, and 19 percent fished between approximately twice a week and every day. The sample population appears to represent fishers with a broad range of fishing frequency but has a statistically significant bias toward more frequent fishers. In addition, consumers with a wide range of consumption frequencies were included in the consumption distribution. Thirty percent of respondents reported consuming their catch only once in the month. An additional 45 percent consumed sport fish between once a month and once a week, for a cumulative total of 75 percent. Only five percent of respondents consumed sport fish more than three times a week. Therefore, the consumption distribution determined from the Santa Monica Bay study data includes anglers with a variety of fishing and consumption rates and patterns, and provides a reasonable representation of consumption rates for sport fishers that consume their catch on a fairly regular basis (*i.e.*, at least once a month). The subpopulation of respondents is, therefore, likely to be representative of the subpopulation of sport fish consumers that is a population of concern (*e.g.*, a population most at risk from exposure to chemicals in sport fish). It is not likely to represent all anglers (total fishing population) fishing a water body such as Santa Monica Bay. In addition, the data were derived from reported consumption by the fishers themselves who were principally males; friends and family members that share the catch may also be subject to risk from exposure to chemical contaminants. The fish consumption rates derived from this study applied to consumption of Santa Monica Bay sport fish only, rather than consumption of fish from all sport and commercial sources. Nevertheless, this study avoided the biases inherent to mail surveys, which rely on a self-selected sample population of respondents, by conducting personal interviews with randomly selected fishers. For all these reasons, the 1991-1992 Santa Monica Bay study is the most representative and best available dataset for estimating sport fish consumption rates among California fishers.

The similarity in results for the distribution of consumption rates derived from the Santa Monica Bay study and from the Michigan study as analyzed by Murray and Burmaster (1994) suggests that these consumption rates may be generalized to fishing populations consuming fish and/or shellfish from large marine and fresh water bodies. Ideally, it is preferable to obtain or apply regional, localized data for specific local areas of concern, particularly when the conditions differ in a substantial way. However, when adequate local data are not available, the results from the Santa Monica Bay study may be useful as default values for other regions in which the populations of interest and other relevant factors are similar.

It is important to note that a number of additional studies of fishing populations have been conducted and reported since this review was conducted. A list of state or regional fish consumption surveys conducted in recent years (primarily in the 1990's) is included in Appendix III. The reader is encouraged to seek out those studies that may be appropriate to the question(s) at hand.

V. DISCUSSION

The following discussion will include a review of studies identifying particular subgroups of the overall U.S. population that may differ in their patterns and rates of consumption of fish and shellfish. Subpopulations could include subsistence fishers, ethnic groups, age and sex groups, and populations residing in certain geographic regions. Rates derived from several studies were reported by region (Table 3b), race or ethnicity (Tables 7, 11, 12, and 15), and age and sex groups (Tables 16 and 17). In some cases, limited information was available for subpopulations. For example, sample sizes tended to be small for the younger age groups and various ethnic populations included in some of the national surveys. In these cases, the reported differences in rates may be indicators of trends or patterns rather than absolute consumption rates. The discussion also considers consumption rates that apply to fish and/or shellfish obtained from different types of water bodies, including freshwater and marine sources. The discussion of subpopulations includes an evaluation of fish and shellfish consumption rates for California populations. A review of "other issues" provides information about meal or portion size. The section is followed by a discussion of the application of fish and shellfish consumption rates (and potential differences among subpopulations) to the risk assessment process that includes recommendations for selection of appropriate estimates and/or default values.

A. Trends in Fish and Shellfish Consumption Rates for Subpopulations

Several studies have suggested that fish consumption rates differ for specific subpopulations. Demographic characteristics, such as race or ethnicity, age, and sex, and the relationships between these variables and fish and shellfish consumption rates and patterns are described below. Some of the national studies (*e.g.*, Rupp *et al.*, 1980) indicated regional differences in consumption rates that could be influenced by local cultural preferences and/or the types of fish and shellfish that are available in certain regions and at certain times of the year, and the amount of sport or subsistence fishing that occurs in a given region. In addition, as indicated previously, rates may vary within the subset of the population that catches and consumes fish. Some recreational fishers may fish primarily in response to the seasonality of their "favorite" species, whereas other recreational fishers may fish more avidly. Subsistence fishers and recreational fishers may also preserve fish for consumption during non-fishing seasons or other times (Puffer *et al.*, 1982; U.S. EPA, 1996b). Subsistence fishers, by definition, are likely to fish on a regular basis in order to secure food for themselves and their families. Thus, subsistence fishers are typically considered to be high-end consumers.

1. Subsistence Fishers

U.S. EPA (1994, 1996b) considered subsistence fishers to be people who rely on noncommercial fish as a major source of protein, and suggested that subsistence fishers tend to consume noncommercial fish and/or shellfish at higher rates than other fishing populations, and for a greater percentage of the year, due to cultural and/or economic factors. However, U.S. EPA

(1996b) also noted that consumption rates can vary considerably among subsistence fishers. Few studies have specifically targeted fishing populations identified as subsistence fishers although U.S. EPA (1996b) indicated that several studies were in progress or recently completed. The definition for subsistence fishers provided by U.S. EPA is a narrative and does not indicate how to actually identify subsistence fishers in a population. There are no particular criteria or thresholds (such as income level or frequency of fishing) that definitively describe the group. Additionally, fishers are not always willing to report their income and do not necessarily identify themselves as subsistence fishers. In some of the "subsistence studies" summarized by U.S. EPA (1996b), the respondents indicated that they did not consider themselves subsistence fishers although they relied on the fish they caught as a major component of their diet. Other subpopulations may be considered to be subsistence populations even though their reported rates of fish consumption are similar to what has been reported nationally for the U.S. population (e.g., APEN, 1998; Shubat *et al.*, 1996). Thus, it may be difficult to define and represent subsistence fishers in a quantifiable way. Furthermore, definitions and perceptions of what constitutes "subsistence fishing" are likely to vary among regions and cultures. Some examples of differences in fish consumption rates reported for "subsistence" populations in different regions follow in the discussion below.

U.S. EPA (1997c) suggested that Native American, lower income urban, rural, and Asian-American populations often include subsistence fishers, and described some of the difficulties in characterizing these subpopulations in general, and subsistence fishers, in particular. For example, subsistence fishers may not have registered for fishing licenses for a variety of reasons, and thus are likely to be underrepresented in surveys based on fishing licenses. In addition, U.S. EPA (1996b) noted that fish consumers might answer survey questions inaccurately for a number of reasons, including language problems, pride, concerns about illegal activity, and fear of restrictions that might jeopardize the fisher's family and/or access to fishing resources.

Problems with defining subsistence fishers contribute to difficulties characterizing consumption of fish and shellfish by the subpopulation of subsistence fishers. The Santa Monica Bay study asked respondents to report their annual household income. Relatively few respondents reported annual household income in the lowest income brackets (less than \$5000 or between \$5000 and \$10,000) and it is not possible to determine whether any, some, or all of these people, or those with higher income, were subsistence fishers. Furthermore, although the median rate of consumption was higher for the lowest-income group, the mean and upper percentile rates were higher for the higher-income groups. The study also asked fishers about their frequency of fishing and found that roughly two percent of the respondents reported having fished every day for the prior month. However, a consumption rate was not determined separately for this group. Additionally, although subsistence fishers would be expected to fish frequently, other fishers (e.g., retired persons) may also fish frequently. On the other hand, if at least some subsistence fishers were included in this survey, then the upper percentile consumption rates that were calculated would have represented this subpopulation to some extent.

The study conducted at Clear Lake, California, although small, represented about half (46 percent) of the Native American Elem population residing near Clear Lake, and suggested that approximately half of the people in this community consumed no sport fish while those that

did eat sport fish consumed them at relatively high rates. The mean level of intake of sport-caught fish by residents (consumers) near Clear Lake was similar to the mean rate calculated for four Native American tribes represented by the CRITFC (1994) study. The average rates of consumption of sport fish determined for fishers in the Elem tribe at Clear Lake and four tribes in the Columbia River Basin were 60 grams per day and 63.2 grams per day, respectively. The rate determined at the 95th percentile in the CRITFC study was 170 grams per day. Because the study in the Columbia River Basin is regarded as one of the most comprehensive surveys of Native American fishing populations (U.S. EPA, 1996b), it is likely to provide reliable estimates of consumption by some Native American subsistence populations residing near and obtaining food from productive fishing waters. CRITFC (1994) described the communities represented in the study as subsistence fishers and provided the following viewpoint, which may serve to describe some subsistence fishers. "The importance of fish, especially salmon, to the tribes can not be overstated for the fishery resource is not only a major food source for tribal members, it is also an integral part of the tribes' cultural, economic and spiritual well-being." However, not all subsistence populations are expected to be Native Americans, and the communities represented in these studies of Native American tribes may be very different than urban or other subsistence fishers. Furthermore, Harris and Harper (1997) suggested that the study populations in the CRITFC (1994) study, and in other studies of Native American populations, are not true subsistence populations, as discussed further below.

The mean rates of consumption in these two studies of west coast Native American fishers were slightly higher than the mean rate calculated for fishers in Santa Monica Bay (60 and 63.2 grams per day compared to 49.6 grams per day), and the upper level intake rates were comparable. SCCWRP and MBC (1994) reported an upper level intake of 107.1 grams per day at the 90th percentile, and OEHHA determined the 95th percentile to be 160.7 grams per day for fishers in Santa Monica Bay. The 95th percentile reported in the CRITFC (1994) survey was 170 grams per day. A comparison of these results suggests that some subsistence fishing populations may be covered by the use of upper level intake rates in exposure calculations provided that the study methodology allows for inclusion of subsistence fishers in the survey (U.S. EPA, 1996b). However, the tribal fishers that were surveyed may not be representative of all subsistence fishers, and the assumption that the estimates of mean and upper level intake rates for consumption of fish and/or shellfish derived from the CRITFC (1994) survey are representative of subsistence populations in general may not be correct. Therefore, it is recommended that this assumption be considered with caution and authenticated when possible.

U.S. EPA (1997b) reported that a few studies have shown exceptionally high levels of intake for certain subsistence populations. Therefore, additional information may be needed to evaluate populations potentially having considerably higher rates of consumption of sport fish and/or shellfish. As one example, Wolfe and Walker (1987) described subsistence economies in Alaska in which annual harvests of fish in some communities provided up to 1239 pounds per capita (equivalent to 1540 grams per day). U.S. EPA (1997a) applied a conversion factor of 0.5 to the data reported by Wolfe and Walker (1987) to convert per capita harvest rates to individual consumption rates (although Wolfe and Walker indicated that the pounds per capita they reported were derived from household harvests divided by the number of household members). Using the conversion factor, a mean of 70 grams per day, median of 81 grams per day, and range of 15.5 to 770 grams per day were reported (U.S. EPA, 1997a; Harris and Harper, 1997).

Harris and Harper (1997) evaluated these data, as well as several other data sources, interviewed members of the Confederated Tribes of the Umatilla Indian Reservation in the Columbia River basin, and concluded that a fish consumption rate of 540 grams per day (excluding shellfish) represents a reasonable subsistence intake. It should be noted that although average intakes derived from the Alaska data were similar to the estimated mean intake in the CRITFC (1994) survey, as a result of the large range of intake reported for subsistence communities by Wolfe and Walker (1987), a substantially greater upper level intake rate would be necessary to represent most of the members of these subsistence populations, inclusive of those with above-average rates of consumption. In addition, it is also noteworthy that the median intake rate derived from these data (81 grams per day) exceeded the mean intake (70 grams per day). This difference results from a left-skewed distribution (in the opposite direction from other fish consumption distributions) in which fewer individuals have rates of consumption below the average and more individuals comprise the higher-consuming percentiles.

In the Native American tribal populations surveyed in the CRITFC (1994) study, the average number of fish meals eaten per week by adult consumers was 1.85 for the entire year. During the two months of the year with the highest consumption, the average number of fish meals per week increased to 2.93. The maximum number reported was 30 meals per week, for only one person. Approximately nine percent of the respondents reported eating four or more fish meals per week, and about four percent reported consuming fish seven or more times per week. Thus, the results from this study indicated that daily consumption of fish and/or shellfish is not necessarily a characteristic of "subsistence fishers." In contrast, Harris and Harper (1997) reported that the subsistence populations they studied consumed fish and/or shellfish as much as several times per day, throughout the year. This difference reflects the difficulties in defining "subsistence fishers" and determining default rates of consumption for these subpopulations.

One of the notable findings of the Santa Monica Bay study was that fishers with the highest income had the highest mean rate and upper (90th) percentile rate of consumption. Therefore, although estimating exposure to chemical contaminants in fish and shellfish is important for subsistence populations that are likely to include individuals that consume above-average amounts of fish and shellfish, economically subsistent fishers do not necessarily consume more fish than other avid (and successful) fishers. All high-end consumers, including fishers with relatively high income, may be subject to exposure to chemical contaminants from consumption of sport fish and/or shellfish. Thus, exposure calculations using an upper percentile or bounding estimate are important to describe *all* high-end consumers. In addition, the fish species that are commonly caught from boats can differ from those taken on shore, and may include larger predatory species that may have accumulated higher levels of chemical contaminants.

Despite the current lack of empirical data to support the idea of a subsistence fisher as one who relies on sport-caught fish and/or shellfish for sustenance and/or one who consumes sport fish and shellfish at rates which exceed those of other avid consumers, the concept remains important from a public health perspective. Subsistence populations, particularly any which do not speak or read English, are likely to have reduced access to information about contaminated fish, and people with limited economic resources may have fewer alternative sources of protein. Some subsistence fishing populations may be comprised of a large proportion of women of

childbearing age and/or children who could be more susceptible to adverse health effects from contaminants (Hutchison and Kraft, 1994). For these reasons, it is essential to develop ways to define potentially at-risk subsistence populations and to provide risk communication specifically targeted toward the population(s) of concern.

The general concept of a "subsistence fisher" lumps together ethnically diverse peoples with different fishing access, preferences, and success on potentially different water bodies (and commonly excludes Caucasian, middle-income, or upper-income consumers with high rates of consumption who are thus also potentially at risk). Because of the difficulty in defining and targeting "globally defined" subsistence populations, it is especially important that subsistence fishing populations be locally defined, characterized, and targeted. Insofar as a quantifiable working definition of subsistence fishers is lacking, and few data are currently available to characterize fish and shellfish consumption for subsistence populations, a more thorough evaluation of consumption rates applicable to subsistence fishers requires both additional data and guidance for obtaining such data. In addition, it is important to recognize, assess, and address potential risks for other subpopulations and/or fishers with exceptionally high rates of consumption.

2. Consumption Rates by Racial or Ethnic Group

Hu (1985) evaluated how various sociodemographic and economic factors, including per capita income, family size, occupation, age, race (Black, White, Oriental, and other), religion (Catholic, Jewish, Protestant, and other)², education level of the head of household, and geographic region, related to seafood consumption. Hu compared data from four national studies conducted between 1970 and 1981 and stated "in general, the Blacks and Orientals consume more than Whites." However, he added that over time, a larger percentage of Whites were eating fish, especially finfish. Hu reported demographic differences such as higher intake of certain types of seafood (such as shrimp) by certain ethnic or racial groups and by variables such as income and region. Other studies have also reported varying fish consumption rates for certain species of fish by specific ethnic groups (Javitz, 1980; West, 1992, 1993; SCCWRP and MBC, 1994).

Javitz (1980) derived mean consumption rates by age and sex, race (White, Black, Oriental, and other), and other demographic variables. Javitz concluded from the 1969-70 Market Facts Survey data that Blacks and Jews had higher mean consumption rates than other subpopulations, and he reported that based on the NPD data, Orientals reached the highest 95th percentile rate. Mean per capita consumption rates based on the NPD data were 14.2, 16.0, and 21.0 grams per day for Whites, Blacks, and Orientals, respectively (Javitz, 1980; Table 15). These differences in average rates of consumption among groups were small; the higher-consuming group was less than two times greater than the lower-consuming group. Because these values represented per capita rates, they may be useful for comparing trends among groups but are not likely to provide accurate estimates of actual consumption rates by consumers.

² These categorizations for race and religion appear to have been made by Hu based on categories reported in the surveys he evaluated; in some of the surveys fewer categories were defined (e.g., some of the studies did not use "Oriental").

USDA (1983) also collected information on age, sex, race (White, Black, or other), education, occupation, income, and employment status. Mean fish and shellfish consumption rates were reported in summary tables by race (Black or White), income, and degree of urbanization (central cities, suburban, and nonmetropolitan). Overall mean per capita consumption rates did not vary by income level by more than one gram per day. Blacks had higher average rates of consumption than Whites (15 grams per day compared to 11 grams per day). Consumption rates were higher in central cities (14 grams per day) compared to suburban (12 grams per day) and nonmetropolitan (10 grams per day) areas. These findings, which were also calculated on a per capita basis, show relatively small differences among groups.

The Santa Monica Bay Seafood Consumption Study (SCCWRP and MBC, 1994) reported that of the "identifiable ethnic groups," the Other group had the highest mean consumption rate (137.3 grams per day per person), and upper decile rates were highest for Whites, Asians, and Other (112.5 grams per day, 115.7 grams per day, and 173.6 grams per day, at the 90th percentile, respectively). The Other group, which included a small number of people (14) of mainly Pacific Island origin, was significantly different from Filipinos, Japanese, and Whites; and Whites were significantly different from Hispanics. On the basis of average rates of consumption, the highest consuming group (Other) exceeded the overall mean by almost three times, and exceeded the lowest consuming group (Hispanic) by nearly five times. The authors also reported that relative to the population around Santa Monica Bay, more Asians, Whites, and other ethnicities (but not including Hispanics or Blacks) fished in the bay.

Puffer *et al.* (1982) also compared subpopulations of fishers in the Los Angeles area. The report noted that most anglers that were interviewed were White and that Orientals (Samoans) and Mexican-Americans may have been underrepresented due to language differences. Statistical tests for differences among group median rates of consumption showed that consumption rates were significantly higher for Orientals/Samoans (70.6 grams per day per person). Also, median consumption rates were lower for Blacks (24.2 grams per day per person) and Mexican-Americans (33.0 grams per day per person) than Whites (46.0 grams per day per person) but statistically significant differences were not indicated. Puffer and colleagues also found ethnic differences in the frequency of fishing in that significantly different proportions of ethnic groups accounted for frequent versus infrequent fishers.

SCCWRP and MBC (1994) compared their results from Santa Monica Bay with those reported by Puffer *et al.* (1982) and stated that the consumption patterns of the ethnic groups were similar. In each study, certain Asian subgroups (Pacific Islander and Oriental/Samoan, respectively) were the highest consuming group, and Hispanics or Mexican-Americans had lower consumption rates. However, in the earlier study, Blacks had the lowest median consumption rate (24.2 grams per day), with Mexican-Americans somewhat higher (33 grams per day). In the 1991-92 study, Hispanics had the lowest median (16.1 grams per day) and Blacks had a median rate of 24.1 grams per day, which was higher than the overall median rate (21.4 grams per day). Whites in both studies had median consumption rates in the mid-range, and consumption rates for Asian groups, depending on how they were defined (which subgroups were included), were similar to, lower than, or higher than the rate calculated for Whites (see further discussion below).

The median rates of consumption reported for Blacks by the Santa Monica Bay study (SCCWRP and MBC, 1994; Allen *et al.*, 1996) and by Puffer *et al.* (1982) for the same geographic area were almost identical, although in the first case, the consumption rate for Blacks was reported to be the highest median rate, and in the second case, reported to be the lowest median rate among racial and ethnic groups. This difference underscores the importance of not only obtaining appropriate regional or site-specific data, but also understanding factors such as how the population groups surveyed were defined, what analyses were performed on the data, and the relevance of these factors to the population of concern. A comparison of the findings in each of these studies suggests that patterns of fish consumption are highly variable within and among groups, and possibly over time. (It is possible, although untested, that differences in the findings of each study regarding consumption patterns of ethnic groups may have resulted from sampling at different times, since the two studies were conducted approximately ten years apart.) Further comparison of the two studies is hindered by the fact that Puffer *et al.* (1982) only reported median rates of consumption, and because the methodologies were so different in each study, comparisons may not be illuminating.

The San Diego Bay Health Risk Study (SDCDHS, 1990) also reported trends for different rates of consumption of fish and shellfish among ethnic groups. They reported that Asians and Filipinos had the highest consumption rates, compared to Whites and Hispanics, and also represented larger proportions of sport fish consumers. They noted differences in fishing success among ethnic groups, with Asians and Filipinos having the highest success rate, which could affect the amount of fish available for consumption (depending on the number of consumers sharing the catch). They also reported that the parts of fish consumed varied by ethnicity. However, sample sizes were too small, especially for Asians and Hispanics, to provide reliable estimates of the consumption rates for these subpopulations or to allow for statistical comparisons of the differences in consumption.

Landolt *et al.* (1985) reported "significant findings in ethnic differences" among fishers in Puget Sound, more so with respect to the patterns and characteristics of fishing populations than fish consumption rates. For example, Blacks fished more from bridges whereas Whites fished more on boats. The number of family members fishing and eating fish differed among ethnic groups, as did fishing success; each of these measures was higher for Asians. The frequency of encounter (and thus being interviewed) was greater for Whites. Based on estimates of the edible portions of catch, Landolt and colleagues determined the total amounts of fish consumed using geometric means for non-U.S. born Asians, U.S. born Asians, Whites, and Blacks to be 10, 11, 11, and 9 kilograms per year, respectively. Landolt and colleagues noted that subpopulations fished in response to favorite species. Therefore, consumption rates could vary based on the seasonality and availability of preferred species. The differences in consumption rates among ethnic groups were small, although trends among groups may be indicated by the results. In addition, variations in the patterns of consumption of fish and shellfish by various ethnic groups, and differences in fishing behavior were well characterized by this study.

West *et al.* (1989a, 1992) surveyed anglers in Michigan to determine potential risks to subpopulations. Rates of consumption were compared among different subpopulations and demographic factors such as race, income, age, level of education, and size of town were examined. They found marginally nonsignificant differences for ethnic groups and reported

mean rates of consumption (in grams per day per person) as follows: 17.9 for Whites, 19.8 for other minorities, including Hispanics, 20.3 for Blacks, and 24.3 for Native Americans. Although West *et al.* (1989a) reported that the highest fish consumers were minorities and low-income groups, statistical analyses showed that race, when controlled for age, became nonsignificant (West *et al.*, 1992). Thus, the interaction of certain demographic factors appeared to be important to the outcome. As another example, fish consumption among Whites was consistent across income, whereas it was highest for middle-income Blacks, and higher for low-income and high-income Native Americans than middle-income Native Americans. A significant positive relationship between the number of years anglers lived in Michigan and fish consumption rates was also found, especially among Blacks. These analyses show that the patterns of fish consumption can vary within and among ethnic groups, and the results underscore the importance of considering regional or other locally specific factors when determining the most appropriate rates for subpopulations.

A comparison of different analyses performed on the same data reveals the importance of the definitions of ethnic groups to the results and conclusions that are drawn. For example, Allen *et al.* (1996) grouped the "Other" category (consisting mainly of Pacific Islanders) from the Santa Monica Bay study together with the Asian groups. SCCWRP and MBC (1994), on the other hand, evaluated the data with "Other" considered separately. Because Pacific Islanders had significantly higher consumption rates than any group, combining them with other Asian groups would appear to show that Asians also had significantly higher rates when, in fact, the remaining Asian fishers, when grouped together, were not significantly different from Whites in average fish consumption. Similarly, Puffer *et al.* (1982) grouped together Samoans and Asians and found that this group had a higher rate of consumption, most likely as a result of the high rates reported by the Samoan portion of the sample population.

The importance of clearly defining the target population is further apparent when reviewing additional analyses performed on the Santa Monica Bay dataset by Hill (1995). In this analysis, mean consumption rates among ethnic groups were compared and each Asian group was considered separately rather than in combination with other Asian subpopulations. The results showed that some Asian groups (*i.e.*, Vietnamese and Japanese) had average consumption rates well below the overall mean (27.9 and 34.5 grams per day, respectively, compared to 49.6 grams per day). The higher consuming Asian groups included Filipino and Other (Pacific Islanders). Chinese and Koreans had average consumption rates comparable to Whites and to the overall mean (Table 11b). Hill (1995) reported that the results of an analysis of variance (ANOVA), with the Other group removed, showed no significant differences among ethnic groups, probably due to the large amount of variability within groups.

In summary, several studies have found differences in consumption rates among ethnic subpopulations. The trends for particular ethnic groups are not consistent across studies. Demographic patterns may vary over time and by region. It is difficult to compare results across studies as the methodologies (and definitions of target groups) used in the surveys are different. This problem was exemplified by the differences found for specific ethnic groups fishing in the same region (Santa Monica Bay), as discussed above.

Consumption studies in progress may contribute further information about ethnic subgroups. Based on data from the studies that are currently available, differences in average rates of consumption among ethnic groups appeared to vary within the range of a five-fold difference. For example, average consumption rates for ethnic subgroups in the Santa Monica Bay study ranged from 28.2 grams per day (Hispanics) to 137.3 grams per day (Other, mainly Pacific Islanders). Additionally, the highest consuming subgroup (Other) exceeded the overall mean rate (49.6 grams per day) by roughly three times. Variability in patterns related to fish and shellfish consumption was also apparent in some studies and could be particularly important to risk communication.

3. Consumption Rates by Age and Sex

Rupp *et al.* (1980) reported average annual per capita consumption rates based on the NPD dataset for each of three age groups: children, aged 1 to 11 years; teens, aged 12 to 18 years; and adults, aged 18 to 98 years (2.1, 3.48, and 5.75 kilograms per year, respectively). The annual amounts correspond to 5.8, 9.5, and 15.8 grams per day, respectively (Table 16a). Although the rate of consumption of fish and/or shellfish increased with age, the rates were not adjusted for differences in body weight.

Javitz (1980) summarized values calculated by age and sex based on the NPD dataset. He reported that the mean and upper 95th percentile consumption quantities of fish increased with each age group up to age 60 in women (19.5 grams per day for the mean, and 50.1 grams per day for the 95th percentile) and age 70 in men (24.4 grams per day for the mean, and 61.1 grams per day for the 95th percentile), with subsequent decreases in the amount consumed after reaching these ages (Table 16a). Javitz reported that the amounts of fish consumed were consistently lower for females than for males. The overall mean consumption rates were 13.2 grams per day for females and 15.6 grams per day for males. Again, whether these differences could be accounted for by differences in body weight was not evaluated. However, dividing these overall mean consumption rates by the average body weights determined for adult women and men of 65.4 kilograms and 78.7 kilograms, respectively (Finley *et al.*, 1994), shows that both females and males consumed, on average and on a per capita basis, 0.2 grams per day per kilogram of body weight.

Miller and Nash (1971) reported "positive indications that older people are more disposed to eating fish products" such as oysters, clams, and scallops based on the 1969 Market Facts Consumer Panel Survey. They suggested that age differences might have been related to differences in income, although consumption of shrimp appeared to be evenly distributed across age groups regardless of income level.

Per capita consumption rates were reported by age and sex for the 1977-78 NFCS (USDA, 1983; Table 16b). Pao *et al.* (1982) also presented fish consumption quantities for consumers by age and sex groups based on the 1977-78 NFCS data (Table 17). Males were consistently higher than females in mean rates of consumption (and in meal size) for fish and shellfish, finfish, tuna, and shrimp. Sum totals by sex were not provided. Pao and colleagues reported that consumption quantities increased consistently with age, but as in many other cases, no

consideration was given to differences in body weight. Because the report did not include average body weights for each age and sex category, it is difficult to evaluate whether the mean consumption rates, if adjusted for body weight, would be equivalent.

USDA (1994) presented per capita fish intake from the 1989-91 CSFII by age and sex, and generally showed increases with age in consumption rates for males and females, with more variability among adult age categories (Table 16c). Males were consistently higher than females in fish intake, with the exception of consumption of fish by men and women over 80 years, which could be influenced by the respective numbers of consumers in the elder age category.

Murray and Burmaster (1994) evaluated consumption rates for various subgroups of adult consumers surveyed in the 1988 Michigan Sport Anglers Fish Consumption Survey. They reported mean rates for total fish consumed by males and females as 47.8 and 42.3 grams per day, respectively.

Puffer *et al.* (1982) reported that individuals over 65 years had the highest median rate of consumption (113.0 grams per day). This rate was approximately three times greater than the overall median rate in the Los Angeles study (36.9 grams per day) and appears to represent a relatively higher consumption rate for fish and shellfish consumers in the eldest age category compared to other studies that evaluated consumption by people in this age category. This relatively high consumption rate for older anglers is not likely to be explained by differences in body weight.

West *et al.* (1992) found that differences by age in consumption rates were statistically significant. Three age categories were compared and the results showed that people over 50 had significantly higher rates of fish consumption. Average consumption rates in the eldest category (51-91 years) were between 1.2 and 2.2 times greater than average rates in the youngest category (1-30 years); the middle-aged groups (31-50) had mid-range consumption rates. Although the youngest age category included children, these differences are not likely to be fully attributable to body weight. In addition, certain demographic variables (age and race) were jointly operative. For example, older Blacks (over 50 years) had "very high rates of fish consumption" (31.9 grams per day per person). Consumption rates for Native Americans were highest in the middle age group, 31-50 years. Thus, different age groups combined with different minority groups to produce the highest consuming subgroups (West *et al.*, 1992). However, as discussed above, statistical analyses of the 1991-92 dataset reported by West *et al.* (1993) found no significant relationship between age and rates of consumption.

The study by Toy *et al.* (1996) provided one of the few measures of fish and shellfish consumption on the basis of weight and gender. The results of this study showed differences in average body weight for each tribal community and relatively large differences in body weight when comparing males and females in each tribe. However, the weight-adjusted consumption rates were similar for males and females and across tribal community.

In summary, the available data indicate that consumption rates (grams per day) tend to increase with age, particularly for adults compared to children, and males tend to consume more fish and shellfish (grams per day or per meal) than females. However, because body weight was not

presented in the results of most of these surveys, it is not possible to evaluate to what extent consumption rates may differ on a "per kilogram of body weight" basis. In some cases, although not all, the differences in rates of fish consumption that have been reported are likely to correspond to differences in body weight. In the Native American tribes surveyed by Toy *et al.* (1996), gender differences in consumption were related to body weight and weight-adjusted consumption rates did not differ. Future studies of consumption rates ideally should investigate the correlation between body weight and consumption rate. It is recommended that exposure assessments consider sex and age-specific consumption rates when available. However, few studies of fishing populations have obtained data for age groups or by sex. In the absence of these data, U.S. EPA (1994) recommends using a multiplier for individuals, such as children, with body weights different than the default value (*e.g.*, 70 kilograms). The multiplier is derived by dividing the alternate consumer body weight by the default adult body weight. The multipliers can be used to adjust recommended or allowable consumption values, such as those expressed in advisories. Although it is a reasonable default approach, using this linear multiplier in exposure assessments does not account for the higher caloric requirements of young children, and pregnant and nursing women. Their relative dose of contaminants on a body weight basis will be higher if they eat more fish and shellfish to meet these requirements.

There is limited evidence that some elderly fishers consume greater than average quantities of sport fish. In situations where a particular subgroup (*e.g.*, older Black anglers in Michigan or elderly fishers in Los Angeles) consumed greater quantities of fish and/or shellfish, the average rates varied on the order of a two-fold to three-fold difference. These higher consuming subgroups are likely to be included within the upper percentile consumption rates derived from a distributional analysis of the consumption data.

4. Differences in Consumption Rates by Geographic Region

Rupp *et al.* (1980) reported the amounts of fish consumed in nine regions of the U.S. based on the NPD survey data. They reported that regional differences were most apparent for freshwater and shellfish species. For example, per capita consumption of freshwater species was greater in inland areas than coastal areas, and per capita consumption of shellfish was lower in certain inland regions. Javitz (1980) indicated that according to the NPD data, the mean and 95th percentile rates were highest for large central cities with population size exceeding two million (19.0 grams per day and 55.6 grams per day, respectively) compared to the mean and 95th percentile rates for areas outside central cities with population size between 50,000 and 250,000 (11.3 grams per day and 31.7 grams per day, respectively).

Miller and Nash (1971) focused on consumption of shellfish and reported regional differences or preferences by species. For example, the amounts of oysters consumed in the U.S. were greatest in the South Atlantic and Pacific regions, consumption of clams was greater in New England, the Mid Atlantic, and Pacific regions, and crabs were consumed in the largest quantities in the Pacific states. Consumption rates for preferred species could also be influenced by seasonal factors such as differences in the times of harvest. Nash (1971) found that per capita rates of consumption (in pounds per year) also varied by region, ranging from 7.9 to 17.6 pounds per year and being lowest in the West-North-Central states.

West *et al.* (1992) found a significant relationship between the size of town and rate of consumption of fish. However, the relationship was nonlinear, and they found significant interactions between race or ethnicity and place of residence. These types of regional differences and interactions among variables indicate the importance of data that apply to the specific geographic location and population(s) of interest. These data should be considered when available. Regional studies are summarized in the following section pertaining to type of water body. It should be noted that differences in methodology among these studies may account for the variability in results, and thus, it is difficult to determine whether differences in estimates of consumption rates depend upon geographic region.

5. Consumption Rates by Type of Water Body: Freshwater versus Marine

Data from the 1973-74 NPD survey have been used to differentiate consumption rates for freshwater and marine fish. Using the NPD data, Ruffle *et al.* (1994) determined mean national per capita intake of freshwater fish and marine fish to be 1.48 grams per day and 10.68 grams per day, respectively. Stephan (1980) utilized the species-specific consumption data included in the NPD dataset to differentiate between marine and nonmarine species. He used the overall mean fish consumption rate for consumers of 14.3 grams per day calculated by Javitz (1980) and adjusted it to derive a national per capita rate of 13.4 grams per day. Based on his analysis of marine and nonmarine species in the NPD dataset, he then calculated a mean per capita consumption rate of 6.5 grams per day for nonmarine (freshwater and estuarine) fish and shellfish species and 6.9 grams per day for marine species.

The values derived by Ruffle *et al.* (1994) were based on per capita estimates reported by Rupp *et al.* (1980) in which only about 14 percent of the population surveyed were reported to be consumers of freshwater finfish (as opposed to 90 percent of the population reporting consumption of marine finfish). In contrast, the results presented by Stephan (1980), although derived from the same dataset, were based on analyses of the type of fish reportedly consumed. Stephan's estimates suggested that marine and freshwater consumption rates were roughly comparable. Stephan (1980) pointed out that differentiating marine and freshwater sources can be difficult because some studies do not indicate the type of fish consumed, or do not do so adequately, and additionally, some researchers classify estuarine species with freshwater species whereas others include them with marine species. Another difficulty with the data obtained in the NPD survey is that consumption of sport fish and shellfish could not be distinguished from commercially obtained species, and the amounts reported are likely to include large, as well as variable, percentages of commercial fish and shellfish.

Rupp *et al.* (1980) reviewed two studies of freshwater anglers in addition to the 1973-74 NPD dataset: one from the Columbia River conducted in the 1960's and one from Lake Michigan from the early 1970's. Although the consumption rates derived from each of these two regional studies were comparably high^{aa}, Rupp *et al.* (1980) reported a relatively low per capita rate of

^{aa} The mean and maximum intakes were approximately 8 grams per day and 90 grams per day for the Columbia River study, and 45 grams per day and 323 grams per day for Lake Michigan fishers.

1.2 grams per day for freshwater fish consumption based on the NPD national data. They also reported, as indicated previously, that only 14 percent of the national survey population consumed freshwater fish. Therefore, the rates per person would actually be relatively high for consumers of freshwater species.

As indicated previously, because the percentage of users is highly variable for freshwater and marine fish species, use of per capita estimates to differentiate rates of consumption for fish obtained from freshwater and marine water bodies may not provide realistic estimates of the rate of consumption by consumers for each of these types of water bodies. However, Rupp *et al.* (1980) also presented limited information for consumers. The total annual amount that they reported for consumption of freshwater species (3.41 kilograms per year) was similar to the amount estimated for marine species (approximately 3.52 kilograms per year); these estimates were derived on a per capita basis for "consumers only." Although it is not possible to discern what proportions of the population consumed either or both freshwater and marine species (and thus, it is not possible to determine consumption rates on an individual basis), the "per capita" consumer rates appear to be roughly comparable for fish obtained from each type (freshwater and marine) of water body. As noted above, these rates are inclusive of commercial species.

In the analysis of the NHANES III national dataset used by U.S. EPA and reported in the *Mercury Study Report to Congress* (1997b), fish and shellfish species were categorized by habitat. Twenty-eight species were considered as marine species, 15 species as estuarine, and five species as freshwater (although only 1 percent of salmon, one of the five species, was considered "freshwater" and 99 percent of salmon was considered to be "marine"). Although U.S. EPA (1997b) stated that marine species were the most frequently consumed, mean estimates of consumption rates were approximately two times greater for freshwater fish compared to marine species (*e.g.*, 274 grams versus 113 grams for males aged 15-44 years). These values were derived from respondents reporting consumption of fish or shellfish during the 24-hour recall period of the survey.

Consumption rates for anglers and other consumers of sport-caught freshwater fish species have been estimated from studies conducted in several regions of the U.S. including Michigan (West *et al.*, 1989a, 1992, 1993), Wisconsin (Fiore *et al.*, 1989), New York (Connelly *et al.*, 1990; 1996), Maine (ChemRisk, 1992), and Alabama (Meredith and Malvestuto, 1996). Ebert *et al.* (1994) reviewed numerous studies that targeted fishing populations consuming freshwater species, discussed the sources of differences in the estimated rates of consumption, and emphasized the importance of comparing like studies. They claimed that the source of fish is a key parameter having significant impact on the consumption rate derived; if the reported amount of fish consumed is based on fish obtained from all sources (commercial, gift, and sport; and from multiple, as opposed to single, water bodies), one would expect a higher amount and rate of consumption than if consumption amounts and rates were derived only from sport-caught fish obtained from a single water body or from any other single source (Ebert *et al.*, 1994). They also proposed that the type of water body used by fishers is one of the factors likely to vary by region. Despite their admonition not to compare dissimilar studies, Ebert *et al.* (1994) compared a number of studies that used different methodologies to derive freshwater fish consumption rates. Most of these studies relied either on mail surveys or creel surveys to obtain annual numbers of sport-caught fish meals which were then multiplied by an assumed meal size (which was

reported in only a few cases and may have varied among studies) to derive a consumption rate. Ebert *et al.* (1994) reported mean consumption rates ranging from 3.7 to 21.8 grams per day for fish caught from multiple fresh water bodies in Maine, Michigan, Wisconsin, New York, and Ontario. As a result of the differences in methodology among these studies, it is difficult to determine whether and/or to what extent the variability in results was related to geographical differences.

Fiore *et al.* (1989) surveyed anglers in Wisconsin and determined the mean number of fish meals per year for both sport and commercial fish. Although the study did not specifically target daily consumption, they estimated consumption rates based on the assumption that meal size was eight ounces, and determined daily mean fish consumption rates to be 12.3 grams per day for sport fish, 13.8 grams per day for commercial fish, and 26.1 grams per day for both sources or total fish consumption. The authors noted that, because fish consumption advisories were in place during the survey, consumption rates were likely to have been lower than usual. However, even if consumption of local sport fish was reduced, nearly half of the daily intake (on average) was from freshwater (sport-caught fish) sources.

Connelly *et al.* (1990) surveyed anglers in New York State to determine the number of fish meals consumed per year. They determined that sport fishers in New York consumed about 50 percent more than the national average, assuming an eight-ounce meal size. They reported annual consumption by statewide anglers to be 45.2 meals per year or 10.1 kilograms per year, which corresponds to 27.7 grams per day. The number of sport fish meals, either freshwater or marine, was not included in the report. Therefore, it is difficult to assess the portion of fish consumption attributable to sport-caught fish and freshwater species, in particular. Connelly *et al.* (1996) reported that sport fish consumption represented 30 percent, on average, of grams of fish consumed (or 26 percent of fish meals consumed). Consumption of commercially obtained fish was not differentiated by type of water body. In addition, Connelly and colleagues suggested that sport fish consumption was suppressed as a result of advisories in the region.

ChemRisk (1992) conducted a mail recall survey asking licensed anglers in Maine to report the numbers and sizes of fish harvested for consumption from Maine fresh water bodies during ice fishing and open water fishing trips. They reported a mean rate of consumption of 6.4 grams per day for fish obtained from fresh water bodies, assuming that the catch was shared equally among a mean household size of 2.5 persons. The results applied strictly to freshwater sport fish, and thus, do not provide comparisons of consumption rates from both marine and freshwater sources. The authors suggested that freshwater consumption rates in Maine, based on their findings, were considerably lower than consumption rates reported from other regions of the U.S. as well as values recommended by U.S. EPA. The authors also noted that low rates of consumption of freshwater species in the state were not surprising given the greater availability of saltwater species (both commercially and recreationally).

Meredith and Malvestuto (1996) reported mean sport fish consumption rates for anglers fishing in fresh water bodies, principally rivers, in Alabama. Overall mean rates calculated from recall during the prior month were 30.3 grams per day for fish from surveyed study sites and 45.8 grams per day including fish caught from other lakes and rivers in the state. Similar results from calculations based on harvested fish indicated that the estimates based on recall were

substantiated by actual catch. This study focused on freshwater fish consumption and did not address consumption of commercial and/or marine fish or shellfish.

West *et al.* (1989a, 1992) surveyed consumption by licensed anglers in Michigan but did not differentiate consumption rates for all types of fish (sport-caught, market, restaurant, and gift) included in their initial survey. In the subsequent yearlong study, West *et al.* (1993) determined consumption rates for both sport-caught fish and total fish consumed. They reported an adjusted mean rate 14.5 grams per day for sport fish, which would consist entirely of freshwater species (obtained from the Great Lakes or waters flowing into them). The overall mean rate for total fish consumed could include both freshwater and marine species. Thus, it is not possible, with these data, to compare consumption of freshwater and marine species.

Murray and Burmaster (1994) used the Michigan data obtained in the initial 1988 study and estimated that adult consumers of self-caught (freshwater) fish averaged 42.3 grams per day. Additionally, they reported mean rates for consumption of sport-caught freshwater fish by anglers as 45.0 grams per day for self-caught fish in general, and 40.9 for anglers consuming fish from the Great Lakes, in particular. These rates are roughly comparable to the overall mean consumption rates of 46.4 grams per day and 49.6 grams per day derived by SCCWRP and MBC (1994), respectively, for anglers in Santa Monica Bay. In addition, upper percentile rates of consumption were roughly similar, although consumption at the 95th percentile in the Michigan study was closer in value to the 90th percentile rate in Santa Monica Bay (98 grams per day for consumption of sport fish by anglers in Michigan and 107 grams per day for anglers in the Santa Monica Bay survey).

The Santa Monica Bay Seafood Consumption Study (1994) and the 1988 Michigan Sport Anglers Fish Consumption Study (as analyzed by Murray and Burmaster, 1994) were comparable in many study parameters and in analytical evaluation and, thus, can be used to compare sport fish consumption rates from marine and freshwater sources. Among the regional studies conducted on fishing populations, these two were the most comprehensive and the results are considered here to be the most reliable. The similarity in rates for adult consumers of sport-caught fish derived from each of these analyses suggests that sport fish consumption rates are likely to be comparable for both marine and fresh water bodies.

Overall, the range of consumption values reported for each type of water body, freshwater and marine, were comparable in regional studies of fishing populations. The values reported for mean consumption rates of sport-caught fish ranged up to 50.2 grams per day (and 63.2 grams per day for Native American fishers) for freshwater fish and up to 49.6 grams per day for marine and estuarine fish. Additionally, the fish consumption rates derived from two comprehensive studies, one based on fishers using a freshwater source (Great Lakes) and the other based on anglers using a marine water body (Santa Monica Bay), support the premise that consumption rates for fishers using roughly comparable freshwater and marine water bodies are equivalent. Although freshwater fish consumption rates may be lower than marine fish consumption rates on a national per capita basis, for consumers of freshwater species, rates of consumption are likely to be comparable to rates for marine species depending on the specific characteristics of the water body and the population fishing from it. A comparison of consumption rates for fish obtained from different types of water bodies would need to consider factors such as productivity

and seasonality, especially when the water bodies are grossly dissimilar, and other factors such as the amount of effort expended by the fishing population or portions thereof. An understanding of the accessibility of the water body for fishing, the availability of desired species, and the relative number of fishing locations could also inform comparisons among different water bodies. Regional or population-specific data are preferred when it is possible to obtain them, provided these data are accurate and relevant. However, in general, for exposure assessments in which potential risks to consumers from consumption of sport-caught fish are to be evaluated, the available data do not support using different rates of consumption for fish obtained from marine and fresh water bodies based solely on salinity type.

B. Fish and Shellfish Consumption Rates for Populations in California

1. Sport Fish

As indicated previously, the Santa Monica Bay Seafood Consumption Study provides the best available dataset for evaluating consumption by California sport fishing populations. The rounded median, mean, and 90th percentile rates of consumption derived from this study were 21, 50, and 107 grams per day, respectively, from the unadjusted results (SCCWRP and MBC, 1994). OEHHA also derived a consumption rate of 161 grams per day at the 95th percentile (Table 11c). Consumption rates reported for specific subgroups were variable, ranging from 28 grams per day to 137 grams per day for mean rates of consumption (SCCWRP and MBC, 1994; Table 11a). The weighted distribution derived from the Santa Monica Bay study included a mean of 30.5 grams per day and a 95th percentile rate of 85.2 grams per day (OEHHA, 2000).

Because a single value is not likely to provide the best estimate of consumption for the population as a whole, it is recommended that consumption of sport fish by populations in California be described by using the full distribution in a stochastic analysis or by using at least a measure of central tendency (the median or mean) in concert with an upper percentile rate from the distribution. Each of these values represents a different point in the distribution and, therefore, a different proportion of the population. Selection of one over another of these values (*i.e.*, a single point estimate) should only be done when the single value (and what it represents) is appropriate to the question at hand or intended use of the consumption rate estimate.

Different exposure scenarios for the amount and frequency of fish consumption may be used in exposure assessments to calculate likely exposure for various segments of a population consuming chemically contaminated fish caught from a given water body. An estimate of the central tendency in the consumption distribution is typically conveyed by using the median consumption rate. This value can be used to characterize a mid-range consumption value, and may be appropriate for describing consumption of a single fish species from a specific water body by the population consuming fish from that water body. The mean will represent an average consumption level for the more frequent consumers in that population, and may be appropriate for describing average consumption of all species of sport fish. High-end consumers are viewed as those represented in the range between the 90th and 99.9th percentile. The

90th percentile consumption rate may be selected to represent the upper end of potential exposure when assessing the risks from consumption of a single species from a single location. In this scenario, the 90th percentile consumption rate would likely be sufficiently health-protective because most sport fish consumers eat meals of different fish species caught from different locations. However, if the exposure assessment is intended to characterize total sport fish consumption (*i.e.*, all species consumed), the 95th percentile rate may provide a more health-protective estimate.

It is recommended, therefore, that the values representing the median and the 90th percentile in the original unadjusted Santa Monica Bay consumption distribution be used in applications that pertain to risks from consumption of a single fish species from a water body (*i.e.*, single pathway exposures where fish consumption is a major exposure pathway). Point estimates (or distributions) adjusted to equally weight infrequent and frequent fishers are more appropriate for cases involving multiple pathways, species, or media where the general population of fishers is the target. Risks from consumption of all species at a given location should be characterized using the mean value and the 95th percentile. In addition, in order to encompass all potential high-consuming groups, including ethnic groups and/or subsistence fishers, it is recommended that the intake rate at the 95th percentile be used to reflect the upper bound estimate of consumption rates for these subpopulations, and when characterizing and aiming to protect the target population as a whole.

It should be noted that the results from the Santa Monica Bay study were based mainly on consumption of finfish as opposed to shellfish, although some fishers in the state may seek invertebrate species rather than fish. Consumption rates for shellfish will be discussed below.

2. Commercial Fish

Studies that specifically address consumption of commercially available fish and/or shellfish by populations in California are lacking. Additionally, national studies of consumption by the general population provide only "acute" consumption estimates for consumers of fish and shellfish (in addition to per capita rates) and may not distinguish commercial from sport fish and shellfish. Therefore, additional studies are needed to provide accurate estimates of consumption of commercial fish and shellfish and/or to interpret the findings from previous studies and use them to derive estimates of "usual" intake. Several studies of fishing populations in the U.S. have evaluated both sport and total (including commercial) fish consumption. These studies showed that fishing populations consumed both sport and commercial fish and shellfish. For example, Murray and Burmaster (1994) determined mean rates of consumption for anglers (eating Great Lakes fish) of 40.9 grams per day for Great Lakes fish and 61.3 grams per day for total fish. The difference amounts to roughly 20 grams per day. The difference between sport fish and total fish consumption among other categories analyzed by Murray and Burmaster (*e.g.*, anglers and others that ate self-caught fish) ranged from 8.1 to 20.4 grams per day at the median, 7.9 to 20.4 grams per day at the mean, and 8.1 to 42.3 grams per day at the 95th percentile rate (see Table 8). These limited data suggest that estimates of consumption rates for sport-caught fish and shellfish may not address the consumption of commercial species by fishers and others who supplement their catch.

The distribution determined for sport fish consumption from the Santa Monica Bay study is similar to the distribution derived by Murray and Burmaster (1994) for consumption by anglers in Michigan, although Murray and Burmaster also calculated rates for total fish consumption. It is likely that fishers and others that consume sport fish in California also consume fish and/or shellfish that are purchased commercially. Therefore, estimates used for consumption of sport fish by California anglers (or others consuming sport fish) should be increased to account for the consumption of commercially available species in addition to sport-caught fish. However, data are not available to use to derive a distribution that describes total fish consumption for fishers and other consumers of sport fish in California. Based on the data obtained from the study of anglers in Michigan, intake of commercial fish and shellfish by consumers of sport fish was at least 8 grams per day and approximately 20 grams per day on average. The difference between sport fish and total fish consumption may be even greater than 20 grams per day at upper levels of intake, as suggested by Murray and Burmaster's analysis. It is not possible to determine from these limited data whether total fish consumption is correlated with sport fish consumption and if there is a correlation, whether it is a positive or an inverse relationship. As a result, only an average amount, 8 grams per day at a minimum and 20 grams per day as a more conservative estimate, can be recommended to be added to sport fish consumption rates to describe total fish and shellfish consumption by consumers of sport fish and shellfish in California. Further studies are needed to address this issue more adequately.

3. Shellfish

The mean national per capita rates reported for shellfish consumption ranged from 2.1 to 3.6 grams per day (Miller and Nash, 1971; Ruffle *et al.*, 1994). Ruffle *et al.* (1994) also reported shellfish consumption rates by region. The highest regional per capita rate was 6.2 grams per day in New England. The Pacific region ranked third with an estimated 4.1 grams per day. However, these rates were all calculated on a per capita basis and were obtained from only two surveys conducted in the late 1960's (Market Facts Consumer Panel Survey) and early 1970's (NPD). Thus, these results have limited use for estimating consumption of shellfish in California.

Rupp *et al.* (1980) reported yearly amounts of seafood actually consumed by adults in the U.S. as 3.41 kilograms per year for freshwater fish, 3.52 kilograms per year for marine fish, and 3.06 kilograms per year for shellfish. These values are roughly equivalent on an annual basis and thus indicate that for those who consumed shellfish, overall yearly consumption was only slightly less than the amounts of freshwater finfish and saltwater finfish consumed. However, because the number of consumers was not reported, it is not possible to estimate consumption rates on an individual ("per consumer") basis. Rupp and colleagues also reported that consumption rates for each type of seafood, *i.e.* freshwater, marine, or shellfish, varied by region, and the Pacific region was noted for greater consumption of crabs, oysters, and clams. In their analyses, the Pacific region had slightly higher average per capita consumption rates than the overall U.S. population (1.16 kilograms per year compared to 1.01 kilograms per year). The percentage of users was also slightly greater in the Pacific region (49.2 percent compared to 41.5 percent). However, there are few data to indicate whether portions of the population consume

primarily shellfish alone or whether, and to what extent, shellfish are consumed in addition to finfish. Therefore, it is uncertain whether a rate that applies to shellfish consumption alone is appropriate. In addition, these rates do not distinguish sport-caught and commercial shellfish.

The Center for Food Safety and Applied Nutrition of the U.S. Food and Drug Administration (FDA) has issued a series of guidance documents addressing heavy metal contamination of shellfish. In this series, "consumer only" consumption rates for crustacean shellfish and molluscan bivalves were presented. The values were derived from data obtained in a 14-day survey conducted by MRCA in 1988 and from analyses conducted by Pao *et al.* (1982) on the 1977-78 USDA NFCS dataset. However, these data were limited to only certain types of commercially available shellfish. Despite these limitations, FDA (1993) reported that for adult consumers, 18-44 years, the 14-day average intake of molluscan bivalves was 12 grams per day, and the 90th percentile was 18 grams per day. The 14-day average intake of crustacean shellfish by adult consumers (18-44 years) was 9 grams per day and the 90th percentile was reported as 19 grams per day. FDA (1993) indicated that these values could be used to model probable chronic or long-term exposure to contaminants. They also reported mean and 90th percentile values for acute or single-exposure intake rates for adults as 117 grams per day and 227 grams per day, respectively, for molluscan bivalves, and 67 grams per day and 135 grams per day, respectively, for crustacean shellfish.

Puffer *et al.* (1982) listed shellfish, principally crabs, mussels, and abalone, among the primary types of "fish" kept by sport fishers. They reported that three percent of the fishers that were interviewed obtained shellfish and that 97 percent of them consumed the catch. They calculated a median rate of consumption of shellfish of 10.0 grams per day per person. Median consumption rates were similarly calculated for the other common species. The species-specific median consumption rates that were reported ranged from 2.0 grams per day per person (for shiner perch) to 143.1 grams per day per person (for halibut). However, the median rate reported for shellfish was similar to rates reported for several of the fish species (*e.g.*, white croaker, jacksmelt, black perch) and the overall median rate of fish and shellfish consumption (36.9 grams per day) determined from the data obtained in this survey represented the amount consumed on average of any type of seafood. There is no reason to assume that a shellfish consumer eats no other type of fish or consumes less or more, on average, than the amount indicated by the overall median rate.

In contrast, data on the consumption of crabs by crabbers along the New Jersey shore indicated relatively high rates of shellfish consumption, particularly compared to the estimated rates of consumption of fish by fishers in the same region. May and Burger (1996) reported average consumption of crabs to be 9.5 crabs per meal at an average frequency of 3.7 times per month, and assuming that each crab would provide 160 grams of edible muscle tissue, determined an average consumption rate of 187 grams per day. The maximum reported intakes were 16 meals per month and 25 crabs per meal. More than 65 percent of the crabbers that were interviewed in this survey indicated that they caught at least three-fourths of the crabs that they ate. These results suggest that in some cases, the average rate of consumption of shellfish species may exceed estimated average rates of consumption of fish.

Data obtained in the Santa Monica Bay study indicated that shellfish comprised a small percentage (5.7 percent) of total catch (based on the number caught). Few individuals who reported consumption of shellfish species were included in the calculations used to derive consumption rates in this survey. Landolt *et al.* (1985) found that the number of crabs (defined as shellfish) caught in the four bays surveyed in Puget Sound comprised less than three percent (of the total number caught) of the twenty most commonly taken species. However, squid (which were not considered in this study to be shellfish, but which are related to other shelled organisms) comprised 39 percent of the most common catch. These studies indicated that some types of shellfish ranked among the most commonly caught seafood, but often comprised only a small percentage of total catch. However, shellfish harvesters are likely to collect their catch in different locations than anglers and may have been encountered less frequently than anglers were. These studies suggest that seasonal differences may be more pronounced for certain types of shellfish, and that regional preferences for favored species may exist and should be taken into account.

Data are not available to indicate what portion of the population in California consumes shellfish, the percentage of consumers that eat a combination of fish and shellfish, whether some consumers eat only shellfish, or to estimate the average percentage of total intake comprised of shellfish. Although the results of the Santa Monica Bay study were reported to include fish and shellfish, only a few shellfish consumers were included in the calculations of consumption rates, and only the estimates derived from the "consumable portions" method would have included shellfish. There is no evidence to suggest that a sport fisher harvesting shellfish in California eats a different amount on average than a sport fisher eating finfish or a combination of fish and shellfish. Therefore, it may be reasonable to assume that the estimates of consumption derived from the Santa Monica Bay study would apply generally to sport fish consumers including consumption of both shellfish and finfish species. However, data are needed to substantiate this assumption.

Clearly there is a need for more data on the consumption of shellfish. Exposure assessments, particularly those conducted in regions such as the Pacific coast or other coastal areas, where certain types of shellfish or other invertebrates are favored, would need to obtain region-specific data in order to fully address shellfish consumption as a component of total fish consumption. Until data are available to elucidate behavior patterns and consumption rates for shellfish species, it will be assumed that the estimated rates of consumption for California fishing populations can be applied to consumption of either fish or shellfish, or fish and shellfish combined.

C. Other Issues

1. Meal Or Portion Size

U.S. EPA (1994) stated that the most commonly reported portion size for the consumption of fish was eight ounces (227 grams). Many studies have used the 8-ounce portion size in assumptions used to calculate fish consumption rates (*e.g.* Connelly *et al.*, 1990; Fiore *et al.*,

1989). However, some studies have assumed other portion sizes. For example, in some analyses performed by U.S. EPA based on data obtained in various studies (e.g., Connelly *et al.*, 1990) portion size was assumed to be approximately 5 ounces (145 grams).

Pao *et al.* (1982) reported the average and the distribution of the quantity consumed per eating occasion for the total survey consumer population and for 16 age/sex subgroups based on data from the 1977-78 NFCS. The average meal size for the total survey consumer population was found to be 117 g, or 4 ounces. The median and 90th percentile values were 85 grams (3 ounces) and 227 grams (8 ounces), respectively. Meal sizes for finfish were slightly higher than for fish and shellfish in general. Average portion size for finfish was 145 grams (5 ounces). Meal sizes tended to be smaller for children compared to adults and greater for men than for women, most likely reflecting differences in body weight. The mean meal size for fish and shellfish for adults ranged from 104 to 123 grams (3.7 to 4.3 ounces) for females and from 124 to 149 grams (4.4 to 5.3 ounces) for males. Average consumption rates of finfish ranged up to 191 grams (6.7 ounces) among males. These estimates were derived from national studies that typically characterize meal sizes for consumption of commercially obtained seafood. Regional studies of fishing populations tend to assume, or indicate, larger portion sizes for sport-caught fish.

West *et al.* (1989a) determined fish meal size by asking respondents to estimate meal size relative to a picture of an eight-ounce portion of fish. If the amount reported was "less" than the pictured meal, portion size was recorded as five ounces (142 grams) and if respondents reported "more" than the eight-ounce picture, portion size was considered to be ten ounces (284 g). However, the frequency of consumption of each portion size was not presented in the results.

In more recent studies of consumption patterns by Lake Ontario anglers, Connelly *et al.* (1996) also asked participants to estimate their meal size by comparison to pictures of eight-ounce (227 grams) fish steaks or fillets. In this study, if respondents indicated that their portion size was smaller, it was recorded as four ounces (114 grams) and if larger, as 12 ounces (343 grams). Connelly *et al.* (1996) determined actual average fish meal sizes to be 216 grams (slightly less than eight ounces), overall, and 232 grams (just over eight ounces) for sport-caught fish meals.

In the fish consumption survey of four Native American tribes in the Columbia River basin, the average serving size for fish meals for adult consumers ranged from less than one to 24 ounces. More than half of the respondents reported an average fish meal size of eight ounces, and the calculated mean serving size was 8.42 ounces (CRITFC, 1994).

May and Burger (1996) reported that the average serving size for fish meals eaten by fishers from three regions of the New Jersey coast ranged from 10.3 to 11.5 ounces per meal. They also reported that an average of 9.5 crabs was eaten per meal by crabbers in the same region. May and Burger assumed that each crab yielded approximately 160 grams of edible muscle tissue, resulting in an average serving size of 53.6 ounces of crab.

In summary, data on actual meal size are limited. Assumptions about average portion sizes are inconsistent among fish and shellfish consumption studies, but typically range from four to eight ounces of fish and/or shellfish per meal. Similarly, actual mean meal or portion sizes, when reported, usually ranged from four to eight ounces. However, in one study, somewhat larger

average portion sizes (up to 11.5 oz) were determined for consumption of fish, and a considerably greater average serving size (54 oz) was reported for consumption of crabs. Although some consumers will exceed or consume less than the average serving size, the full range of meal sizes is often not reported.

Obtaining accurate estimates of portion sizes, comparing estimates from different studies, and using meal size estimates (such as in exposure assessment or risk characterization) are complicated by inconsistency in the use of cooked and uncooked weights. Surveys can vary in terms of whether raw or cooked weight is used, and often the differences are not taken into account or reported. Cooking procedures can result in weight loss of the fish tissue, and the concentrations of chemical contaminants can be altered by various cooking methods. In addition, portion sizes can have different implications (*e.g.*, when estimating concentrations of chemical contaminants) depending on which parts of the fish and/or shellfish are consumed. These types of differences (*e.g.*, cooking methods, parts consumed) may relate to ethnic or cultural practices, and should be investigated and considered when possible.

U.S. EPA (2000b) suggests a default value of eight ounces (227 grams) of uncooked fish fillet as an average meal size for the general adult population (for a 72-kilogram person) for use in exposure assessments and fish advisories if population-specific data are not available. They noted, however, that this meal size is not likely to represent higher-end exposures, where persons consume more than the average amount in a given meal. These larger meal sizes are important to consider in cases where acute and/or developmental effects from consumption of contaminated fish are of concern.

VI. RECOMMENDATIONS FOR SELECTION OF APPROPRIATE ESTIMATES OR DEFAULT VALUES FOR THE CONSUMPTION OF FISH AND SHELLFISH

In order to select the most appropriate estimates of consumption of fish and/or shellfish, it is essential to identify the purpose and use of these values as well as to determine the applicability and reliability of the study or studies from which the estimated rates are derived. Consumption estimates or default values are used for conducting exposure assessments for consumption of chemically contaminated fish and shellfish, and may be used in the development of water quality criteria. Estimates of consumption of fish and shellfish derived from consumption studies are useful for risk assessment, and locally applicable data can enhance exposure assessment for local populations. However, it should be acknowledged that estimates of consumption are not critical or necessarily applicable to the development of the recommended guidelines included in fish consumption advisories. Therefore, fish consumption advisories may be based on consumption rates that differ from national or local estimates. As an example, to achieve statewide consistency, a fish advisory program may choose to issue advice based on standard meal sizes (*e.g.*, an eight ounce portion size) and standardized meal frequencies (*e.g.*, once per week or once per month). The applicable meal frequencies for each advisory are selected after considering the concentrations of the chemicals of concern measured in fish tissues and the amount of fish that can be eaten without exceeding acceptable daily doses for the chemical of concern. Estimates of the rates of consumption by the population using the water body for which an advisory has been developed can be compared to the recommended guidelines, but are not needed to determine acceptable or safe levels of consumption.

When fish consumption estimates are to be used to conduct an exposure assessment for locally abundant pollutants only, where fish consumption is a major exposure pathway, consumption rates that are applicable to sport fish consumption from the affected water bodies should be used. The first choice for "applicable" consumption rates would be those derived from surveys of the water body in question. When studies from the water body in question are not available, the results of other well-conducted studies deemed appropriate for application to the population at risk and/or water body of concern can be used. Additionally, in order to characterize potential risks to public health from consuming contaminated fish and/or shellfish, consumption rates that apply to people who actually consume sport fish and/or shellfish, rather than per capita estimates, should be used. In these cases, using either per capita estimates or a consumption rate derived from a low percentile of the consumption distribution will not accurately estimate exposure to at-risk consumers from contaminants in sport fish. This situation occurs because the portion of the population that frequently consumes sport fish is often relatively small, and these consumers are represented by the upper percentiles of a distribution that is based on the complete population. As a result, consumption rates that specifically include consumers must be used in local exposure assessments and consequent management actions in order to describe exposure to the highest risk subpopulation of consumers (as opposed to the general population) accurately and to provide for adequate protection of public health.

In addition, decisions must be made regarding what percentile of the distribution will protect the population of concern (*e.g.*, the 50th, 80th, 90th, 95th, or 99th percentile). U.S. EPA (2000c) recognizes that different percentiles may be used to represent and protect specific target populations, and the proportion of a population that is represented by a given percentile depends on how the distribution was constructed. U.S. EPA suggested that the scientific validity of selecting a portion of a distribution be demonstrated by showing that the target population is protected by the selection.

Thus, an understanding of the construction of the distribution (*e.g.*, which data are input) can be critical to making choices that are scientifically valid. As an example, in a distribution of consumption rates for fishers in which only those that ate fish were included, a value that represents the central tendency (*i.e.*, the mean or the median) would include actual consumers. However, consumption rates based on a central tendency estimate of consumption from a distribution constructed for a population inclusive of fishers and/or others that did not consume fish may not represent average consumption by actual consumers. In this case, selecting a percentile that represents a sufficient percentage of the subpopulation that consumes sport fish and shellfish is a decision that must consider scientific validity and the population reflected in the distribution. Other factors that bear on the scientific validity of an upper bound estimate (usually ranging from the 90th to the 99th percentile) include the quality of the estimate, which is often dependent on sample size and the power of the study to calculate consumption in the tails of the distribution, and whether the upper percentiles reflect discrete subpopulations such as subsistence fishers.

In some circumstances, estimates of consumption of fish and/or shellfish from all sources may be appropriate. For example, if a risk assessment is conducted to evaluate exposure to a chemical(s) of concern with a global distribution, such as methylmercury, then rates for total fish consumption from all sources, including commercial and sport fish, may be relevant for evaluating total exposure to the chemical of concern. In addition, for multipathway exposure assessments, it may be appropriate to apply fish consumption estimates that represent individuals who consume sport fish less frequently, or not at all, as well as those who are frequent consumers. High-end rates (*e.g.*, the mean or an upper bound consumption rate) from such studies would be protective of the majority of the population.

The selection of consumption studies and consumption rates to develop water quality criteria is another special situation. In this case, the rates are not used to assess risk but to set limits to prevent the potential for excess risk developing. Selection of consumption rates in these cases must be flexible so that criteria can be targeted to protect different populations. The target population may differ on a national, statewide, or local basis. U.S. EPA's national water quality criteria are aimed at protecting the majority of the general population from chronic adverse health effects. National consumption studies and high-end consumption rates from such studies of the entire general population (consumers and nonconsumers) are considered protective in this case. These studies and consumption rates, however, may not be protective of state or local target populations. U.S. EPA (2000c) has developed a series of preferences for states selecting consumption rates to use to develop water quality criteria. The preferred option for states is to use regional or local consumption studies and consumption rates to adequately protect the most highly exposed population when developing state or local criteria.

A. Sport Fishing Populations in California

The Santa Monica Bay Seafood Consumption Study provides the best available dataset for estimating consumption of sport fish and shellfish in California. This study provided a distribution of consumption rates for the population that regularly fishes and consumes fish and shellfish from Santa Monica Bay, and reflects the range of values and the variability within the population. Consumption of sport fish and/or shellfish by populations in California can be described either by using the full distribution in a stochastic analysis or by using, at a minimum, a measure of central tendency (the median or mean) in concert with an upper percentile intake rate from this distribution. Although this study applied to a population fishing from a marine water body, a similar distribution of consumption rates was determined from data obtained in Michigan on a population fishing from fresh water bodies. Thus, the default values derived from the Santa Monica Bay study can reasonably be applied to fishers using any productive water body in the state. Until reliable data become available which describe consumption of freshwater sport fish in California, it is recommended that the rounded unadjusted values from the Santa Monica Bay study of 21 grams per day for the median, 50 grams per day for the mean, 107 grams per day for the 90th percentile, and 161 grams per day for the 95th percentile rate be used to estimate frequent consumption from both marine and freshwater sources of sport fish and shellfish in California. These values are most applicable to fishers that consume sport fish and shellfish on a frequent (*i.e.*, at least once a month) and regular basis. For cases where the adjusted results are appropriate, such as when the target population is the general fishing population and fish may not be a major exposure pathway, the mean value of 30.5 grams per day and 95th percentile of 85.2 grams per day can be used.

Decisions about which of these default values to select when applications necessitate the use of only one or two statistics should be based on the appropriateness of the selected value to the question at hand. It is recommended that the values representing the median (21 grams per day) and the 90th percentile (107 grams per day) from the Santa Monica Bay dataset be used in applications that pertain to risks from consumption of a diet of a single fish species. In this scenario, the median and 90th percentile consumption rates from the unadjusted results would be sufficiently health-protective because most sport fish consumers eat meals of different fish species caught from different locations. It is recommended that risks from consumption of a diet of a mixture of fish species at a given location be characterized using the mean value (50 grams per day) and the 95th percentile (161 grams per day) that were calculated from the Santa Monica Bay study. In addition, in order to encompass all potential high-consuming groups, including ethnic groups and/or subsistence fishers, it is recommended that the intake rate at the 95th percentile be used to reflect the upper bound estimate of consumption rates for these subpopulations and for the entire population potentially at risk.

As indicated previously, in cases where the general fishing population is the target, the weighted distribution derived from the Santa Monica Bay study may be used. For further discussion of the derivation and application of the adjusted results from the Santa Monica Bay study, the reader is referred to the *Air Toxics Hot Spots Risk Assessment Guidelines. Part IV: Technical Support Document for Exposure Assessment and Stochastic Analysis* (OEHHA, 2000).

B. Sport Fishing Populations in Other Regions

Regional studies of sport fishing populations in the U.S. reported overall mean rates for consumption of sport fish ranging from 12.3 to 63.2 grams per day. These studies can provide default values for populations fishing in these regions and can be used to derive estimates for sport fishing populations in other regions where geographic and population characteristics are similar. However, the limitations of a given study as discussed in this document should be considered and factored into decisions about which default values are appropriate for use. Additionally, it is recommended that estimates for populations include at least a measure of central tendency (the median or mean) and upper percentile rate (rather than a single value)^{bb} or that the full distribution be used to reflect the variability in consumption rates typical of sport fish consuming populations.

In some cases, an adequate dataset may not be available to represent the population in question. Because the Santa Monica Bay Seafood Consumption Study represents the most comprehensive and well-conducted study to date of sport fishing populations, the distribution of consumption rates or default values derived from this study can be used to represent other populations that regularly consume sport fish and/or shellfish when locally specific data are not available or are not considered adequate. The similarity in the consumption distributions derived for sport fish consumers fishing in Santa Monica Bay and in Michigan, coupled with findings of comparable consumption rates by freshwater fishers using rivers and lakes in Alabama, suggests that precise matching of demographic characteristics of populations in different regions may not be imperative to adequately describe rates of consumption of sport fish by these different populations. The similarity in consumption distributions also lends support to the applicability of these estimates to other sport fish-consuming populations.

C. Consumption Rates for Subpopulations

Consumption rates can vary among subpopulations by race or ethnicity, age, sex, income, fishing mode, geographic region, and other demographic variables. However, an evaluation of differences in average consumption rates for subpopulations showed that the differences, when they occurred, were less than an order of magnitude. The greatest differences in consumption rates for specific subpopulations were on the order of a maximum of five times greater when comparing the highest-consuming and lowest-consuming ethnic subpopulations in a survey. Additionally, average consumption rates for the highest consuming ethnic subgroups were approximately three times the overall mean rate for the survey population. These differences would contribute a relatively small amount of error in exposure assessments, if the appropriate rate for a particular subpopulation were not included, relative to the degree of uncertainty

^{bb} The median, mean, and an upper percentile value each represent a different point in the distribution and, therefore, a different proportion of the population. Selection of one over another of these values (*i.e.*, a single point estimate) should only be done when the single value (and what it represents) is appropriate to the question at hand or intended use of the consumption rate estimate.

already inherent to risk assessment. Although every effort should be made to obtain the most relevant data and to adequately describe consumption by subpopulations of interest, in those cases where inadequate data are available for subpopulations suspected to have above-average consumption rates, upper level intake rates from a distributional analysis are likely to represent subgroups with above-average consumption. Use of default values from a consumption distribution should not preclude direct evaluation of exposure to populations of concern, when it is possible and circumstances warrant this evaluation.

VII. CONCLUSIONS

A number of factors contribute to the variability in reported fish consumption rates. As stated previously, how fish and/or shellfish are defined; how populations are defined; which population is targeted and how adequately the sample population represents the target population; the sources of fish and how they are defined, differentiated, and measured; the type of data collected and by which methods; the time period of the study; methods of data analysis and how researchers work with biases in the dataset; and other locally specific factors all contribute to variability in results.

Ideally, site-specific data that reflect the full distribution of consumption rates for the population of interest would be available. However, given time and resource constraints, exposure and risk assessors will have to look for the most relevant, representative, and reliable data sources for the populations of concern and make decisions based on the best available information at the time.

Given the information reviewed in this paper, the following conclusions can be drawn:

- **Careful identification of the context in which fish consumption rates will be applied is key to selecting appropriate estimates of consumption.**

When selecting the most appropriate estimates of fish and shellfish consumption, it is essential to identify the purpose and use of the estimated fish consumption rates. In particular, one needs to clearly define the population of concern or "target population." In order to characterize potential risks to public health from consuming contaminated fish and/or shellfish, consumption studies that represent people who actually consume the fish and/or shellfish should be used. If consumption rates are to be used to develop state or local water quality criteria, estimates that describe actual consumption of fish and/or shellfish such as those that apply to the water bodies of concern, or similar water bodies, are appropriate for describing potential impacts from fish consumption from contaminated water bodies. Alternatively, water quality criteria can be developed without the use of specific local data, but should be based on representative consumption rates such that the criteria will support consumption of fish from the water body at rates at which local users consume fish. In addition, assessors must consider the sources of contaminants for which exposure is being assessed. If the chemical(s) of concern is one with a global distribution, such as methylmercury, and the objective is to characterize total exposure to this chemical, then estimates of total fish consumption from all sources, including commercial and sport fish, are needed to evaluate the potential health risks from exposure to this chemical via ingestion of fish and/or shellfish.

- **Per capita consumption rates describe trends for the general population.**

Per capita rates are estimates derived for the general population inclusive of both consumers and nonconsumers. Thus, per capita rates are primarily useful for trend analyses rather than representing actual consumption by consumers. Average per capita rates for fish and shellfish consumption for the general population derived from national surveys ranged from 10 to 17.9 grams per day. Several analyses of data used to estimate per capita consumption of

fish and shellfish found an increase of approximately 25 percent between 1970 and 1997, indicating that the U.S. population as a whole consumed more fish in more recent years.

- **U.S. EPA has updated their default value of 6.5 grams per day and provided recommendations for selecting the most applicable fish consumption values; therefore, use of the old default value of 6.5 grams per day is inappropriate and unjustified.**

U.S. EPA has revised their recommended default fish consumption values, taking into account many studies that have been conducted since they originally promulgated the 6.5 grams per day default value. Although many agencies adopted and used this value over the years, it was applied in innumerable instances inappropriately and often without an adequate understanding of its derivation and applicability. Consequently, the widespread use of 6.5 grams per day as a default value for fish consumption, particularly for sport fishers, has been unjustified and inappropriate, and the continued use of this per capita default estimate to represent actual consumption by consumers of sport fish would be scientifically inappropriate. U.S. EPA has provided updated recommendations for selecting fish consumption rates for the derivation of water quality criteria and for fish advisory programs.⁹ These recommendations include a hierarchy of preferences for selecting the most appropriate and protective values. In particular, States and Tribes are encouraged to use local or regional data when available and appropriate to protect fish-consuming populations such as recreational and subsistence fishers that are most at risk.

- **Consumption estimates for consumers are preferred but not widely available on a national basis.**

Consumption rates derived for consumers are preferable to per capita rates for use in describing actual consumption of fish and shellfish in the U.S. However, national data that apply to "consumers only" are limited. National surveys that have targeted the general U.S. population have determined "acute" consumption patterns for respondents reporting consumption of fish and/or shellfish during the short-term reporting period of the survey. Therefore, the results may not characterize long-term or "usual" consumption rates for consumers. National studies that have been conducted thus far were not designed to fully address consumption of sport fish and shellfish. Thus, the results of these surveys are applicable mainly to consumption of commercial fish and shellfish and are not suitable for characterizing consumption by fishers or other consumers of sport fish and shellfish.

- **Regional surveys provide estimates of fish consumption for sport fishing populations for their respective regions, and may be applicable to other populations with similar characteristics.**

Regional studies of sport fishing populations in the U.S. reported overall mean rates for consumption of sport fish ranging from 12.3 to 63.2 grams per day. Many of these studies were conducted at locations where consumption advisories were in place for water bodies used by the sport fishers surveyed. The overall mean rates for total fish consumption calculated from the studies that targeted fishing populations (and reported on consumption of both sport and commercial fish and shellfish) ranged from 16.1 to 61.3 grams per day. These studies indicated

that sport fishers consumed both sport fish and commercially available species. Estimates of average consumption rates for commercially available species added approximately 8-20 grams per day (and up to 42 grams per day) to the average consumption rates for sport-caught fish. The consumption studies of fishing populations can be used to derive estimates for sport fishing populations in regions where geographic and population characteristics are similar, provided that the limitations of a given study are considered. Additionally, estimates for populations should include at least a value representing central tendency (*i.e.*, the median or mean) used in concert with an upper percentile rate, or use the full distribution to reflect the variability in consumption rates typical of sport fish consuming populations.

- **Fish consumption by sport fish consumers in California is best represented by the Santa Monica Bay distribution.**

Consumption of sport fish by populations in California can be described by the consumption distribution determined from the Santa Monica Bay Seafood Consumption Study. The distribution of unadjusted data from the study included 21 grams per day, 50 grams per day, 107 grams per day, and 161 grams per day for the median, mean, 90th and 95th percentile rates, respectively. These values are appropriate for use when the target population is the subpopulation most at risk, (*i.e.*, frequent consumers), particularly for risk assessments when fish consumption is a major pathway for exposure to chemical contaminants. When fish consumption is not a major source of exposure and the target population is the general fishing population, the weighted default values of 30.5 grams per day for the "average" and 85.2 grams per day for "high-end" derived from the Santa Monica Bay study data may be appropriate. Few studies have specifically addressed rates of consumption of commercial fish and shellfish in California. However, several studies have indicated that total consumption by fishers is greater than sport fish consumption, and suggested that the difference in amount between sport and total consumption ranges from approximately 8 to 42 grams per day. Adding an additional amount to the estimated consumption rate for sport fish and shellfish (at least 8 to 20 grams per day, on average, of commercially available species) will account for supplemental consumption of commercial species, or total consumption, by sport fishing populations in California. Additionally, national estimates for consumers (particularly those derived from the most current studies) can be used to describe consumption by the general population in California that consumes only commercial species, although the results may not adequately characterize "typical" consumption rates for consumers over time. Insufficient data are available to estimate consumption rates for shellfish; further studies are needed to describe patterns and rates of consumption of shellfish. The rates provided for sport fish consumption in the Santa Monica Bay Seafood Consumption Study may encompass consumption of shellfish species by those people who catch shellfish as opposed to finfish.

- **The Santa Monica Bay distribution may also be applied to sport fishing populations with similar characteristics in other regions.**

The Santa Monica Bay Seafood Consumption Study represents the most comprehensive and well-conducted study to date of sport fishing populations. Although this study sampled fishers using a marine water body, the similarity in results between this dataset and the analysis of data on freshwater fishers in Michigan by Murray and Burmaster (1994) suggests that the results are

applicable to sport fish consuming populations in any region, particularly when geographic and population characteristics are similar. Moreover, precise matching of demographic characteristics of populations in different regions may not be imperative to adequately describe rates of consumption of sport fish by these different populations. Thus, the distribution of consumption rates derived from the Santa Monica Bay dataset can be used as default values when locally specific data are not available (or appear to be inadequate). This distribution is most applicable to fishers that consume sport fish and shellfish on a frequent (*i.e.*, at least once a month) and regular basis.

- **Fish consumption rates do not differ greatly for fresh water and marine water bodies.**

The available data suggest that consumption rates for sport-caught marine and estuarine fish tend to be comparable to those for sport-caught freshwater fish. Additional data are needed to evaluate the potential for differences in consumption of fish obtained from water bodies in specific regions of the U.S. where variables such as access and availability of fish and/or shellfish may differ. However, in general, for exposure assessments in which potential risks to consumers from consumption of sport-caught fish are to be evaluated, the available data do not support using different rates of consumption for fish obtained from marine and fresh water bodies based solely on salinity type.

- **Portion sizes generally range from four to eight ounces of fish per meal, but more data are needed to improve the accuracy of portion size estimates.**

Data on meal or portion size are limited. Assumptions about portion sizes are inconsistent among fish and shellfish consumption studies, but typically range from four to eight ounces of fish and/or shellfish per meal. Actual mean meal or portion sizes, when reported, usually ranged from four to eight ounces. Thus, U.S. EPA's recommendation of eight ounces as a standard meal size is a health protective default value. This value is useful for consistency (*e.g.*, for developing consistent statewide consumption advice) and ease of comparison by consumers. Differences in the reporting of raw versus cooked weights, the parts of fish consumed, and methods of preparation can affect the accuracy of portion size estimates and have implications when consumption estimates are used in risk assessment or in the development of advisories or water quality criteria. More data on meal size and the frequency of consumption of fish and/or shellfish, with consideration given to these variables, can be used to improve the accuracy of estimates of consumption rates.

- **Defining subsistence fishers is difficult, but important for protecting human health; population-specific data on fish consumption are needed for this purpose.**

Difficulties in defining and evaluating subsistence fishers have resulted in limited information pertaining to consumption rates for subsistence populations. A number of subpopulations shown in some studies to be high-consuming groups (*e.g.*, Native Americans and some Asian populations) may be underrepresented in consumption surveys, especially if the sampling frame is based on fish license holders. Language and literacy issues may also be barriers to survey participation. A few datasets are currently available for sport fishing populations believed to either represent or include subsistence fishers. The CRITFC (1994) study of Native American

subsistence fishers reported a mean consumption rate of 63.2 grams per day and a rate of 170 grams per day at the 95th percentile. However, data obtained from some subsistence populations indicated that consumption of fish and shellfish can range up to 770 grams per day. Thus, in locations where exceptionally high consumption by subsistence populations or other people is expected, using data for the subpopulation of interest would be preferable to the use of default values. Locally applicable data would be particularly useful in areas where potential subsistence populations have easy free access to productive water bodies.

- **Demographic variables such as ethnicity may influence consumption rates for subpopulations. Upper percentile consumption rates from consumption distributions may be used to represent high-consuming individuals in the population when population-specific data are not available.**

Consumption rates can vary by race or ethnicity, income, fishing mode, region of the country, and other demographic variables. Per capita studies and regional surveys of fishers showed differences in the type of species preferred for consumption in certain regions of the U.S. A number of studies have demonstrated trends in higher rates of fish consumption related to factors such as race or ethnicity. These studies showed that fish consumption rates were higher for certain subpopulations including some Asian populations, Blacks, Native Americans, and other minority groups, although the trends were not consistent across studies. Survey methodologies and the definitions of subpopulations differed among surveys so that comparisons among studies are difficult. The results of these studies showed that careful definition of ethnic groups is important to the outcome, particularly for "Asian" populations as a result of the variability in consumption of fish and shellfish among these different cultures. Some studies also found differences in the patterns of fish consumption and fishing behavior among subgroups. The interaction of demographic variables and region-specific factors must be taken into account to fully understand potential differences among subpopulations. However, reported mean consumption rates for ethnic subpopulations differed at most by five times and the highest-consuming ethnic subpopulation had an average consumption rate that was approximately three times higher than the overall average rate for the study population. Higher-consuming ethnic subpopulations and other high-end consumers are likely to be represented by the upper percentile consumption rates (such as the 90th, 95th, or 99th percentile) derived from a distributional analysis of the consumption data.

- **Fish consumption rates can vary by age and sex, although many of the differences are related to differences in body weight. Upper percentile rates of consumption from a distributional analysis of fish consumption can be used to represent high-consuming members of the population.**

Studies that differentiated fish consumption rates (grams per day) by age and sex showed that, generally, males consumed more than females did, and the amount of fish consumed increased with age. However, few of these studies accounted for differences in body weight in their analyses. To some extent, the differences are likely to be attributable to differences in body weight. Exposure assessments should consider body weight as a parameter and use sex and age-specific consumption rates, when available, or adjust for differences in body weight when evaluating subsets of the population. Additionally, there is limited evidence that elderly fishers

in certain regions and some subpopulations in which a combination of demographic variables interact (*i.e.* ethnicity and age) consume fish and/or shellfish at rates that exceed the average for adult sport fish consumers. In these studies, elderly fishers consumed fish at mean rates that were two to three times greater than the overall average rate. Because of these demographic differences, region-specific data are preferred when available and adequate. In the absence of actual data, higher consuming subgroups are likely to be included within the upper percentile consumption rates derived from a distributional analysis of the consumption data.

- **Fish consumption distributions should be used (rather than single point estimates) to describe consumption rates in order to address the variability in fish-consuming populations.**

The results of distributional analyses of intake rates reflect the large amount of variability within populations consuming fish and shellfish. Distributional analyses rather than single point estimates can best represent consumption rates within a population. Using a stochastic analysis or at least a measure of central tendency (the median or mean) in combination with an upper percentile rate of intake derived from a distributional analysis will allow a better characterization of consumption in a population and the variability within that population. However, it is also essential to understand how a given distribution has been derived and what types of data were used as inputs to construct the distribution. In particular, the inclusion or exclusion of nonconsumers and the application of sampling weights can have significant effects. As a result, point estimates or percentile rates of consumption derived from distributions constructed differently can have vastly different meanings and applications, and thus, it is important to understand these differences. When point estimates such as the median, mean, 90th, 95th, or 99th percentile consumption rate must be selected from a distribution to represent a population of sport fish consumers, the choice of which statistic(s) to use depends on a number of scientific and technical issues. These issues include, but are not limited to, the strength of the study to determine the tails of the distribution, the scientific validity of the distribution, and the specific context in which the estimated consumption rates are to be used.

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APPENDIX I: GLOSSARY

angler - one who fishes with hook and line (note that this is the technically correct definition, however, several studies have used this term to denote "fishers")

aquatic - from or living in a water body, including both marine and freshwater

bivalves - aquatic animals (belonging to the phylum Mollusca and the class Bivalvia) whose body is enclosed in a shell consisting of two valves, *e.g.*, clams, mussels, oysters, scallops

cephalopods - aquatic animals (belonging to the phylum Mollusca and the class Cephalopoda) having tentacles attached to the head, *e.g.*, octopus, squid, cuttlefish, nautilus

commercial fisher - an individual who derives income from catching and selling living aquatic resources

creel survey - on-site interviews with fishers to obtain information such as species caught; number, length, and weight of catch; location; etc.; typically for use by fisheries managers; may or may not include information on consumption

crustaceans - primarily aquatic animals (belonging to the phylum Arthropoda and the subphylum Crustacea) typically having a body covered by a jointed exoskeleton, *e.g.*, shrimps, crabs, lobster

echinoderms - marine animals (belonging to the phylum Echinodermata) typically having pentaradial symmetry (in adult forms) and a calcareous skeleton, often with projecting spines, *e.g.*, sea urchins, sand dollars, sea cucumbers, sea stars

estuarine - from an estuary, *i.e.*, a partly enclosed water body, such as an inlet of the ocean or the mouth of a river where it meets the ocean, that contains brackish water (a mixture of salty and freshwater) such as San Francisco Bay

finfish - fish; a term that is usually applied to the consumption of fish as opposed to shellfish

fish - any of various aquatic animals (belonging to the subphylum Vertebrata) having gills, commonly fins, and bodies usually but not always covered by scales, including those having bony skeletons (bony fishes) and more primitive forms with cartilaginous skeletons (lampreys; hagfishes; and sharks, skates, and rays)

fisher - one who fishes for any type of seafood by any method, inclusive of hook and line and other methods of catching seafood

fish in hand - fish and/or shellfish that a fisher has caught and which he/she has at the time of being interviewed (in a creel survey)

freshwater - water bodies including lakes, ponds, rivers, and streams that contain water with relatively low salinity, *i.e.*, less than 0.5 ppt; species inhabiting fresh water bodies

game fish - sport fish that are caught for food

gastropods - aquatic and terrestrial animals (belonging to the phylum Mollusca and the class Gastropoda) typically having an asymmetrical spiral shell that (when present) is used as a protective retreat, *e.g.*, snails, limpets, slugs, abalone

marine - from, or living in, the ocean; saltwater, with a salinity of approximately 35 ppt

mollusks - members of the highly diverse invertebrate phylum Mollusca, including soft unsegmented animals usually protected by a shell and having a muscular foot for locomotion; includes the gastropods (snails), bivalves (clams, oysters), and cephalopods (squids, octopus)

noncommercial fisher - one who fishes for recreation and/or home consumption, synonymous with recreational fisher, sport fisher

recreational fisher - one who fishes primarily for recreational purposes; recreational catch is used primarily for home consumption, synonymous with noncommercial fisher, sport fisher

seafood - aquatic organisms that are consumed, including mainly fish and shellfish, and less frequently, other invertebrate animals or plants or marine mammals

self-caught fish - fish that are caught by a sport fisher as opposed to purchased commercially, synonymous with sport, sport-caught, recreationally caught, and noncommercial fish

shellfish - aquatic invertebrate animals having a shell or exoskeleton, the term usually used in the context of food, including species belonging to the following taxa (some of which have evolved such that the shell has become internal and/or reduced, or has disappeared entirely): 1) mollusks, including bivalves (*e.g.*, clams, oysters, mussels, scallops), gastropods (*e.g.*, snails, limpets, abalone), and cephalopods (*e.g.*, squid, octopods); 2) crustaceans (*e.g.*, crabs, shrimps, lobsters); and 3) echinoderms (*e.g.*, sea urchins, sea cucumbers)

sport fish - fish that are caught by a sport fisher as opposed to purchased or caught commercially, synonymous with sport-caught, self-caught, recreationally caught, and noncommercial fish

sport fisher - one who fishes, by any method, for recreation, synonymous with recreational fisher, noncommercial fisher

subsistence fisher - one who fishes for food, for economic and/or cultural reasons, and for whom the fish and/or shellfish caught is a major source of protein in the diet

APPENDIX II: TABLES

Table 1. Annual Per Capita Consumption Estimates^{cc} for the U.S. for Fish and Shellfish Based on Food Disappearance into Commercial Markets

Fishery Product	Year	Pounds per year	Grams per day
Finfish (fresh and frozen)	1987	6.0	7.5
	1991	6.0	7.5
	1993	6.3	7.8
Shellfish (fresh and frozen)	1987	4.0	4.9
	1991	3.7	4.6
	1993	3.9	4.9
Combined Finfish and Shellfish (fresh, frozen, canned and cured)	1960	10.3	12.8
	1970	11.8	14.7
	1980	12.5	15.5
	1987 ^{dd}	16.2	20.1
	1990	15.0	18.7
	1993	15.0	18.7

Source: NMFS (1994)

^{cc} Quantities of commercial seafood available for consumption were derived by deducting exports, inventory changes, and nonfood use from data on production, imports and beginning inventories for fresh, frozen, canned, and cured commercial fishery products. Calculated per capita rates were based on an "edible weight basis." Civilian population size was estimated at the middle of the census period.

^{dd} record year for fish purchases (NMFS, 1994)

Table 2. Per Capita Consumption Rates (grams per day) for Fish and Shellfish in the U.S. Based on National Surveys

Survey	Median	Mean	Upper %	Reference
1969-70 Market Facts Consumer Panel Survey		14	77 (99th) 165 (99.9th)	Finch (1973)
		16.8 ^{cc}		Hu (1985)
1973-74 National Purchase Diary (NPD)		18.7 ^{ff}		Cordle <i>et al.</i> (1978)
		14.3	41.7 (95 th)	Javitz (1980)
		15.3 ^{cc}		Hu (1985)
1981 NMFS Market Research Corporation of America (MRCA)		8.1 ^{ff}		Hu (1985)
1977-78 USDA National Food Consumption Survey (NFCS)		12		USDA (1983)
		17.9 ^{ee}		Hu (1985)
1987-88 USDA National Food Consumption Survey (NFCS)		11 ^{ff}		USDA (1993)
1989-91 USDA CSFII		13 ^{gg}		USDA (1994)
	0	15.65	78.3 (95 th)	Jacobs <i>et al.</i> (1998)
1994-96 CSFII		10		USDA (1997)

^{cc} "at-home" consumption

^{ff} value considered invalid or unreliable

^{gg} based on one-day intake records

Table 3a. Annual Consumption of Fish and Shellfish in the U.S.

Target Population	Freshwater Finfish		Saltwater Finfish		Shellfish	
	kg/yr	g/day	kg/yr	g/day	kg/yr	g/day
Per capita rate for U.S.	0.43	1.2	3.20	8.8	1.01	2.8
Per capita rate for U.S. consumers	2.43	6.7	3.52	9.6	2.91	8.0
Per capita rate for U.S. adult consumers	3.41	9.3	3.52 ^{hh}	9.6 ^{hh}	3.06	8.4

Source: 1973-74 National Purchase Diary (NPD) Survey (Rupp *et al.*, 1980)

Table 3b. Regional Summary of the Average Per Capita Consumption Rate of Fish and Shellfish (kilograms per year) and Percent Users (Adults Only)

Census region	Freshwater Fish	% Users	Saltwater Fish	% Users	Shellfish	% Users
U.S.	0.43	15.9	3.20	90.0	1.01	41.5
New England	0.08	5.1	3.78	93.4	1.69	59.6
Mid Atlantic	0.27	10.6	3.67	92.2	1.06	44.3
S. Atlantic	0.33	12.4	3.43	89.2	1.43	49.6
E. S. Central	0.70	23.7	2.87	89.5	0.82	34.5
E. N. Central	0.56	18.9	2.97	88.0	0.61	29.5
W. N. Central	0.64	22.4	2.58	31.1	0.60	31.1
W. S. Central	0.84	25.0	2.97	88.7	1.14	39.4
Mountain	0.46	17.0	2.73	88.2	0.79	42.2
Pacific	0.33	14.1	3.51	91.2	1.16	49.2

Source: 1973-74 National Purchase Diary (NPD) Survey (Rupp *et al.*, 1980)

^{hh} An annual rate for adult consumers of saltwater fish was not given. Rupp *et al.* (1980) reported that this amount was not much different from the per capita rate for all consumers, thus, 3.52 kilograms per year was used for these estimates.

Table 3c. Per Capita Fish and Shellfish Consumption Rates (grams per day) for Adults in the U.S. and the Pacific Region

Type	All regions			Pacific region		
	median	mean	90 th %	median	mean	90 th %
Freshwater fish	0	1.48	5.12	0	1.07	4.05
Saltwater fish	7.29	10.68	23.73	7.84	11.37	25.59
Shellfish	0	3.59	10.96	0	4.05	11.64

Source: 1973-74 NPD Survey (Ruffle *et al.*, 1994)

Table 4a. 1985-86 USDA Continuing Survey of Food Intake of Individuals (CSFII) Combined Fish and Shellfish Per Capita Consumption Rates (grams per day)

Time period/ days sampled	Population sampled ⁱⁱ	Mean	Reported users (%)	Source
Summer 1985 1 day	men	21	11	USDA (1986b) No. 85-3
Spring 1985 1 day	women	13	11.5	USDA (1985) No. 85-1
Spring 1986 1 day	women	11	10	USDA (1987b) No. 86-1
1985 4 nonconsecutive days	women	11	32.8 ^{jj}	USDA (1987a) No. 85-4
1986 4 nonconsecutive days	women	12	30.4 ^{jj}	USDA (1988) No. 86-3
Spring 1985 1 day	low income women	11	7.5	USDA (1986a) No. 85-2
Spring 1986 1 day	low income women	9	8	USDA (1987c) No. 86-2
1985 4 nonconsecutive days	low income women	9	23.3 ^{jj}	USDA (1988a) No. 85-5
1986 4 nonconsecutive days	low income women	9	26.2 ^{jj}	USDA (1989) No. 86-4
1985-86 3 days	women	20.4 ^{kk}	44.7	Popkin <i>et al.</i> (1989)

ⁱⁱ All groups were aged 19-50 years

^{jj} using at least once

^{kk} includes seafood in mixed dishes

Table 4b. 1989-91 USDA Continuing Survey of Food Intake of Individuals (CSFII)^{ll} Combined Fish and Shellfish Per Capita Consumption Rates (grams per day)

Population sampled	Mean rate	Reported users (%)	Source
men ≥ 20 yrs	17	11	USDA (1994) ^{mmm}
women ≥ 20yrs	14	10.9	USDA (1994)
all individuals	13	9.6 ⁿⁿ	USDA (1994)
all individuals	16	*	Jacobs <i>et al.</i> (1998)

* not reported

^{ll} preliminary results

^{mmm} data from one-day

ⁿⁿ Reported using on day of interview

Table 5. "Consumer-Only" Consumption Rates (grams per day) for Fish and Shellfish Combined

Survey (Reference)	Median	Mean	90 th Percentile	95 th Percentile
1977-78 NFCS (Pao <i>et al.</i> , 1982)	37	48	94	128
1977-78 NFCS (Popkin <i>et al.</i> , 1989 ^{oo})	*	111.0	*	*
1985-86 CSFII (Popkin <i>et al.</i> , 1989 ^{oo})	*	88.2	*	*
1989-91 CSFII (U.S. EPA ^{pp})	0	100.6	197.4	253.4

* not reported

^{oo} Consumption rates derived for women aged 19-50 years

^{pp} Unpublished results, communicated by Helen Jacobs, 6/97

Table 6. Fish Consumption Rates for Fishers - Self-Caught and Commercial Fish (grams per day)

Survey (Source)	Fish Category	Mean	Upper Level Intake (%)
1988 Michigan Sport Anglers Fish Consumption Study (West <i>et al.</i> , 1989)	Total Fish	16.1 ^{qq}	75 (96 th)
1991-92 Michigan Sport Anglers Fish Consumption Study (West <i>et al.</i> , 1993)	Sport Fish	14.5 ^{qq}	81.6 (96 th)
	Total Fish	24.3 ^{qq}	102.0 (95 th)
1988 New York Statewide Angler Survey (NYSDEC, 1990)	Total Fish	28.1 ^r	*
1992 Lake Ontario Angler Survey (Connelly <i>et al.</i> , 1996)	Sport Fish	4.9	17.9 (95 th)
	Total Fish	17.9	42.3 (95 th)
1985 Wisconsin Angler Study (Fiore <i>et al.</i> , 1989)	Sport Fish	12.3	37.3 (95 th)
	Total Fish	26.1	63.4 (95 th)
1991-92 Columbia River Basin Fish Consumption Survey (CRITFC, 1994)	Total Fish	58.7 ^{ss}	170 (95 th)
1992 Sulphur Bank Mercury Mine/Clear Lake, CA	Sport Fish	60	*
	Commercial	24	
1994 Urban Fishers and Crabbers in New York/New Jersey Harbor Estuary (May and Burger, 1996)	Total Fish	52.8	220 (max.)

* not reported

^{qq} Adjusted downward by 2.2 grams for nonresponse

^r Value based on 45.2 meals per year and half pound portions of fish per meal.

^{ss} This estimate included nonconsumers (7 percent); the mean rate for consumers was 63.2 grams per day. Although these values included fish from all sources, the majority of fish consumed (87.6 percent) was harvested rather than purchased.

Table 7. Self-Caught and Commercial Fish Consumption Rates (grams per day) by Ethnic Group and Overall in Michigan

A. 1988 Michigan Sport Angler Study - West et al. (1989)

Ethnic Group	Number in Group	Mean
Black	69	20.3
Native American	139	24.3
Other minorities (Hispanics, mixed, other)	123	17.9
White	3339	17.9
Total	3670	18.3

B. 1991-92 Michigan Sport Angler Survey - West et al. (1993)

Ethnic Group	Number in Group	Mean Sport Fish	Mean Total Fish
Minorities ^{tt}	160	23.2	35.9
White	2289	16.3	25.9
Total	2450	16.7	26.6

^{tt} Includes Blacks and Native Americans.

Table 8. 1988 Michigan Sport Anglers Fish Consumption Study - Murray and Burmaster (1994)

Population group	Number in group	Fish consumed	Median	Mean	95 th %
All/ate fish	1061	Total fish	32.7	45.3	103.9
Females/ate fish	474	Total fish	32.7	42.3	85.7
Males/ate fish	587	Total fish	32.7	47.8	106.1
Anglers/ate fish	511	Total fish	32.7	47.9	106.1
All/ate self-caught fish	418	Total fish	40.8	50.2	106.1
All/ate self-caught fish	418	Self-caught	32.7	42.3	98.0
Anglers/ate self-caught fish	191	Total fish	40.8	55.1	114.3
Anglers/ate self-caught fish	191	Self-caught	32.7	45.0	98.0
All/ate Great Lakes fish	188	Total fish	40.8	54.8	122.4
All/ate Great Lakes fish	188	Great Lakes	32.7	38.5	81.6
Anglers/ate Great Lakes fish	89	Total fish	53.1	61.3	123.9
Anglers/ate Great Lakes fish	89	Great Lakes	32.7	40.9	81.6

Table 9. Fish and Shellfish Consumption Studies of Native American Fishing Populations (West coast)

Survey	Study method/ # respondents	Geography	Target Population	Demographic variables	Type of consumption	Mean rate of consumption (grams/day)	Type of rate	Comments
1991-92 Columbia River Basin	mail/interview 513	Columbia River (freshwater)	Umatilla, Nez Perce, Yakama, Warm Springs tribes		all sources (88% sport)	63.2 (58.7)	adult consumers (per capita)	
1992 Clear Lake, California	interview 68	Clear Lake (freshwater)	Elem tribe (63) and other residents (5)		sport and commercial	60 (sport) 24 (commercial)	consumers	nonreservation
1994 Fish Consumption Survey of the Tulalip and Squaxin Island tribes	interview 190	Puget Sound (marine/estuarine)	Tulalip and Squaxin Island tribes	age; sex; income; tribe	sport and commercial combined	NA	weight-adjusted adult tribal members (per capita)	0.55 g/kg/day (Tulalip) 0.52 g/kg/day (Squaxin Island)

NA: Not Available/Applicable (i.e., consumption rates were reported in an alternate form)

Table 10. Fish and Shellfish Consumption Studies of Marine or Estuarine Fishing Populations

Survey	Study method/ # respondents	Geography	Target Population	Demographic variables	Type of consumption	Mean rate of consumption (grams/day)	Type of rate	Comments/caveats
1991-92 Santa Monica Bay Seafood Consumption	creel/recall 554	Santa Monica Bay	fishers	age, sex, ethnicity, income	sport	49.6	per angler	advisory in effect
1980 Los Angeles Metropolitan	creel 1059	Santa Monica Bay	fishers and households	age, sex, ethnicity	sport	NA	per household member	reported median rate of 37 grams/day
1988-89 San Diego Bay	creel 59	San Diego Bay	anglers and household	ethnicity	sport	31.2	bay-wide mean	
1980 Commence-ment Bay	creel/telephone follow-up 504	Commence-ment Bay	fishers and household	ethnicity	sport	NA	per household member	reported edible catch as 453 grams/day inclu. boaters exclu. salmon
1983-84 Puget Sound	creel 4437	Puget Sound	fishers	age; race; education; employment	sport	NA	per household member	reported geometric mean of 11 grams/day
1994 New York/New Jersey Harbor	intercept 318	NJ shore (3 locations)	fishers and crabbers	age; sex; residence; occupation	total fish; crabs	52.8 (fish) 187 (crabs)	per fisher or crabber	advisory in effect

NA: Not Available/Applicable (i.e., consumption rates were reported in an alternate form)

Table 11. Self-Caught Fish Consumption Rates (grams per day) in Santa Monica Bay by Ethnic Group and Overall

A. SCCWRP and MBC (1994)

Ethnic Group	Number in Group	Median	Mean	Upper Level Intake (90 th %)
White	217	21.4	58.1	112.5
Hispanic	137	16.1	28.2	64.3
Black	57	24.1	48.6	85.7
Asian	122	21.4	51.1	115.7
Other	14	85.7	137.3	173.6
All	555	21.4	49.6	107.1

B. Hill (1995)

Ethnic Group	Number in Group	Mean	Standard Deviation
Other	14	137.3	175.96
Filipino	39	66.63	168.53
White	217	58.11	143.25
Chinese	18	55.51	73.30
Korean	28	50.41	59.48
Black	57	48.61	72.79
Japanese	30	34.51	42.43
Hispanic	137	28.20	35.06
Vietnamese	7	27.93	35.00

C. OEHHA Distribution of Consumption Rates for Santa Monica Bay (grams per day)*

N	Mean	SD	Percentile Total Consumption Rates						
			5	10	25	50	75	90	95
552	50	111	5	5	11	21	48	107	161

*rounded to integers

Table 12. Selected Self-Caught Fish Consumption Rates (grams per day) by Ethnic Group

A. Los Angeles Metropolitan Area - Puffer et al. (1980)

Ethnic Group	Number in Group	Median	Mean	Upper Level Intake (90 th %)
White	445	46	*	*
Mex.-American	169	33	*	*
Black	254	24.2	*	*
Oriental/Samoan	138	70.6	*	*
Other	53	*	*	*
All	1059	36.9	*	224.8

* not reported

B. San Diego Bay - San Diego County Health Department (1990)

Ethnic Group	Number in Group	Median	Mean	Upper Level Intake (95 th %)
White	20	*	10.8	*
Filipino	26	*	49.5	*
Asian	4	*	81.9	*
Hispanic	5	*	23.6	*
All	59	*	31.2	73.4

* not reported

C. Puget Sound Embayments - Landolt et al. (1985)

Ethnic Group	Geometric Mean ^{uu}
Overall Non-U.S. born Asian	10
Non-U.S. born Filipino	8
Non-U.S. born SE Asian	11
Non-U.S. born Chinese/Japanese	8
U.S. born Caucasian	11
U.S. born Black	9
U.S. born Asian	10
Overall	11

^{uu} Consumption rates are expressed as the geometric mean grams of cleaned fish available for consumption per person per day.

Table 13. Fish and Shellfish Consumption Studies of Freshwater Fishing Populations

Survey	Method/N	Geography	Target Pop	Demographic	Type of Fish	Mean rate (g/d)	Type of rate	Comments
38 Michigan statewide	mail 1230	Great Lakes and rivers flowing in	licensed anglers	race; income; education; residence	sport and commercial combined	18.3 (16.1 ^{vy})	GPD per household member	7-day recall advisory in effect
91-92 Michigan Sport anglers	mail 3276	Great Lakes and rivers flowing in	licensed anglers	race; income; education; residence	sport and commercial	14.5 ^{vv} (sport) 24.3 ^{vv} (total)	per fisher	7-day recall advisory in effect
38 NY statewide	mail 1190	state waters	licensed anglers	age; income; education	total and sport ^{ww} meals	28.1 (total)	per angler	assumed 8 oz per meal; adv'y in effect
92 Lake Ontario Angler survey	diary 366	Lake Ontario, tributaries, and other NY waters	licensed anglers in 6 bordering counties	age; sex; income; residence; education	sport and total	4.9 (sport) 17.9 (total)	per angler	advisory in effect
85 Wisconsin	mail 801	state waters	licensed anglers ^{xx}		sport and total meals	12.3 (sport) 26.1 (total)	per angler	assumed 8 oz per meal; adv'y in effect
90 Maine	mail 1612	freshwater lake, pond, river, stream ^{yy}	licensed anglers		sport	6.4	per household member	advisory in effect
92-1993 Alabama	creel/ interview 1303	rivers, lakes, reservoirs	anglers		sport	30.3 (survey sites) 45.8 (all sites)	per angler	similar results from creel estimates

adjusted for nonresponse

^v limited information provided for sport fish taken from Lake Ontario

anglers selected from counties with advisories

ice fishing and open-water seasons

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Table 14. Fish Consumption Values Recommended in U.S. EPA Documents

Source	Target Population	Default Consumption Rate (grams/day)	Statistic of Dispersion	Based on	Comments
989 Exposure Factors handbook	recreational fishers	30	median	Pierce <i>et al.</i> (1981) Puffer <i>et al.</i> (1982)	averaged results from two studies
		140	90 th %		
989 Risk Assessment guidance for Superfund Vol. I, Part A (RAGS)	finfish consumers (residential exposure)	38 (averaged over 3 days)	median	Pao <i>et al.</i> (1982) (1977-78 USDA NFCS)	recommended ingestion rates: 0.113 kg/meal (50 th %) 0.284 kg/meal (95 th %) 6.5 g/day (ave'd over one year)
		132	95 th %		
991 RAGS Supplemental guidance	recreational fishers	54 (2 meals/week)	mean	Pao <i>et al.</i> (1982) (1977-78 USDA NFCS)	assumed 8 oz. per meal
	subsistence fishers	132 (4 meals/week)	95 th %		
997 Exposure Factors handbook	recreational fishers: Marine (Pacific coast)	2.0 6.8	mean 95 th %	NMFS ^{aaa}	
	Freshwater ^{zz}	5; 5; 12; 17 13; 18; 39	mean 95 th or 96 th %	4 studies ^{zz}	ME; NY; MI; MI ME; NY; MI
U.S. EPA, 2000a fish advisory guidance, Volume I, 3 rd edition)	recreational use	17.5	90 th %	1994-96 CSFII ^{bbb}	also in U.S. EPA, 2000c (Methodology for Ambient Water Quality/Human Health)
	subsistence use	142.4	99 th %		

^a Multiple recommendations were provided based on four study locations only in Maine (Ebert *et al.*, 1992), New York (Connelly *et al.*, 1996), and Michigan (West *et al.*, 1989; 1993). U.S. EPA reanalyzed the data and thus these values do not match the rates reported by the authors.

^{aa} This study was not referenced in this report as it was a creel survey, but not a consumption survey. The complete reference is: National Marine Fisheries Service (NMFS). (1993) Data tapes for the 1993 NMFS provided to U.S. EPA, National Center for Environmental Assessments.

^{bb} U.S. EPA (2000a) noted that these values also represented average consumption for recreational and subsistence fishers, respectively, as explained further in *Estimated Per Capita Fish Consumption in the United States*. EPA-821-R-00-025. Office of Science and Technology, Washington, DC.

11861

Table 15. Mean Per Capita Consumption Rates for Fish and Shellfish (Combined) (grams per day) by Race or Ethnic Group

Survey (Reference)	Black	White	Oriental	Other	Overall
1969-70 Market Facts, Inc. (Nash, 1971)		15.27	*	20.05	16.8
1973-74 NPD (Javitz, 1980)	16.0	14.2	21.0	13.2	14.3
1977-78 NFCS (Hu, 1985)	20.01	16.97	*	20.32	17.9
1981 MRCA (Hu, 1985)	7.52	8.12	*	11.09	8.12

* no data available

Table 16a. Mean National Per Capita Fish and Shellfish Consumption Rates (grams per day) by Age and Sex Based on the 1973-74 NPD

Source	Age	Male	Female	Male & Female
Rupp <i>et al.</i> (1980) ^{ccc}				
	1-11	*	*	5.8
	12-18	*	*	9.5
	19+	*	*	15.8
Javitz (1980)				
	0-9	6.3	6.1	6.2
	10-19	11.2	9.0	10.1
	20-29	16.1	13.4	14.5
	30-39	17.0	14.9	15.8
	40-49	18.2	16.7	17.4
	50-59	22.8	19.5	20.9
	60-69	24.4	19.0	21.7
	70+	15.8	10.0	13.3

* no data available

^{ccc} Consumption rates for the "Male and Female" column were derived by summing the given average rates for freshwater and saltwater finfish and shellfish.

Table 16b. Mean Per Capita Fish and Shellfish Consumption Rates (grams per day) by Age and Sex Based on the 1977-78 USDA NFCS

Source	Age	Male	Female	Male & Female
USDA (1983) ^{ddd}				
	<1	*	*	0-0.5
	1-2	*	*	4
	3-5	*	*	6
	6-8	*	*	7
	9-11	8	4	5.9
	12-14	9	9	9
	15-18	10	11	10.5
	19-22	14	11	12.3
	23-34	16	11	13.1
	35-50	15	13	13.8
	51-64	18	14	15.7
	65-74	17	12	14.2
	75+	10	8	8.8
USDA (1983)				
	0-11	*	*	5.6
	12-18	9.6	10.1	9.8
	19+	15.8	12.1	13.6

* not reported

^{ddd} Following the 6-8 age category, consumption rates for each age interval in the "Male and Female" column were derived by the formula: $\{[(\text{male sample size}) \times (\text{male rate of consumption})] + [(\text{female sample size}) \times (\text{female rate of consumption})]\} / (\text{male sample size} + \text{female sample size})$. Rates do not incorporate breast-fed infants.

Table 16c. Mean Per Capita Fish and Shellfish Consumption Rates (grams per day) by Age and Sex Based on the 1989-91 USDA CSFII

Source	Age	Male	Female	Male & Female
USDA (1994) ^{eee}				
	1-2	2	3	2
	3-5	5	4	4
	6-11	10	9	*
	12-29	7	6	*
	20-29	12	8	*
	30-39	15	13	*
	40-49	25	19	*
	50-59	19	14	*
	60-69	21	19	*
	70-79	18	14	*
	80+	3	18	*
	20+	17	13	*
	Total	*	*	13
Jacobs <i>et al.</i> (1998)				
	< 14	9.4	8.2	8.8
	15-44	19.5	14.3	16.7
	≥ 45	20.5	17.9	19.0
	All ages	17.3	14.1	15.7

* not reported

^{eee} Preliminary results, one day

Table 17. Mean National Fish and Shellfish Consumption Rates (grams per day) for Consumers by Age and Sex

Age	Male	Female	Male & Female
<1	*	*	15
1-2	*	*	22
3-5	*	*	27
6-8	*	*	32
9-14	40	33	*
15-18	46	45	*
19-34	62	44	*
35-64	62	49	*
65-74	62	50	*
75+	51	45	*

* not reported

Source: Pao *et al.* (1982) based on the 1977-78 USDA NFCS

**APPENDIX III: PARTIAL LIST OF STATE OR REGIONAL SURVEYS OF
FISH CONSUMPTION CONDUCTED IN RECENT YEARS**

ALASKA

George GD, Bosworth RG (1988). Use of fish and wildlife by residents of Angon, Admiralty Island, Alaska. Alaska Dept. of Fish and Game. Division of Subsistence. Technical Paper No. 159.

Nobmann ED, Byers T, Lanier AP, Hankin JH, Jackson MY (1992). The diet of Alaska native adults: 1987-1988. *Amer J Clin Nutr* 55:1024-1032.

CALIFORNIA

APEN (1998). *A Seafood Consumption Survey of the Laotian Community of West Contra Costa County, California*. Asian Pacific Environmental Network. Oakland, CA. March 1998.

SFEI (2000). San Francisco Bay Seafood Consumption Study. San Francisco Estuary Institute, Richmond, CA.

CONNECTICUT

Balcom NC (1999). Quantification of fish and seafood rates for Connecticut. Connecticut Sea Grant College Program. January 1999.

DELAWARE

KCA Research Division, David C. Cox & Associates. Fish Consumption Patterns of Delaware Recreational Fishermen and Their Households. Prepared for the State of Delaware, Department of Natural Resources and Environmental Control in support of the Delaware Estuary Program. April, 1994.

GEORGIA

creel surveys: Georgia Department of Natural Resources, Wildlife Resources Division, Fisheries Management Section, 2070 U.S. Highway 278, S.E, Social Circle, GA 30279.

GREAT LAKES

Fitzgerald E, Hwang SA, Briz KA, Bush B, Cook K, Worswick P (1995). Fish PCB Concentrations and Consumption Patterns Among Mohawk Women at Akwesasne. *J Exp Anal Environ Epid* 5(1):1-19.

Steenport DM, Anderson HA, Hanrahan LP, Falk C, Draheim LA, Kanarek MS, Nehis-Lowe H. (2000). Fish Consumption Habits and Advisory Awareness among Fox River Anglers. *Wisconsin Medical Journal* Volume 100, Number 1. November 2000.

Tilden J, Hanrahan LP, Anderson H, Palit C, Olson J, Mac Kenzie W, and the Great Lakes Sport Fish Consortium (1997). Health Advisories for Consumers of Great Lakes Sport Fish: Is the Message Being Received? *Environmental Health Perspectives* Volume 105, Number 12:1360-1365. December 1997.

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Sheaffer AL, O'Leary JT, Williams RL, Mason D (1999). An Examination of Fish Consumption by Indiana Recreational Anglers: Mail Survey of Resident License Holders, Technical Report 99-D-HDFW-1. Department of Forestry and Natural Resources, Purdue University. 1999. Available from URL: <http://www.state.in.us/idem/owm/planbr/wqs/fishstudy.html>

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Anderson and Rice (1993). Survey of fish and shellfish consumption by residents of the greater New Orleans Area. *Bull Environ. Contam. Toxicol.* 51:508-514.

MASSACHUSETTS

The Greater New Bedford PCB Health Effects Study. Massachusetts Department of Public Health. 1987.

MINNESOTA AND NORTH DAKOTA

Fish Consumption Survey: Minnesota And North Dakota. Final Report. October 2001. Prepared by: Benson SA, Crocker CR, Erjavec J, Jensen RR, Nyberg CM, Wixo CY, Zola JM. Energy & Environmental Research Center, University of North Dakota. Prepared for: AAD Document Control, U.S. Department of Energy, National Energy Technology Laboratory, Pittsburgh, PA. 2001-EERC-10-01.

NEW YORK

Connelly NA, Brown TL, Knuth BA (1997). New York Statewide Angler Survey 1996, Report 1: Angler Effort and Expenditures. NYSDEC, Bureau of Fisheries, Albany, NY. 107pp.

NOTE: These authors conduct ongoing surveys of Lake Ontario fishers and have an extensive list of publications concerning fish consumption, and attitudes and values; for more information, see the following URL:

<http://www.dnr.cornell.edu/hdru/PUBS/fishpubs.htm#recreation>

NEW JERSEY

Burger J, Pflugh KK, Lurig L, von Hagen LA, von Hagen S (1999). Fishing in Urban New Jersey: Ethnicity Affects Information Sources, Perception, and Compliance. *Risk Anal.* 19(2):17-229.

NOTE: J Burger has conducted numerous studies and published extensively on fish consumption habits and perceptions for the New Jersey/New York Harbor as well as other locations in the U.S. Her Web site is: <http://lifesci.rutgers.edu/~burger/>

PENNSYLVANIA

Duda MD, Bissell SJ, Wang P, Herrick J, Morral G, Yoder J, Lanier A, Testerman W (2000). Levels of Trout Consumption and Attitudes toward Consumption Advisories among Pennsylvania Trout Anglers. Conducted for the Pennsylvania Fish and Boat Commission. December 2000.

SOUTH CAROLINA

Burger J, Stephens, WL, Boring CS, Kulinski M, Gibbons JW, Gochfield M (1999). Factors in exposure assessment: Ethnic and socioeconomic differences in fishing and consumption of fish caught along the Savannah River. *Risk Anal* 19(3):427-438.

NOTE: J Burger and colleagues have several publications resulting from studies of fishers at the Department of Energy's Savannah River Site in South Carolina. To search for additional publications, go to: <http://www.cresp.org/products.html>

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Carney D, Kvittek R (1991). Assessment of nongame invertebrate harvest in Washington State. Final Report. Washington Department of Wildlife. EPA/910/9-91-034.

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McCallum M (1985). Recreational and subsistence catch and consumption of seafood from three urban industrial bays of Puget Sound: Port Gardner, Elliott Bay and Sinclair Inlet. Washington Department of Social and Health Services, Division of Health, Olympia, WA.

Nakano C, Lorenzana RM (1996). Asian and Pacific Islander Seafood Consumption Study: Exposure Information Obtained Through a Community Centered Approach, Planning Phase. EPA 910/R-96/007.

Parsons AH, Algeo ER, Keenan RE (1991). Risk assessment for dioxin in Columbia River fish. *Chemosphere* 23 (11-12):1709-1717.

Sechena R, Nakano C, Liao S, Polissar N, Lorenzana R, Truong S, Fenske R (1999). Asian and Pacific Islander Seafood Consumption Study in King County, Washington. EPA 910/R-99-003, May 1999.

Suquamish Tribe. (2000). Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservation, Puget Sound Region. Suquamish Tribe Fisheries Department, P.O. Box 498 Suquamish, Washington 98392.

U.S. EPA (1988). Health Risk Assessment of Chemical Contamination in Puget Sound Seafood. Puget Sound Estuary Program. EPA/910/9-88/249.

AMERICAN SAMOA

Agency for Toxic Substances and Disease Registry (1995). Biologic indicators of exposure to heavy metals in fish consumers, American Samoa, Final Report. Technical Assistance to the American Samoa Government Department of Health Services, Pago Pago, American Samoa.

Ponwith, BJ (1991). The Shoreline Fishery of American Samoa: a 12 year Comparison, Department of Marine and Wildlife Resources, P.O. box 3730, Pago Pago, American Samoa, DMWR Biological Report Series, No. 2.

UPCOMING

ORSANCO (the Ohio River Valley Water Sanitation Commission) is preparing to do a fish consumption survey for the Ohio River. See their Web page at <http://www.orsanco.org/>

ADDITIONAL STUDIES TO NOTE:

CANADA

Kuhnlein HV (1984). Factors influencing use of traditional foods among the Nuxalk people. J Can Diet Assoc 50(2):102-106.

Richardson GM, Currie DJ (1993). Estimating fish consumption rates for Ontario Amerindians. J of Exp Anal and Environ Epi 3(1):23-38.

Shatenstein *et al.* (1999). Exploratory Assessment of Fish Consumption among Asian-Origin Sportsfishers on the St. Lawrence River in the Montreal Region. Environmental Research Section A. S57-S70.

NOTE: A series of reports are available on a consumption study of Great Lakes fishers in Canada conducted in 1995-1997 by the Fish and Wildlife Nutrition Project under a contract to Health Canada.

OTHER STUDIES DONE BUT NOT LOCATED:

Subsistence fish consumption at the Savannah River Site in Georgia and South Carolina by May Linda Samuel, Benedict College, South Carolina; abstract presented at the National Association of Environmental Professionals in 1999.

Hudson River Angler Survey by Hudson River Sloop Clearwater, Inc. (Bridget Barclay) 1993.

