SELECTION OF FISH CONSUMPTION ESTIMATES FOR USE IN THE REGULATORY PROCESS

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The rate of fish consumption is a critical parameter in the assessment of human exposure to persistent chemicals in surface waters. Ideally, exposure assessors should use site-specific information concerning fish consumption rates from a contaminated area; however, this information is not readily available for most bodies of water, and time and economic constraints often do not permit its collection. In such situations, it is necessary to derive a fish consumption rate for the exposed population, based on data presented in existing studies. However, because of differences in the types of waterbodies evaluated, the types of fish consumers surveyed, and the types of survey methods used, the fish consumption estimates available in the scientific literature range widely, making selection of a specific rate a complex task. In the absence of clear understanding of the differences in the studies underlying these fish consumption estimates, exposure assessors have often arbitrarily selected the results of studies that report high rates of intake in order to ensure that public health is being adequately protected. This paper presents a framework to evaluate the applicability of existing studies to different exposure scenarios. It discusses the strengths and limitations of the various survey methods used to estimate fish consumption rates. Its intent is to provide a framework for exposure assessors to assist them in their selection of the most applicable and relevant fish consumption estimates for use in the regulatory situation being considered.

INTRODUCTION

The most significant pathway of potential human exposure to persistent and bioaccumulatable chemicals in aquatic environments is through the ingestion of fish (Rifkin and LaKind, 1991). In an effort to assess whether the presence of these chemicals in surface waters may adversely affect public health, it is often necessary to characterize the potential for human exposure

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2. Abbreviations: cm, centimeter; EPA, United States Environmental Protection Agency; g, grams; g/d, grams per day; kg, kilogram; km, kilometer; NMFS, National Marine Fisheries Service; NPD, National Purchase Diary; NYSDEC, New York State Department of Environmental Conservation; USDA, United States Department of Agriculture.

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through this pathway. To conduct such an exposure assessment, it is necessary to first define the potentially exposed populations and then determine the likely quantities of fish consumed and the chemical concentrations in the fish tissues that are eaten.

The U.S. Environmental Protection Agency (EPA) has acknowledged that it is best to use site-specific fish consumption data whenever possible (EPA, 1989a,b). However, site- or region-specific data are not always available because only a limited number of fish consumption studies have been performed. As a result, it is often necessary for exposure assessors to select surrogate fish consumption rates from existing studies.

In general, assessments of exposure to environmental contaminants have sought to either estimate a typical intake or an above average intake, such as either the "reasonable worst case" (EPA, 1989a) or "high end" (EPA, 1992a,b) angler intake. Estimates of typical intake have ranged from 1.2 (Rupp et al., 1980) to 54 g/d (Pao et al., 1982), while the reasonable worst case estimates have ranged from 5 g/d (Rupp et al., 1980) to 339 g/d (Puffer et al., 1983). The vast ranges and apparent discrepancies among consumption rate estimates have led to confusion among exposure assessors who, in the absence of clear guidance on the selection of a fish consumption rate, have often arbitrarily selected study results from upper ends of these ranges in order to ensure that public health is being adequately protected. However, these apparent discrepancies are primarily the result of differences in the types of populations and fisheries studied, and the study methodologies used to collect consumption data. When the different studies are categorized according to these important factors, the result is reasonably consistent estimates of consumption within each category.

In selecting a rate of consumption to be used in an exposure assessment, it is critical that the characteristics and size of the potentially exposed population(s), the extent of contamination, and the types and numbers of waterbodies affected be identified and considered (Ebert et al., 1993). In situations where contamination is widespread or fish are commercially harvested, a regional population or even the general population of the United States may have potential for exposure. In other situations, contamination may be limited to a single, small waterbody, and only anglers using that body of water will have access to the affected fish.

In setting water quality standards, state or federal discharge permit limits, or environmental restoration goals, it is critical that risk assessors and risk managers select a fish consumption estimate that is reasonable for the sites being evaluated (Keenan et al., 1994). Careful selection of appropriate estimates will result in more accurate assessments of risks, and in a more credible selection of risk management options. Ultimately, the result will be standard setting and remedial actions that protect public health without putting unmanageable and unnecessary burdens on those responsible for compliance or clean-up.

This paper discusses the ways in which estimates of fish consumption traditionally are derived, and explores the strengths and limitations of the various methods used to collect fish consumption data. It provides a system for categorizing the major surveys of fish

consumption, based on the populations of concern and the number, types, and sizes of fisheries being considered. It also provides insights into the differences and limitations of the survey methodologies and the inherent biases of each, thereby providing exposure assessors with information that will assist them in their interpretation of the applicability of specific survey results. Its intent is to provide guidance for exposure assessors in their selection of the most applicable and relevant fish consumption estimates for the specific situations being evaluated.

SOURCES OF VARIATION IN FISH CONSUMPTION ESTIMATES

There are a number of factors responsible for the large variations in rates of fish consumption found in the scientific literature. Generally, these variations are attributable to the survey methodology used, the type of waterbody studied, and the characteristics of the populations evaluated. Some of these sources of variation are discussed below.

Targeted Populations

A major difference among studies of fish consumption is attributable to the population being surveyed. Some studies have investigated fish consumption rates in the general population (Javitz, 1980; Rupp et al., 1980; USDA, 1980; Pao et al., 1982), while other studies have reported rates of consumption by recreational anglers (Soldat, 1970; Honstead et al., 1971; Pierce et al., 1981; Puffer et al., 1981; Turcotte, 1983; Landolt et al., 1985, 1987; Cox et al., 1985, 1987, 1990; Fiore et al., 1989; West et al., 1989; NYSDEC, 1990; ChemRisk, 1991a,b; Connelly et al., 1992; Ebert et al., 1993; Richardson and Currie, 1993). Rates of fish ingestion are likely to differ between the general population and the population of anglers (EPA, 1991). Even within the angling group, rates are likely to be variable due to the fact that some anglers consume no sport-caught fish, some consume only sport-caught fish, and others consume both sport-caught fish and fish from other commercial sources. This is apparent in evaluating the fact that some studies have investigated anglers' intakes of fish from all sources, including purchased, gift, sport-caught, and that consumed at restaurants (West et al., 1989; NYSDEC, 1990), while other studies have reported on the rate of sport-caught fish consumption (Honstead et al., 1971; Soldat, 1970; Pierce et al., 1981; Puffer et al., 1981; Turcotte, 1983; Cox et al., 1985, 1987, 1990; Landolt et al., 1985, 1987; Connelly et al., 1992; Ebert et al., 1993). In addition, some differences in the literature can be attributed to the fact that certain researchers have focused on consumption by subpopulations known to have higher than average intakes (Humphrey, 1987; Richardson and Currie, 1993).

Targeted Waterbodies

In some studies, the rate of sport-caught fish consumption reported by anglers may include marine and estuarine fish (Pierce et al., 1981; Puffer et al., 1981; Landolt et al., 1985, 1987). Other studies specifically evaluate consumption of freshwater fish but include fish obtained from multiple freshwater locations (Cox et al., 1985, 1987, 1989; Fiore et al., 1989; Connelly et al., 1992; Ebert et al., 1993). Still other surveys have only considered consumption of sport-caught fish from a single body of water (Soldat, 1970; Honstead, 1971;

Turcotte, 1983, ChemRisk, 1991a). Surveys conducted for individual waterbodies are greatly affected by the productivity of those waters and the availability of access for fishing. Consequently, there is substantial variation in the resulting estimates of intake.

Regional Considerations

In evaluating the reported estimates of fish consumption for anglers, a further complication is introduced by the existence of regional differences in climate, fishing regulations (e.g., length of season, bag limits, etc.), accessibility to good fisheries, availability of desirable target species, and ethnic or cultural backgrounds. These factors may contribute to variations in reported fish consumption rates. Individuals living in coastal areas are more likely to consume higher quantities of marine fish and lower quantities of freshwater fish while individuals living in inland regions of the country may consume more freshwater fish (Rupp et al., 1980). Due to the migratory patterns of fish, certain species may be available commercially and recreationally year-round in certain regions of the country, but only for limited periods of time in others. Additionally, in some states or on certain bodies of water, fishing may be permitted on a year-round basis, while in other cases, the fishing season is restricted. Finally, fisheries may have catch and release restrictions or limits on the numbers, species, and sizes of fish that may be harvested during the season. All of these factors can significantly effect the rate at which anglers may consume sport-caught fish.

Biases in Consumption Survey Methodologies

Numerous survey types and methods, each with its own inherent biases, have been used to estimate fish consumption rates. These biases can contribute substantially to the variations observed in consumption estimates. The most common methodologies include diary studies, on-site creel surveys, short-term recall surveys, long-term recall surveys, and biological monitoring techniques. Each of these survey methodologies offers distinct advantages and limitations that must be considered when evaluating the fish consumption rates that are derived from them (EPA, 1991).

Diary Studies. Many of the most commonly cited estimates of fish consumption have been based on diary studies. In the 1973/1974 National Purchase Diary (NPD) Study, which underlies the rates reported by Javitz (1980) and Rupp et al. (1980), heads of households were asked to complete a diary of fish purchases each month over a 12-month period. Similarly, the data reported by Pao et al. (1982) were based on a 3-day study conducted by the USDA which included one day of recall and two days of diary entries. Long-term diary studies, like the NPD study, are a useful way of determining per capita rates of fish consumption by the general population. If study participants are diligent in recording the numbers, types, and sizes of fish meals consumed, excellent estimates of annual per capita fish consumption can be derived.

Short-Term Recall Surveys. Short-term recall surveys are the best possible means of gathering accurate information on fishing and consumption activity for a specific period of time. Like long-term surveys, they are generally used to provide information on total consumption over the recall period. However, the extrapolation of annual or other long-term

intake rates results in additional uncertainty when based on short-term recall surveys, particularly for the upper and lower ends of the intake distribution.

The reason for this is as follows. Although an individual may consume fish at a rate in the upper 5th percentile of the distribution during a specific brief period of time (such as a few days or weeks), it is not necessarily true that the same individual will be an upper 5th percentile consumer for each of the brief periods that make up an entire season. Rather, that individual may only consume fish occasionally, may only be interested in consuming certain species when they are available, and if the individual is an angler, is not likely to be equally successful on every trip. The same uncertainty exists for anglers who have had no activity or success during a single two-week period but may, in fact, have different behavior at other times. It is likely that activity and consumption by individual anglers are highly variable through the season due to weather, fishing regulations, differences in species availability, and fluctuations in success rates for the individual angler. Although much of this variability tends to be averaged out in longer-term estimates, extrapolation from single-day or short-term measurements can result in an overestimation in the inter-individual variation of annual intake in a population (EPA, 1992b). Thus, short-term surveys may be useful for characterizing the central tendency in consumption rates but not the variance within the population.

Long-Term Recall Surveys. Long-term recall surveys provide an opportunity for individuals to summarize their activities throughout a fishing season or calendar year. Thus, developing estimates of annual intake from such surveys does not require that the data be extrapolated, and the impact short-term variability in activity patterns is minimized. However, long-term recall studies have potential for recall bias resulting from the tendency of an individual to systematically over- or underestimate his or her activities due to a difficulty in recalling detail over a long period. Westat (1989) reported that recall bias in 6-month or year-long fishing and hunting surveys results in overestimations of angler participation. By analogy, long recall periods can be expected to lead to overestimated rates of fish ingestion.

Creel Surveys. Creel surveys can provide very accurate, waterbody-specific data on the species and sizes of fish consumed but are limited as a basis for deriving longer term consumption rates. As with the short-term recall survey, data collected in a creel survey only represent a snapshot in time for each angler interviewed. Because each angler is only interviewed once during the course of the survey, extrapolation to annualized rates requires that assumptions be made concerning the angler's behavior during the remainder of the year.

In addition, creel surveys tend to over sample the most highly active anglers and under sample the less active individuals. This occurs because the probability of participating in a survey is much greater for frequent anglers who spend more time at a particular fishery (Puffer et al., 1981; Price et al., 1994). Due to this sampling bias, consumption estimates based on creel surveys are likely to be representative only of more frequent anglers and are not representative of the total population of anglers using the surveyed waterbody. Pierce et al. (1981) demonstrated this phenomenon when they showed that approximately 60% of the anglers

interviewed indicated that they fished at least once per week. However, when the total population of anglers using the body of water was determined, anglers who fished at least once per week represented only 6.8% of all anglers.

Biomonitoring. A final method of estimating fish consumption rates is the use of biomonitoring data (Richardson and Currie, 1993). Under this approach, samples of hair, nails, tissue, or bodily fluids are taken from individuals known to consume fish from contaminated waterbodies. The samples are analyzed for the contaminants known to occur in fish. Pharmacokinetic models are then used to determine the dose rate of the contaminant necessary to produce the measured levels (or body burden). This dose rate is then converted to a fish consumption rate based on the average level of contamination in fish tissue.

Biomonitoring offers a number of advantages in estimating fish consumption rates. There is no potential for bias in the self-reporting of consumption rates since the effect of an individual's intake is directly measured. In addition, the measurement of contaminant intake also incorporates the individual's fish preparation and cooking practices. Finally, biomonitoring results reflect the individual's consumption over a long period of time (several months or years).

Despite these advantages, the method also suffers from a number of limitations. The variation in individual measurements of body burden across the population may reflect variations in human metabolism of the contaminant or different chemical concentrations in the fish consumed, rather than a variation in the rate of fish intake. In addition, there may be other sources of exposure to the chemicals of interest that could compound the problem. Because of the multiple sources of variation, biomonitoring can only successfully provide estimates of the average intake rate and cannot be used to accurately characterize the range or "high end" of intake rate in an exposed population. The methodology is also limited to populations whose only source of exposure to a contaminant is from the consumption of contaminated fish. Finally, the approach requires the availability of a reliable, chemical-specific pharmacokinetic model that can quantitatively predict intake from the measurements of an individual's body burden.

SELECTION OF CONSUMPTION RATES

When selecting a fish consumption rate for regulatory decision-making, it is essential that risk assessors carefully evaluate the population that is potentially affected and select a fish consumption rate that is relevant and applicable to that population. It is important to recognize that total fish consumption by an individual is likely to include fish from a combination of sources (Figure 1). An individual may buy marine, estuarine or freshwater fish and shellfish from a local grocer or fish market. In addition, certain individuals may consume marine, freshwater or estuarine fish or shellfish they have caught personally. Finally, individuals may consume fish that have been sport-caught by someone else and given to

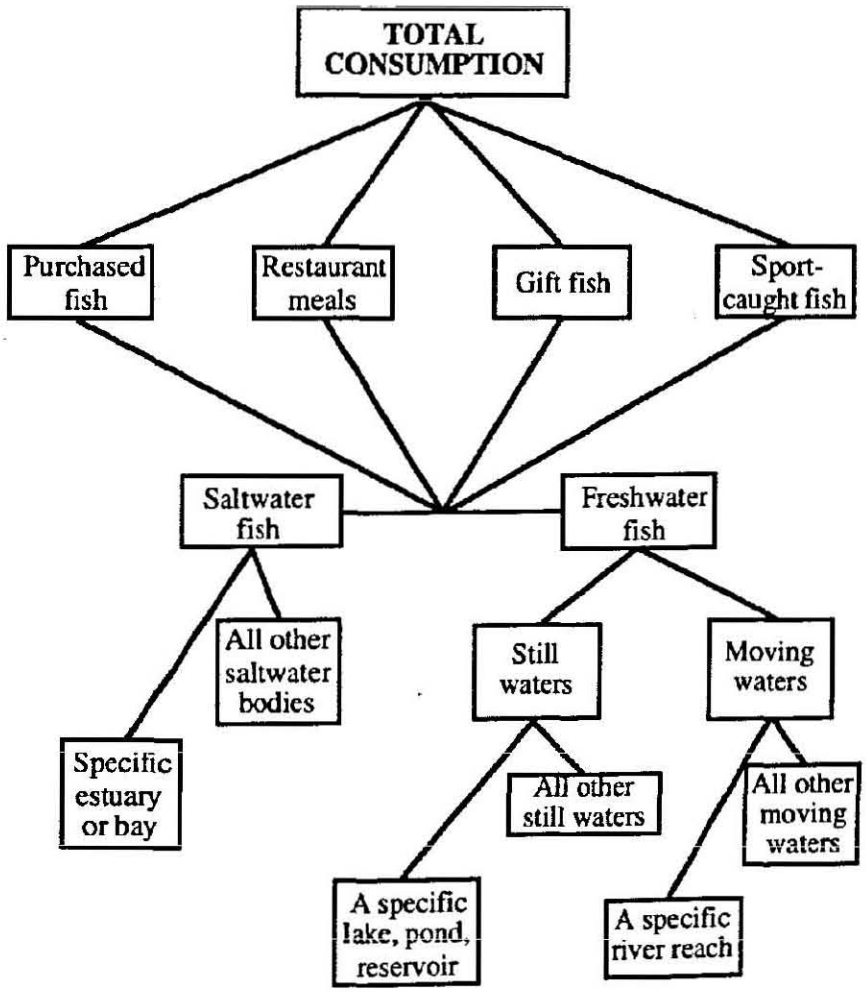

FIGURE 1. Total consumption of fish.

them. These fish may have been obtained from one or more bodies of water. 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.

In light of this discussion, it is not surprising that a number of different consumption estimates have been derived and are commonly cited in the literature or used as the basis for regulatory decisions. To clarify the bases for these differences and to assist exposure assessors in their selection of the most applicable estimates for their particular situations, the following studies have been grouped according to the types of situations to which they are most relevant.

General Population - Per Capita Estimates

If setting chemical residue levels for fish found in the marketplace is of primary interest, then per capita ingestion estimates for the general population of the United States may be

appropriate. It is important to note, however, that these per capita estimates include nonconsumers of fish. Their inclusion may result in estimates that are not representative of consumers.

These per capita estimates consider the population as a whole, for whom some fraction of the consumed fish may be affected by chemical contamination. They include all types of fish available to the general population: marine, estuarine, freshwater, fresh, frozen, and processed fish from a number of geographic locations. Examples of these types of consumption estimates include the following studies, which are summarized in Table 1.

TABLE 1. Fish Consumption Estimates for the General Population of the United States

Study	Consumption Rates (g/d)		
	Mean	Median	"High End"
Per Capita Estimates — All Types of Fish			
Javitz (1980)	14	—	42[a]
Rupp et al. (1980)	13	—	—
USDA (1980)	21	—	—
Per Capita Estimates — Specific Types of Fish			
Rupp et al. (1980) marine fish	11[b]	7.3[b]	24[b,c]
Rupp et al. (1980) shellfish	3.6[b]	0[b]	11[b,c]
Rupp et al. (1980) freshwater fish	1.5[b]	0[b]	5.1[b,c]
Consumers Only — All Types of Fish			
Pao et al. (1982)	54	37	128[a]

[a] 95th percentile.
[b] Adults only.
[c] 90th percentile.

Javitz, 1980. In 1973-1974, the National Marine Fisheries Service (NMFS) funded a study by NPD Research, Inc. (Javitz, 1980). Each month, individuals participating in this year-long household diary study were asked to record all types of marine and freshwater fish and shellfish meals consumed. Based on these data, Javitz (1980) estimated a per capita rate of consumption that included individuals who did not consume fish, as well as consumers. No distinction was made between the consumption of commercially-harvested and sport-caught fish.

Rupp et al., 1980. Rupp et al. (1980) used the data generated from the NMFS diary survey to estimate consumption of marine fish, freshwater fish, and shellfish for three different age groups within the general population of the United States. Separate estimates of consumption were derived on a regional basis. Although these estimates identified the specific types of fish being consumed (marine, freshwater, etc.), they did not differentiate between commercial and sport-caught fish. There was substantial variation among the region-specific consumption estimates.

USDA, 1980. From 1977 to 1978, the United States Department of Agriculture (USDA, 1980) conducted a survey of 37,874 individuals. This survey included one day of recall and two days of diary records for each survey participant. Based on these survey data, USDA reported a mean consumption rate of fish and shellfish. Because this survey did not target anglers and did not differentiate between types of fish consumed, this estimate includes consumption of all types of fresh, frozen, and processed, freshwater and marine, fish and shellfish.

General Population - Fish Consumers Only

Because per capita estimates of consumption for the general population of the United States are averaged across all individuals, including those who do not consume fish, they may underestimate rates for that portion of the population that eats fish. Thus, when setting chemical tolerances or establishing a generic standard, it may be preferable to use estimates of consumption that are based on fish consumers only, to ensure that levels are adequately protective of the population most likely to be affected.

Pao et al., 1982. Pao et al. (1982) used the data collected in the 1977-1978 USDA survey to derive frequency distributions for the rates of consumption of different foods. Based on their analysis of these data, Pao et al. reported median, mean, and 95th percentile consumption rates for all types of fish and shellfish. These rates were based on data collected from individuals who had eaten fish at least once during the 3-day study period. EPA (1989a) has indicated that data from 3-day dietary records should not be used to estimate annual rates of consumption because many individuals eat fish less frequently than once in three days.

Anglers - Fish from All Commercial and Recreational Sources

Because anglers may consume sport-caught fish in addition to commercially available fish, they are generally assumed to have a higher rate of fish consumption than the general population. As a result, many regulatory programs identify anglers as a subpopulation of concern. Use of an angler's total sport-caught and commercial fish consumption rate is appropriate when evaluating areas where contamination is widespread and where a number of commercial and recreational fisheries are affected, because angler's total fish consumption is likely to include fish from both sources. Examples of studies focusing on total consumption by anglers are discussed below and are summarized in Table 2.

NYSDEC, 1990. Connelly et al. (NYSDEC, 1990) conducted a long-term recall mail survey of New York State anglers in which anglers were asked to recall the number of fish meals consumed over a one-year period. The authors reported that the average New York angler consumed 45 fish meals annually. Assuming an average fish meal size of 227 g (1/2 pound), the average New York angler would consume approximately 28 g of fish daily. Even though anglers were the population targeted for the survey, this estimate included sport-caught fish as well as freshwater, marine, and estuarine fish obtained from markets, restaurants, and as gifts.

TABLE 2. Fish Consumption Estimates for Recreational Anglers

Study	Consumption Rates (g/d)		
	Mean	Median	"High End"
All Commercial and Recreational Sources			
Fiore et al. (1989)	26	—	63[a]
NYSDEC (1990)	28	—	—
West et al. (1989)	18.3	—	—
Marine - Self-Caught			
Landolt et al. (1985; 1987)	—	15[b]	—
Pierce et al. (1981)	—	23	>54[a]
Puffer et al. (1981)	—	37	339[a]
Multiple Fresh Water bodies			
Connelly et al. (1992)	6.8	—	32[c]
Cox et al. (1985)	21.8	—	—
Cox et al. (1987)	19.4	7.5	—
Cox et al. (1990)	—	7.5	—
Ebert et al. (1993)	6.4	2.0	26[a]
Fiore et al. (1989)	12.3	—	37.3[a]
West et al. (1989)	7	—	—
Multiple Flowing Waterbodies			
Ebert et al. (1993)	3.7	0.99	12[a]
Multiple Lakes and Ponds			
ChemRisk (1991b)	4.2	1.7	15[a]
Richardson and Currie (1993)	16.2	—	—
Specific Waterbodies			
ChemRisk (1991a)	3.0	0.49	11[a]
Soldat (1970)	1.8	—	—
Honstead et al. (1971)	7.7	—	—
Turcotte (1983)	7.4[d]	—	—

[a] 95th percentile.
[b] Calculated using a Monte Carlo simulation based on frequency distributions provided by authors.
[c] 92nd percentile.
[d] Calculated based on 2.5 consumers per angler.

West et al., 1989. West et al. (1989) conducted a stratified mail survey of Michigan's anglers and asked them to report their consumption of all types of freshwater fish meals for the previous two-week period. The average consumption rate reported by West et al. (1989) included sport-caught, purchased, gift, and restaurant-purchased freshwater fish.

Fiore et al., 1989. Fiore et al. (1989) used a long-term recall mail survey to evaluate consumption of fish by Wisconsin's anglers. In this survey, the authors differentiated between sport-caught and commercially obtained meals. Average daily intakes were reported.

Anglers - Sport-caught Marine Fish

When the affected surface water is a marine waterbody that is frequented by recreational anglers, it is advisable to use estimates of consumption that have been derived from surveys of marine anglers.

Pierce et al., 1981. Pierce et al. (1981) interviewed anglers fishing Commencement Bay in Puget Sound near Tacoma, Washington. Estimated rates were based on the consumption of sport-caught marine finfish and shellfish. Using the Pierce et al. (1981) data, the EPA (1989a) estimated the median rate of consumption by these fishermen to be 23 g/d. A reanalysis of the original raw data, which corrected for oversampling of frequent anglers, resulted in an estimated median rate of 1.0 g/d (Price et al., 1994).

Puffer et al., 1981. Puffer et al. (1981) conducted a creel survey of the consumption of marine fish by anglers who fished Los Angeles Bay. Although all of the fishermen observed in the study were counted, only those fishermen who had creeled fish were subsequently interviewed. The authors reported that the median consumption rate for those successful anglers was 37 g/d. This consumption rate represented consumption of sport-caught marine species from a large marine fishery. Because it oversampled the most frequent Los Angeles Bay anglers (Puffer et al., 1981), it likely overstates consumption for the majority of anglers using that fishery. Price et al. (1994) report that when a correction is made for the oversampling of frequent anglers in the Puffer et al. (1981) study, the resulting median consumption rate is less than 2.9 g/d.

Landolt et al., 1985, 1987. Landolt et al. (1985; 1987) conducted a two-year creel survey of Puget Sound anglers. Based on data collected during interviews with over 2,000 anglers, Landolt et al. reported distributions for the number of trips per year, number of fish caught per trip, numbers of individuals sharing the catch, and the edible weight of each fish caught. Landolt et al. (1985; 1987) calculated average, species-specific consumption rates that ranged from 11 to 40 g/d. However, because angler effort and availability of those species were highly variable through the season, these species-specific estimates cannot be combined to produce estimates of total annual consumption rates.

Anglers - Sport-caught Freshwater Fish from Multiple Waterbodies

In some situations, contamination may affect numerous freshwater recreational fisheries within a given region, but does not impact commercial fisheries. In this situation, it is recommended that exposure assessors select estimates of total sport-caught fish consumption for use in their analyses.

West et al., 1989. As discussed previously, West et al. (1989) reported an average consumption rate for freshwater fish of 18.3 g/d. Although the authors did not specifically derive an estimate of consumption of sport-caught fish, they did indicate that 39% of the freshwater fish consumed by Michigan anglers were sport-caught. Thus, applying this percentage to their mean consumption estimate, an estimate of 7 g/d can be derived for the amount of sport-caught fish eaten by Michigan anglers. This estimate includes fish caught from all fresh waterbodies in Michigan.

Fiore et al., 1989. In the Fiore et al. (1989) analysis, consumption of fish by Wisconsin's anglers was evaluated. Average and 95th percentile rates of consumption of sport-caught freshwater fish were reported from all sources in Wisconsin.

Ebert et al., 1993. A long-term mail recall study of Maine's anglers was conducted by Ebert et al. (1993). In this survey, anglers were asked to recall numbers and sizes of fish harvested for consumption during ice fishing and open water fishing trips in Maine. A distribution of percentiles of fish consumption rates for those respondents who indicated that they had consumed some fish during the year was provided. These estimates included sport-caught freshwater fish harvested from all fresh waterbodies in Maine.

Connelly et al., 1992. A long-term recall mail survey was used by Connelly et al. (1992) to determine rates of sport-caught freshwater fish consumption by licensed New York anglers. The authors reported that mean consumption was 11 meals per year. Using a conservative estimated meal size of 227 g results in an estimated annualized consumption rate of 6.8 g/d. From the data provided by Connelly et al. (1992) the 92nd percentile can be estimated at 32 g/d.

Cox et al., 1985, 1987, 1990. Cox et al. have reported results of a number of surveys conducted of Ontario anglers. These surveys were in the form of questionnaires included in the "Guide to Eating Ontario Sport Fish", which gives consumption advice and is updated annually. Based on responses received from the 1983 questionnaire, Cox et al. (1985) reported a mean freshwater fish consumption rate of 21.8 g/d. A similar mean of 19.4 g/d was reported by Cox et al. for their 1986 survey (Cox et al., 1987). Although the raw data from the 1983 Ontario survey are no longer available, Cox et al.[1] have reported that the median consumption rates from both the 1986 and the most recent Ontario study (Cox et al., 1990) were both 7.5 g/d.

Anglers — Sport-caught Fish from Multiple Rivers/Streams

Ebert et al. (1993) and ChemRisk (1991b) established that consumption rates for fish taken from moving waters (rivers and streams) differ from consumption rates for still waters (ponds and lakes). When contamination affects multiple rivers and streams that are recreational fisheries in a given region, but does not affect standing waters, it is most appropriate to use

[1] Cox — Personal Communication

estimates of consumption of river/stream fish by anglers. To our knowledge, this is the only published study of the consumption of fish from multiple flowing waters.

Ebert et al., 1993. As discussed previously, Ebert et al. (1993) conducted a recall survey of Maine's resident freshwater anglers. Although responding anglers were not asked to recall exact locations where individual fish were harvested, they were asked to report numbers of fish harvested for consumption that were obtained from standing waters (lakes and ponds) and from flowing waters (rivers and streams). Using these data, the authors evaluated consumption from individual types of waterbodies by considering only those fish reported by anglers to have been harvested from the particular type of waterbody. Thus, it was possible to estimate a full distribution of consumption rates for those anglers who reported that they ate fish from rivers or streams. These estimates were not waterbody-specific, but rather were estimates of total consumption of freshwater river/stream fish by Maine's consuming resident anglers.

Anglers — Sport-caught Fish from Multiple Lakes/Ponds

When contamination affects multiple lakes and ponds that are recreational fisheries in a given region, but does not affect flowing waters, it is preferable to estimate ingestion of lake/pond fish by anglers.

ChemRisk, 1991b[2]. In an additional, unpublished analysis of data obtained from their Maine angler survey (Ebert et al., 1993), ChemRisk (1991b) reported the rates of consumption of fish recreationally obtained from lakes and ponds in Maine. These estimates were not waterbody-specific but rather were estimates of total consumption of lake/pond fish by Maine's consuming resident anglers.

Richardson and Currie, 1993. Richardson and Currie (1993) used measured concentrations of total mercury in the hair of Ontario Amerindians as a means of estimating rates of fish consumption by this population. An average concentration of mercury in fish tissues (regardless of species) from multiple lakes within a 100 km radius of each reserve was assumed to be the concentration in consumed fish. To derive estimates of consumption, it was assumed that all measured mercury in fish was methyl mercury, that 100% of the mercury was absorbed, that the half-life in the body is 70 days, and that hair grows at a rate of 1 cm per month. Actual sources of fish consumed, species consumed, and number of meals consumed were unknown. Using the levels of mercury measured in the hair of study participants, the authors reported geometric mean consumption rates of 19 and 14 g/d for male and female Amerindians, respectively.

Anglers — Sport-caught Fish from Specific Waterbodies

Often regulatory actions, like effluent permitting or the selection of remedial options, are targeted to a specific waterbody. When contamination is limited to a single waterbody, the proportion of total consumption resulting from that waterbody is the relevant estimate of

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[2] Unpublished data.

interest. If possible, waterbody-specific estimates should be based on local data collected for the site (EPA, 1989b). If it is not possible to collect information on potential consumption from the waterbody in question, then the next step is to evaluate whether estimates of waterbody-specific consumption from other similar waterbodies can be substituted and used as reasonably representative of the waterbody being studied. While a number of surveys have been conducted over the years to determine fishing participation and harvest rates, only a few have specifically evaluated rates of consumption of fish harvested from a specific waterbody.

Soldat, 1970. Soldat (1970) conducted a creel survey of the Upper Columbia River in the Hanford area and reported that the average angler surveyed took 4.7 trips per year and harvested 0.7 meals per trip from the Upper Columbia River annually. Soldat (1970) reported that 45,000 meals were caught, representing 20,000 pounds of edible fish (202 grams per meal). Using this reported 202 g fish meal size, the resulting estimate of consumption from the Soldat study is 1.8 g/d.

Honstead et al., 1971. As reported by Rupp et al. (1980), Honstead et al. (1971) conducted a recall survey and reported that Upper Columbia River anglers consumed an average of 14 meals of sport-caught fish per year and that the average meal size was 200 grams. Based on this, it can be estimated that anglers consumed 2.8 kg per year or approximately 7.7 g/d on average.

Turcotte, 1983. Through data collected in a creel survey, Turcotte (1983) evaluated harvest of freshwater species from non-tidal reaches of the Savannah River and estimated that the average angler harvested 22.6 kg of fish per year. Using an EPA (1989b) estimate that 30% of the harvested fish is edible, results in an edible harvest of 6.8 kg/year or 19 g/day. However, this estimate does not account for sharing of fish with other individuals. In addition, it is based on the assumption that all harvested fish were consumed and did not consider that some fish were likely to have been given away, discarded, or used as bait. If it is assumed that all harvested fish are eaten and that an average of 2.5 individuals shared in the consumption, a value that has been reported in several studies (Puffer et al., 1981; Landolt et al., 1985; Ebert et al., 1993), the resulting estimate is 7.4 g/d.

ChemRisk, 1991a[3]. ChemRisk (1991a) conducted a creel survey of the West Branch of the Penobscot River. In estimating an upper-bound annual consumption rate based on data collected from single interviews of successful anglers, ChemRisk conservatively assumed that each angler was successful on every trip and that the frequency of fishing trips taken up to the time of the interview continued throughout the remainder of the season. Using this methodology for the consuming angling population, a full distribution of consumption rates, with a mean of 5.1 g/d, was reported. However, because it was believed that these assumptions were likely to result in overestimates of consumption by the interviewed anglers, ChemRisk conducted an additional analysis, using fisheries management data simultaneously

[3] Unpublished data.

collected from the West Branch, in which the trends in participation and harvest rates over the season were identified. These trends were used to calculate monthly adjustment factors for fishing frequency and harvest rates which were then incorporated into a Monte Carlo analysis to derive a distribution of consumption rates for the West Branch that considered seasonal fluctuations. This analysis indicated that consumption rates were lower than originally estimated with a mean of 3.0 g/d and a median of 0.49 g/d.

DISCUSSION

While the wide range of consumption values that have been reported in the scientific literature would seem to indicate that rates of fish consumption are highly variable, this variability can be attributed primarily to differences in the types of fish being eaten, the source or sources of those fish, the characteristics of the population being evaluated, and the methods used to collect consumption data. As demonstrated in Table 3, the sources (recreational vs. commercial, marine vs. freshwater, etc.) from which fish have been obtained appear to have a substantial effect on the estimated rates of consumption. Surveys that have considered all sources of fish tend to have the highest estimates of average intakes, while surveys that have focused on a single fresh waterbody tend to have the lowest. When surveys involving similar sources of fish are compared, estimates of consumption are similar.

Based on the data presented in Table 3, the following conclusions can be reached:

- Rates of intake from individual bodies of water are lower than rates of intake from multiple bodies of water;
- Rates of consumption of sport-caught marine fish are generally higher than rates of consumption of sport-caught freshwater fish; and,
- Rates of intake from moving waters are lower than rates from still waters.

Although it appears that rates of consumption of marine fish may be higher than rates of consumption of freshwater fish when comparing studies of marine anglers with those of freshwater anglers, the recent Price et al. (1994) reanalysis of the Puffer et al. and Pierce et al. studies indicates that consumption of marine fish by anglers may be comparable to consumption of freshwater fish, when survey biases are minimized. However, this conclusion cannot be reached with certainty and is an área for future research.

An important additional observation is that the estimate of the "high end" angler intake (the top 10% of anglers) is greatly affected by the duration of the survey. Table 4 presents intake rates of sport-caught fish at the 95th percentile, according to the survey method used. Available intake estimates for the 95th percentile consumer are less than 40 g/d for all long-term (greater than 30- day recall period) surveys. Much higher estimates are found in surveys of shorter duration, likely due to short-term variability biasing the results upward. Because the

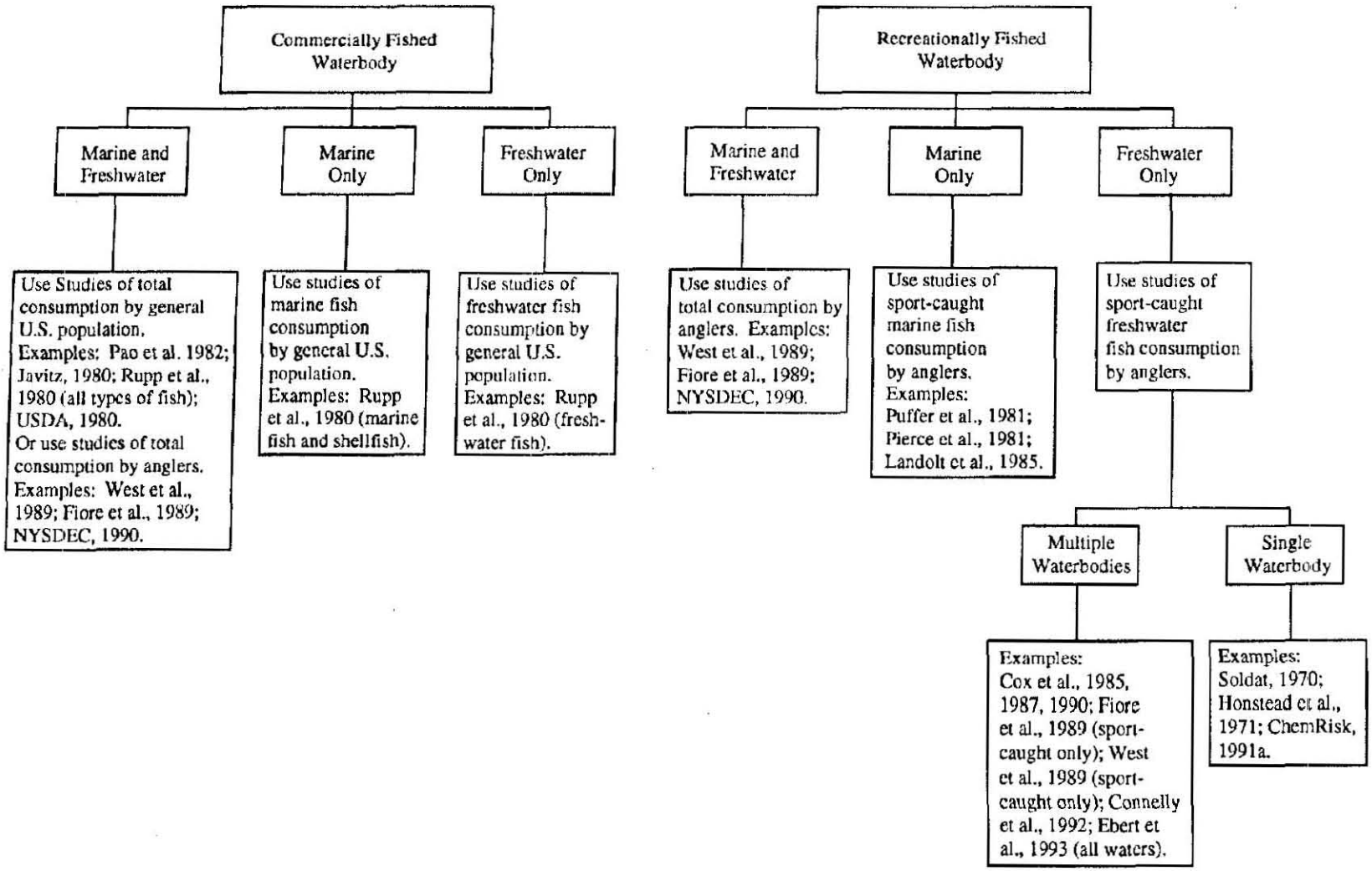

FIGURE 2. Selection of fish consumption rates based on type of waterbody and potentially exposed population.

TABLE 3. Estimates of Average Fish Consumption Rates Per Sources of Consumed Fish(g/d)

Source and Waterbody Type	Range of Average Rates	Reference
General Population Surveys[a]		
Marine, freshwater, and estuarine	12.7 to 54	Javitz et al., 1980 Rupp et al. 1980 USDA, 1980 Pao et al., 1982
Marine only	8.8	Rupp et al., 1980
Freshwater only	1.2	Rupp et el., 1980
Angler Surveys[b]		
Marine, freshwater, and estuarine	18.3 to 28	West et al., 1989 Fiore et al., 1989 NYSDEC, 1990
Marine only	15 to 37[c]	Pierce et al., 1981 Puffer et al., 1981 Landolt et al., 1985
Freshwater-multiple waterbodies	6.4 to 21.8	Cox et al., 1985, 1987, 1990 Fiore et al., 1989 West et al., 1989 Connelly et al., 1992 Ebert et al., 1993
Freshwater-multiple standing waters	4.2 to 16	Richardson and Currie, 1993 ChemRisk, 1991b
Freshwater-multiple flowing waters	3.7	Ebert et al., 1993
Freshwater-single waterbody	1.8 to 7.7[c]	Soldat, 1970 Honstead et al., 1971 Turcotte, 1983 ChemRisk, 1991a

[a] Estimates of consumption by the general population of the United States, including anglers and non-anglers.
[b] Estimates of consumption by anglers only.
[c] These rates are likely to be overestimated due to the oversampling of more frequent anglers during creel surveys.

estimates from the long-term surveys are not subject to short-term variability, they are preferred for estimating average annual consumption rates by risk assessors. This analysis suggests that consumption rates for the general angler population rarely reach the levels of between 140 and 180 g/d frequently recommended for evaluating "high-end" intake (EPA,

1989a,b). Although Puffer et al. (1981) reported a 95th percentile value in exceedance of 180 g/d, Price et al. (1994) have recently demonstrated that this high estimate is not representative of the 95th percentile of the total angler population using the fishery. Reanalysis of the Puffer et al. (1981) data to correct for sampling bias has resulted in an estimated 95th percentile of approximately 35 g/d.

TABLE 4. A Comparison of Estimated Rates of Self-Caught Fish Consumption Per Duration of Recall Period

Recall Period	Range of "High-End" Intakes (g/d)	Reference
1 day	54 to 339	Pierce et al., 1981[b] Puffer et al., 1981[b]
3 day	128	Pao et al., 1982
30 days	42	Javitz, 1980
365 days	26 to 37	Fiore et al., 1989 Connelly et al., 1992 Ebert et al., 1993

[a] All values are reported 95th percentile except Connelly et al. (1992) for which the reported value represents the 92nd percentile.
[b] Reanalyses of these data by Price et al. (1994) have resulted in substantially lower estimates of "high-end" intakes.

The EPA (1989b) has acknowledged that there are substantial regional- and site-specific variations in consumption rates and, as a result, has recommended that site- or region-specific consumption estimates be used wherever possible. Clearly this is preferable due to the variability that can occur among fisheries because of differences in lengths of fishing seasons, the availability of fisheries, the availability of target species, fishing regulations, and the cultural or ethnic backgrounds of the fish consumers.

Unfortunately, due to time constraints or resource limitations, it is not always possible to collect site-specific information or to have the complete distribution. In lieu of these, it becomes necessary to select the most representative consumption estimate based on the population, region, waterbody type, and fishery type of interest.

In risk assessments performed for regulatory purposes, it is important that the fish consumption rate selected be derived from studies that are consistent with the type of waterbody and target population being evaluated. Freshwater fish consumption estimates should not be based on studies of marine fisheries because there are likely to be differences in the species present, the relative productivities of the waters, and the preferences of the anglers. If fish ingestion from a single waterbody is being evaluated, it is best that the rate of intake be based upon a valid intake study from a similar, individual waterbody. It is particularly important to consider whether there are any commercial fisheries on the waterbody of interest.

If there are none, then the rates of intake used should be based on studies which have considered only the intake of sport-caught fish and should not include consumption of fish that have been obtained from restaurants, markets, or other, non-angling sources. General guidance on the selection of appropriate fish consumption estimates is provided in Figure 2.

It is also important to consider the species and size of fish available in the waterbody of interest. Because the species targeted vary among fisheries and among regions, and because different species vary in their propensity to bioaccumulate persistent compounds, exposure potentials may differ substantially. Thus, for risk assessment purposes, it would be ideal to derive species-specific rates of consumption for individual anglers and to combine the intake rates with species-specific fish tissue levels to more accurately define exposures.

It is important to note that a discussion of the selection of consumption rates for subpopulations that may consume more fish than recreational anglers is beyond the scope of this paper. In conducting an exposure assessment, careful consideration must be given to whether such a sensitive subpopulation exists due to income level or ethnic background. If it does, it may be appropriate to select consumption rates that are based on either site-specific studies or studies of similar populations.

In the absence of site-specific information, the selection of a fish consumption rate to be used in the assessment of risks from a contaminated area involves three critical factors. First, the population most likely to be affected must be identified. Second, if possible, the selection of a fish consumption rate for a particular geographic area should be based on a study that has evaluated similar areas with similar resources. Differences in climate, target species, length of fishing season, availability of marine and freshwater fisheries, and cultural/ethnic background can substantially influence rates of consumption. Lastly, waterbody and fishery types are important considerations. Often the population that is most likely to be affected includes anglers who fish the contaminated waters. If contamination is widespread throughout an area, then it may be appropriate to select a consumption estimate from a study that has evaluated total consumption of sport-caught fish by anglers (Fiore et al., 1989; Ebert et al., 1993). If the area affected is a marine area, then estimates of marine fish consumption are most appropriate. Conversely, if the area affected is an inland area, then estimates of freshwater fish consumption should be used. Finally, if only a single waterbody is affected by contamination, the fish consumption rate selected for the evaluation should, if possible, be a rate that has been derived from a study of a waterbody that is similar in nature to the one of interest. If it is not possible to identify a single waterbody within a given region that is directly comparable with the waterbody being evaluated, then a more general estimate of consumption, based on the most comparable study, may serve as a useful surrogate.

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