GE Corporate
Environmental Programs

John G. Haggard
Engineering Project Manager
Hudson River

General Electric Company
1 Computer Drive South, Albany, NY 12205
518 456 6619 Dial Comm: 8*920-9000
Fax: 518 458-9247

February 10, 1995

Douglas J. Tomchuk
Emergency and Remedial Response Division
U. S. Environmental Protection Agency
290 Broadway, 20th Floor
New York, NY 10007-1866

Dear Doug:

At our last meeting, I offered to send to you information we had put together relating to Hudson River risk assessment issues. Recently, Pete Lanahan discussed this with Kathleen Callahan and provided her with a number of documents we had prepared relating to these issues. For your information find enclosed copies of these papers, which were prepared by our consultant, ChemRisk:

1. Estimating Fish Consumption Rates for the Upper Hudson River

2. Determining the Intake of Hudson River Fish by Species

3. Evaluating the Impact of Cooking Processes on the PCBs in Fish

4. Estimating Exposure Duration for Hudson River Risk Assessment

In addition to these papers, I have also included copies of papers recently published in the peer review literature that relate to these topics. These include;

1. The Effect of Cooking Processes on PCB Levels in Edible Fish Tissue (R. A. Sherer and P. S. Price, J. Quality Assurance, V. 2, 1993)

2. Estimating Consumption of Freshwater Fish Among Maine Anglers (E. S. Ebert and N. W. Harrington; North American Journal of Fisheries Management, V. 19, 1993)

3. Selection of Fish Consumption Estimates for Use in the Regulatory Process (E.S. Ebert, P.S. Price, and R. E. Keenan, J. Exposure Analysis and Environmental Epidemiology, V4, #3, 1994)

4. The Effect of Sampling Bias on Estimates of Angler Consumption Rates in Creel Surveys (P.S. Price, S. H. Hu, and M. N. Gray, J. Exposure Analysis and Environmental Epidemiology, V. 4, #3, 1994)

We are trying to arrange a meeting to discuss these papers and related topics. Please include these in the Site Administrative Record. If you have any questions, let me know.

Yours truly,

John G. Haggard

John G. Haggard
Engineering Project Manager

cc: Walter Demick, NYSDEC
Bob Montione, NYSDOH

Enc:
8 Copies of each Report

803762

North American Journal of Fisheries Management 13:737–745, 1993

Estimating Consumption of Freshwater Fish among Maine Anglers

ELLEN S. EBERT AND NATALIE W. HARRINGTON

ChemRisk® Division, McLaren/Hart Environmental Engineering Corp.
Stroudwater Crossing, 1685 Congress Street, Portland, Maine 04102, USA

KEVIN J. BOYLE

207 Winslow Hall, University of Maine, Orono, Maine 04469, USA

JAMES W. KNIGHT

Gradient Corp., 3775 Iris Avenue, Boulder, Colorado 80301, USA

RUSSELL E. KEENAN

ChemRisk® Division, McLaren/Hart Environmental Engineering Corp.

Abstract.—In deriving water quality standards and appropriate restoration levels for contaminated surface waters, the potential for human exposure is often the most important factor to be considered. For certain persistent compounds, like 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) or mixtures of polychlorinated biphenyls, a primary pathway of human exposure is through ingestion of fish obtained from affected waters. Pending water quality regulation for TCDD in Maine required that estimates be made of the rate of consumption of freshwater fish obtained from rivers that receive TCDD discharges. Because commercial freshwater fishers do not exist on Maine rivers, any freshwater fish that are eaten have been caught by anglers. A statewide mail survey of Maine's licensed anglers was undertaken to characterize rates of fish consumption from rivers and streams in Maine. The survey was mailed to 2,500 licensed resident anglers who were randomly selected from state license files. The response rate of 70% (based on deliverable surveys) resulted in a usable sample of 1,612 anglers. Results of this study indicated that, if fish are shared with other fish eaters in the household, the annual average consumption of freshwater river fish per consuming angler in Maine is 3.7 g/d. Comparisons of findings of this study and of studies in other regions of the United States show considerable variations in fish consumption rates, supporting the use of state- or region-specific estimates of fish consumption in establishing water quality regulations for persistent, biologically accumulative compounds.

As society attempts to reduce the amounts of contaminants released into surface water resources, and to determine appropriate restoration levels for contaminated waters, a critical consideration is the quantity of fish that the public consumes from those waters. Ingestion of freshwater fish is potentially the most common pathway of human exposure to certain chemical contaminants in surface waters (Rifkin and LaKind 1991). Recognizing that a relationship may exist between the presence of contaminants in surface waters and uptake by humans through fish ingestion is only the first step in developing water quality regulations. It is also necessary to determine the quantities of fish consumed, the levels of chemical contaminants in the fish tissues consumed, and the potential toxicity to humans who consume those fish (Sherman et al. 1992). While the health effects of certain compounds have been studied extensively, and levels in fish are frequently monitored, estimates of fish consumption from specific water bodies are not readily available (EPA 1992). This lack of data is due largely to the fact that fishery managers and natural resource agencies are primarily concerned with controlling harvest and not with the final disposition of the harvest. Monitoring the consumption of freshwater fish often does not come under the direct purview of any public agency.

An example of this limitation is the recent rule-making process to set an ambient water quality standard for 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) in Maine's rivers. Because there are no commercial freshwater fisheries in the state, only those individuals who consume sport-caught fish have the potential to be exposed to TCDD in the fish from Maine's impacted rivers. Thus, estimation of angler consumption of freshwater fish from affected rivers was critical to the rule-making process in Maine.

803763

TABLE 1.—Existing fish consumption estimates (mean g/d per person). Numbers in parentheses are median values. Consumption estimates from studies on the U.S. population are per capita.

Reference	Consumers studied	All types of fish, all sources[a]	Marine–estuarine fish		Freshwater fish	
			All sources[a]	Sport-caught[b]	All sources[a]	Sport-caught[b]
Fiore et al. (1989)	Wisconsin anglers			26	12	
Honstead et al. (1971)	Columbia River anglers					7.7
Javitz (1980)	U.S. population	14[c]				
Landolt et al. (1985)	Washington anglers			(15)[c]		
NYSDEC (1990)	New York anglers	28				
Pao et al. (1982)	U.S. population	(37)				
Pierce et al. (1981)	Washington anglers			(23)[d]		
Puffer et al. (1981)	California anglers			(37)		
Rupp et al. (1980)	U.S. population	16	14		1.5	
Soldat (1970)	Columbia River anglers					1.8
Turcotte (1983)	Savannah River anglers					31[e]
West et al. (1989)	Michigan anglers				18	7[f]

[a] All sources includes fish purchased in stores and restaurants as well as recreationally caught fish.
[b] Sport-caught includes only fish that have been obtained by angling.
[c] Estimate based on Monte Carlo simulation using frequency distributions for edible weight of fish, fish per trip, trips per year, and household size.
[d] EPA (1989b) estimate.
[e] Based on harvest estimates; no correction for sharing of harvest.
[f] Estimated value based on data presented in Table 19 in West et al. (1989).

There are several reasons why the existing fish consumption estimates derived elsewhere could not be used to infer freshwater fish consumption in Maine. First, fish consumption studies by Javitz (1980), Rupp et al. (1980), Pao et al. (1982), and NYSDEC (1990) did not distinguish between the consumption of commercially harvested and recreationally harvested fish (Table 1). Thus, the fish consumption estimates from these studies include purchased and sport-caught freshwater and saltwater fish. Consumption of saltwater species was not relevant to the TCDD risk assessment for Maine's rivers, and there are no commercial freshwater fisheries on Maine's rivers.

Second, studies by Pierce et al. (1981), Puffer et al. (1981), and Landolt et al. (1985), although focused on consumption of sport-caught fish, gave consumption estimates for marine or estuarine fishes. There are no data available to evaluate the comparability of consumption of recreationally caught saltwater fish with consumption of recreationally caught freshwater fish.

Third, only six studies specifically estimated consumption of freshwater fish (Soldat 1970; Honstead et al. 1971; Rupp et al. 1980; Turcotte 1983; Fiore et al. 1989; West et al. 1989). Of these studies, only four reported consumption rates for sport-caught fish, and only three estimated consumption of sport-caught fish from riverine fisheries. The river studies were conducted in the Pacific Northwest (Soldat 1970; Honstead et al. 1971) and the southeastern United States (Turcotte 1983). These studies demonstrated considerable variation in estimated consumption; mean rates ranged from 2 to 31 g/d per person.

Therefore, to estimate consumption rates of recreationally caught freshwater species in Maine, we conducted a statewide mail survey of licensed resident anglers. We have identified potential issues in developing fish consumption estimates that we hope will stimulate research to enhance the validity and reliability of future fish consumption estimates. It is also our intent to raise fishery biologists' awareness of the need for estimating fish consumption rates so that future studies of fishing effort, when possible, will include estimates of harvest and consumption.

Methods

Sample Selection

Freshwater fish consumption was estimated for adult anglers who held a Maine resident, inland fishing license.[1] Nonresident anglers were not included in the sample because prior research in-

[1] All adult anglers (≥16 years) are required to obtain a fishing license to fish Maine's inland waters, except members of the Penobscot Indian Nation, who can fish riverine waters adjacent to selected portions of their land without a license. The Penobscots must obtain a complimentary license to fish all other riverine and standing waters in the state. Holders of these complimentary licenses were represented in the sample.

803764

dicated that there is substantially more effort each year by resident anglers, and resident anglers are more likely to fish in Maine every year (Boyle et al. 1989). By sampling only licensed resident anglers, consumption data were collected for the subset of licensed anglers who, as a group, were believed to have the greatest potential opportunity for exposure to TCDD.

A sample of 2,500 licensed resident anglers was randomly selected from Maine's license files. Prior research indicated that participation in warmwater fishing is substantially lower than participation in coldwater fishing in Maine, and that the warmwater species with the lowest participation rates were yellow perch *Perca flavescens* and white perch *Morone americana* (Phillips et al. 1990). Multiplying the inverse of the combined rate for participation in yellow perch and white perch fishing by the desired number of consumption observations for perch (100) led us to conclude that we needed to receive 1,363 completed surveys. To determine the sample size necessary to ensure this number of responses, we assumed that 90% of the mailed surveys would be deliverable, that 90% of the 1989 license holders fished in 1990, and that the survey response rate would be 75%. This resulted in a required sample size of approximately 2,000. An additional 500 anglers were added to the sample to compensate for an unknown percentage of Maine anglers who practice catch-and-release fishing or do not consume fish. This procedure ensured that the number of consumption observations for all other fish species of interest would exceed those for yellow perch and white perch.

Because inland fishing licenses are valid for one calendar year, and recording of license sales is not completed by Maine's Department of Inland Fisheries and Wildlife (IF&W) until March of the following year, the sample was selected from among all anglers who held a 1989 fishing license. This process resulted in a sample of anglers who held licenses in both 1989 and 1990. Boyle et al. (1990) surveyed resident anglers licensed in 1987 regarding their open-water fishing effort during 1988 and found this sampling method to be valid.

The mail survey was pretested with 50 randomly selected anglers. Telephone interviews were conducted with 40% of the pretest participants to learn if they had difficulty in answering or understanding any of the questions. Final revisions were made to the survey, based on responses to the telephone interviews and reviews of returned pretest mail surveys.

All open-water fishing in Maine closes on October 31. However, because open-water fishing for most Maine waters (all but one river) closes on September 30, the survey was implemented in mid-October 1990. Postcards were sent 1 week later, thanking those who had already returned the survey, and asking those who had not yet returned the survey to do so. Three weeks later, on November 7, 1990, a follow-up survey packet was mailed to 1,111 anglers who had not yet responded, and the recipients were asked to complete and return the survey by December 3, 1990.

Survey Design

The design of the survey focused on asking anglers to report the disposition, particularly consumption, of freshwater fish they caught in Maine. This strategy differed from some of the previous fish consumption studies where survey respondents were asked to report the number of fish meals they ate each week (Javitz 1980; Rupp et al. 1980; Pao et al. 1982; West et al. 1989; NYSDEC 1990). To address the TCDD issue, it was important to know where the fish were caught and to exclude fish consumption from sources other than Maine's freshwater (i.e., saltwater species or freshwater species purchased at the market). Only 320 km of Maine's rivers, less than 1% of all riverine environments in Maine, were potentially contaminated by TCDD. Therefore, to obtain a usable sample and to provide an appropriate context, anglers were asked about their fish consumption from flowing (rivers, streams, and brooks) and standing (lakes and ponds) water bodies.

Each respondent was asked to report how many trips had been made to ice fish, open-water fish in standing waters, and open-water fish in flowing waters during the last completed season. Anglers were also asked to report the number of each species of fish caught during the 1990 open-water season and the 1989–1990 ice-fishing season. For fish caught during open-water season, anglers were asked to report the number of fish consumed for each of 15 groups of species, and to identify the number taken from flowing or standing water bodies. Anglers were also asked to estimate the average length for each species of fish that was eventually consumed. In addition to those fish caught by the responding angler, the respondents were asked to describe the number, species, and average length of each sport-caught fish they had consumed that had either been obtained from other members of their households or from individuals outside of their households.

TABLE 2.—Regression parameters for weight–length equations and edible portion (E) of fish species harvested by freshwater anglers in Maine. NR = not reported.

Species	Regression coefficients: Intercept	Slope	Length range[a] (mm)	Water body and location	Source[b]	E[c]
Landlocked salmon (lacustrine Atlantic salmon *Salmo salar*)	−5.145	3.035	270–750	Rivers and lakes, Maine	IF&W	0.40[d]
Atlantic salmon	−5.038	3.00	NR	Unspecified, Scotland	Carlander (1969)	0.40[d]
Lake trout *Salvelinus namaycush*	−5.879	3.306	290–840	Rivers and lakes, Maine	IF&W	0.30
Brook trout *Salvelinus fontinalis*	−5.054	3.022	150–750	Rivers and lakes, Maine	IF&W	0.30
Brown trout *Salmo trutta*	−5.096	3.037	167–936	Rivers and lakes, Maine	IF&W	0.30
Yellow perch *Perca flavescens*	−3.519	2.390	127–320	Rivers and lakes, Maine	IF&W	0.30
White perch *Morone americana*	−5.273	3.177	100–457	Rivers and lakes, Maine	IF&W	0.30
Largemouth bass *Micropterus salmoides*	−3.844	2.606	209–686	Rivers and lakes, Maine	IF&W	0.30[d]
Chain pickerel *Esox niger*	−5.491	3.098	229–566	Unspecified, Florida	Carlander (1969)	0.30
Lake whitefish *Coregonus clupeaformis*	−5.677	3.241	NR	Lake Superior, USA–Canada	Carlander (1969)	0.30
Brown bullhead *Ameiurus nebulosus*	−5.061	3.065	152–192	Lake Butte des Mortes, Wisconsin	Carlander (1969)	0.30
White sucker *Catostomus commersoni*	−5.395	3.223	NR	Shadow Mt. Lake, Colorado	Carlander (1969)	0.30
Creek chub *Semotilus atromaculatus*	−3.972	2.98	NR	Des Moines River, Iowa	Carlander (1969)	0.30
Rainbow smelt *Osmerus mordax*	−6.2	3.40	80–220	5 lakes in the Sebago region, Maine	IF&W	0.78[d]
Redbreast sunfish *Lepomis auritus*	−4.69	3.01	NR	Unspecified, Alabama	Carlander (1977)	0.30

[a] Represents the range of lengths of fish used for the regression analysis.
[b] IF&W = Maine's Department of Inland Fisheries and Wildlife (unpublished data).
[c] Portion of whole fish that is edible, based on EPA (1989b) except where noted.
[d] Based on Maine-specific data collected by ChemRisk (unpublished data).

Estimating Fish Consumption Rates

The total weight of freshwater fish from each source that was consumed within each respondent's household was estimated from respondent-provided data on quantity and average length of each fish species eaten that was obtained as a result of the respondent's, other household members', and nonhousehold members' fishing activities. The weight of fish consumed for each species group was estimated as follows:

$$C_i = Q_i \times W'_i \times E_i; \quad (1)$$

C_i = total weight (g) of species group i consumed within the angler's household;
Q_i = number of fish of species group i consumed within the angler's household;
W'_i = weight (g) per fish of species group i, based on reported average length (lengths were reported in inches but converted to millimeters);
E_i = portion of fish weight that is edible for species group i.

Data on the number of fish consumed were directly obtained from survey responses. The weight was predicted by using the reported average lengths from the survey and length–weight regression equations estimated by IF&W based on several years of length and weight measurements from rivers and lakes in Maine (Table 2). For those species for which Maine-specific equations were not available, the appropriate relationships were obtained from Carlander (1969, 1977).

Because not all of a fish is edible, it was necessary to characterize the edible portion of a whole fish (E_i). Stansby and Olcott (1963) reported that commercial filleting of finfish yields between 20 and 40% edible tissue and that actual yield depends upon the species. The EPA (1989a) has recommended that 30% be used to characterize the edible portion of finfish.

To explore the range and variability of the edible portion, studies were undertaken to estimate the edible portions (fillets) of smallmouth bass *Micropterus dolomieu* and landlocked salmon in

803766

Maine. Twenty-two smallmouth bass were collected from two Maine rivers and 12 landlocked salmon were collected from one river. The whole fish were weighed and then carefully filleted to remove as much flesh from the bones as possible. Fillets from each fish were then weighed, and the fillet weight was compared with the whole-body weight for that fish to determine the edible portion. For smallmouth bass, the mean edible portion was 30%, with a 90% confidence interval ranging from 27 to 30%. The mean edible portion for landlocked salmon was 37% with a 90% confidence interval ranging from 36 to 39%. For the current analysis, the results of the landlocked salmon analysis were used to assume edible portions of 40% for landlocked salmon and Atlantic salmon. The EPA (1989a) recommendation, confirmed by the smallmouth bass analysis, was used to assume an edible portion of 30% for all species in Table 2 except rainbow smelt. For this species, we assumed that half of those consumed were eaten without the head or viscera, and half were eaten with the viscera but without the head. Rainbow smelt data were not available, but for landlocked salmon, the body without the head and viscera represented 68% of the whole fish weight and the body without the head represented 87%, giving an average edible portion of 78%. This average value was used for rainbow smelt.

The total freshwater fish weight consumed from Maine rivers and streams by the angler and other people in the household was then calculated as the sum of C_i for the 15 groups of species. Daily freshwater fish consumption for each individual respondent was estimated by summing the source-specific rates (e.g., open-water fishing, ice fishing), and then dividing by the number of fish consumers residing in the respondent's household and the number of days in a year. To estimate rates of consumption from rivers and streams, equation (1) was used but Q_i and W_i were based only on fish that had been reportedly harvested from rivers or streams during the season.

Our initial analysis of consumption rates was based on the assumption that all freshwater fish obtained for consumption by the angler were shared equally with other household members who consume fish. This assumption was also used by Puffer et al. (1981) and is the approach supported by EPA (1989a). Some researchers have divided total fish consumed by the total number of persons in the household to obtain per-capita fish consumption estimates (Pierce et al. 1981; Landolt et al. 1985). Whereas this approach may be reasonable for estimating consumption of marine species, it is questionable for estimating consumption of freshwater fish because the percentage of the population that eats freshwater species is generally lower than the percentage that consumes marine fish (Rupp et al. 1980). We also conducted a sensitivity analysis to consider the impacts of different assumptions about sharing on consumption rate estimates. Three scenarios were considered: (1) all household fish consumers eat an equal share of consumed fish; (2) only adults in the household consume fish; and (3) the angler alone consumes all of the fish reported.

Statistical analyses were conducted without assuming a distributional model. Because of certain physical limitations (e.g., the high number of zero consumers and limited number of high consumers), fish consumption data do not fit a standard distribution model. To force a fit of these data to a standard model would obscure the true nature of the distribution.

Results

In total, 1,612 surveys were completed and returned, representing 70% of the deliverable surveys. Of these, 1,251 (78%) of the respondents reported having fished during the 1990 open-water season or the 1989–1990 ice-fishing season. Also, 118 individuals did not fish but consumed freshwater fish caught by other anglers, either within or outside of their households. These 118 respondents, with the 1,251 who fished, constituted the 1,369 angler observations (85% of total responses) used in data analyses.

In total, 599 (44%) of the respondents indicated that they ice fished, and 1,127 (82%) of the respondents participated in open-water fishing during the period of interest. Of the individuals who open-water fished, 93% reported having fished in ponds or lakes and 66% reported having fished in streams and rivers.

Twenty-three percent of all anglers surveyed reported that they consumed no freshwater fish caught in 1990. Forty-three percent of the river anglers indicated that they did not consume fish from rivers or streams during the 1990 season, and 19% of river anglers consumed no freshwater fish from any source during that period.

The median fish consumption per angler for those who had eaten fish was 2.0 g/d based on catch from all waters and 0.99 g/d based on fish taken from flowing waters (Table 3). The arithmetic mean consumption by consuming anglers was 6.4 g/d (all waters) and 3.7 g/d (flowing waters). These arithmetic means represented the 77th

803767

TABLE 3.—Estimates of fish consumption (g/d per person) by anglers licensed to fish in Maine's lakes, ponds, streams, and rivers during the 1989–1990 ice-fishing or 1990 open-water seasons. Estimates are based on rank except for those of arithmetic means.

Percentile	All waters: All anglers[a] (N = 1,369)	All waters: Consuming anglers[b] (N = 1,053)	Rivers and streams: River anglers[c] (N = 741)	Rivers and streams: Consuming anglers[b] (N = 464)
50th (median)	1.1	2.0	0.19	0.99
66th	2.6	4.0	0.71	1.8
75th	4.2	5.8	1.3	2.5
90th	11	13	3.7	6.1
95th	21	26	6.2	12
Arithmetic mean[d]	5.0 (79)	6.4 (77)	1.9 (82)	3.7 (81)

[a] Licensed anglers who fished during the seasons studied and did or did not consume freshwater fish, and licensed anglers who did not fish but ate freshwater fish caught in Maine during those seasons.

[b] Licensed anglers who ate freshwater fish caught in Maine during the seasons studied.

[c] Those of the "all anglers" category who fished on rivers or streams.

[d] Values in parentheses are percentiles at the mean consumption rates.

and 81st percentiles of the consumption distributions, respectively.

Consumption estimates varied depending on how fish were shared among household members (Table 4). If we assumed that only the angler ate all of the fish consumed, then median rates increased by roughly a factor of 2.5 relative to the scenario in which fish are shared by all household fish consumers. If we assumed that fish were shared by adults in the household, median consumption estimates increased by approximately a factor of 1.2.

Discussion

The EPA (1989b) has recommended that when data on local consumption are not available, a default value of 30 g/d per person "be used to represent consumption rates for recreational fishermen in any area where there is a large water body present and widespread contamination is evident." This rate is the average of the median consumption rates derived in two studies of marine anglers (Pierce et al. 1981; Puffer et al. 1981). Application of this rate to TCDD rule-making for Maine's rivers is inappropriate because it is based on the consumption of marine species. Furthermore, TCDD discharges are not widespread in Maine, but rather affect only 320 (0.5%) of the 59,500 km of rivers and streams in the state. In its recently proposed document entitled "Estimating Exposures to Dioxin-Like Compounds," EPA (1992) has revised its approach to estimating fish consumption from a single small water body and has indicated that a consumption estimate ranging from 1 to 4 g/d may be more appropriate under these circumstances.

The results of the Maine angler survey demonstrate a median consumption per consuming resident sport angler of 2.0 g/d for all freshwater finfish and 0.99 g/d for fish from flowing bodies of water. Both of these estimates are considerably lower than the median value of 30 g/d previously recommended by the EPA, but fall within the revised EPA recommendation of 1–4 g/d.

These consumption estimates fall at the low end of the range of reported consumption estimates for freshwater fish in other geographic locations (Table 1). Although differences could be due to survey methodology, average lengths of fish and harvest rates reported by survey respondents were consistent with IF&W data. Thus, we believe that these differences are likely due to differences in

TABLE 4.—Sensitivity analyses of the effects of assumptions about sharing of fish among household members on estimated consumption rates (g/d per person).

Percentile	All household consumers share: All waters	All household consumers share: Rivers and streams	Only adults share: All waters	Only adults share: Rivers and streams	Anglers are only consumers; no sharing: All waters	Anglers are only consumers; no sharing: Rivers and streams
50th (median)	2.0	0.99	2.3	1.2	5.0	2.5
66th	4.0	1.8	4.4	2.0	9.1	4.1
75th	5.8	2.5	6.6	3.0	13	6.1
90th	13	6.1	16	6.5	32	14
95th	26	12	28	20	57	27
Arithmetic mean[a]	6.4 (77)	3.7 (81)	7.5 (78)	4.5 (83)	15 (78)	8.9 (83)

[a] Values in parentheses are percentiles at the mean consumption rates.

803768

catch rates, fish size, and length of fishing seasons in Maine relative to other geographic locations. The magnitude of variation of fish consumption estimates reported in Table 1 demonstrates that fish consumption does vary geographically and underscores the need to develop more extensive data on fish consumption so that regional variations can be considered.

It is important to recognize that consumption is likely overestimated in the current study for the purpose of TCDD rule-making in Maine. First, the study was designed to collect data on consumption from all flowing bodies of water, and not just the 320 km of contaminated water. Thus, although individuals may fish in affected river reaches some of the time, it is highly unlikely that all fishing effort is focused on these waters, particularly because there are numerous alternative fisheries in close proximity to each river. Over 80% of Maine's resident anglers fish two or more bodies of water each year, approximately 60% fish three or more, nearly 40% fish four or more, and most riverine fishing in Maine occurs in headwaters and small streams and brooks, not in main stems of larger rivers where TCDD may be present (K. J. Boyle, unpublished data). Consequently, whereas the estimates for rivers and streams include all consumed fish from rivers and streams during the season, it is likely that only a portion of the consumption can be attributed to a single water body.

Second, in a study done for the U.S. Fish and Wildlife Service, Westat (1989) reported that 6-month or 1-year recall periods produce "substantial overestimates" of fishing participation (see also Chu et al. 1992). If participation estimates are overstated in a 6-month to 1-year recall study, it may also be reasonable to assume that consumption is overestimated due to recall bias. To date, there have been no studies specifically conducted for the purpose of evaluating recall bias in fish consumption surveys. This issue needs to be addressed in future studies of fish consumption.

Although fish consumption may be estimated by equating it to harvest, this approach inappropriately assumes that all harvested fish are consumed by the angler. In fact, we found that approximately 30% of the harvested fish were either thrown away, given away, used as bait, or fed to pets. Furthermore, anglers may share catch with friends or family members. Thus, equating the amount of fish harvested with consumption, even if adjustments are made for the edible portion, will overestimate fish consumption.

As noted earlier, some researchers have asked respondents to recall the total number of fish meals consumed over a period of time and to estimate the average size of those meals (West et al. 1989; NYSDEC 1990). This approach was not used in the current study because it was critical to collect information on the sources of the fish consumed. Anglers were surveyed, rather than other household members, because it was believed that they would be best able to accurately report where the fish had been caught. This is an important issue for future research in that anglers may be able to accurately report catch location, a critical issue in contamination studies, but may not accurately report consumption by all household members. Alternatively, household members may be able to report their consumption habits but may not be able to identify the locations from which the fish have been obtained.

Other issues that require further investigation when assessing exposure to chemical contaminants in fish are the sizes of fish consumed, the number of individuals who share in consumption, and the species consumed. Consideration should be given to the household member who consumes the largest quantity of fish, and the sex and age composition of fish consumers. Estimates of exposure must also consider the differences among species in their potentials to accumulate chemical contaminants in their tissues. Anadromous species such as Atlantic salmon and rainbow smelt are likely to have low body burdens of chemical contaminants, whereas other species indigenous to riverine environments, such as white perch, yellow perch, brown bullhead, creek chub, and white sucker, may have larger body burdens of chemical contaminants. All of these factors, although not necessary in estimating total fish consumption, may be crucially important in assessing exposures due to fish consumption.

The need to develop fish consumption estimates is not motivated solely by a single contaminant like TCDD but also arises for numerous other contaminants in aquatic ecosystems. If fish consumption levels for particular types of water bodies in specific regions of the country are known, it will be possible to assess human exposure to any contaminant once the concentration in edible fish tissue has been determined. The specific contaminant being addressed will, however, define the location and extent of fish consumption data required. Therefore, regular collection of fish consumption data as a part of the fishery management process will enhance future assessments of potential contamination and the ultimate restoration of contaminated waters.

Regulators are often faced with multiple factors that need to be considered in rule making, including public health risks, the size of the potentially affected population, and social factors. Unnecessarily stringent water quality standards could result in substantial economic and social costs. The methodology used in this study allows estimates of consumption to be derived for each respondent. It provides regulators with a full distribution of consumption estimates to be used in the decision-making process. The selection of the most appropriate consumption percentile to be used can then rightfully be made as part of the risk management or policy decision.

References

Boyle, K. J., M. L. Phillips, and S. D. Reiling. 1989. Highlights from the survey of anglers holding a 1987 Maine fishing license. University of Maine, Department of Agricultural and Resource Economics, Staff Paper Series in Resource Economics. ARE 398, Orono.

Boyle, K. J., R. K. Roper, and S. D. Reiling. 1990. Highlights from the 1988 survey of open-water fishing in Maine. University of Maine, Department of Agricultural and Resource Economics. Staff Paper Series in Resource Economics. ARE 416, Orono.

Carlander, K. D. 1969. Handbook of freshwater fishery biology, volume 1. Iowa State University Press, Ames.

Carlander, K. D. 1977. Handbook of freshwater fishery biology, volume 2. Iowa State University Press, Ames.

Chu, A., D. Eisenhower, M. Hay, D. Morganstein, J. Neter, and J. Waksberg. 1992. Measuring the recall error in self-reported fishing and hunting activities. Journal of Official Statistics 5:13–39.

EPA (U.S. Environmental Protection Agency). 1989a. Assessing human health risks from chemically contaminated fish and shellfish: a guidance manual. EPA, Office of Marine and Estuarine Protection, Office of Water Regulations and Standards, EPA-503/8-89-002, Washington, D.C.

EPA (U.S. Environmental Protection Agency). 1989b. Exposure factors handbook. EPA, Office of Health and Environmental Assessment, EPA/600/8-89/043, Washington, D.C.

EPA (U.S. Environmental Protection Agency). 1992. Consumption surveys for fish and shellfish: a review and analysis of survey methods. EPA, Office of Water (WH-585). EPA 822/R-92-001. Washington, D.C.

Fiore, B. J., H. A. Anderson, L. P. Hanrahan, L. J. Olson, and W. C. Sonzogni. 1989. Sport fish consumption and body burden levels of chlorinated hydrocarbons: a study of Wisconsin anglers. Archives of Environmental Health 44:82–88.

Honstead, J. F., T. M. Beetle, and J. K. Soldat. 1971. A statistical study of the habits of local fishermen and its application to evaluation of environmental dose. Battelle Pacific Northwest Laboratories. Report to U.S. Environmental Protection Agency, Washington, D.C.

Javitz, H. 1980. Seafood consumption data analysis. SRI International. Final Report to U.S. Environmental Protection Agency, Office of Water Regulations and Standards, EPA Contract 68-01-3887, Washington, D.C.

Landolt, M. L., F. R. Hafer, A. Nevissi, G. van Belle, K. Van Ness, and C. Rockwell. 1985. Potential toxicant exposure among consumers of recreationally caught fish from urban embayments of Puget Sound. Final Report to NOAA (National Oceanic and Atmospheric Administration), Technical Memorandum OMA 33, Rockville, Maryland.

NYSDEC (New York State, Department of Environmental Conservation). 1990. New York statewide angler survey, 1988. NYSDEC, Albany.

Pao, E. M., K. H. Fleming, P. M. Guenther, and S. J. Mickle. 1982. Foods commonly eaten by individuals: amount per day and per eating occasion. U.S. Department of Agriculture, Home Economics Report 44, Washington, D.C.

Phillips, M. L., K. J. Boyle, and S. D. Relling. 1990. Highlights from the survey of anglers holding a 1988 Maine fishing license. University of Maine, Department of Agricultural and Resource Economics, Orono.

Pierce, R. S., D. T. Noviello, and S. H. Rogers. 1981. Commencement Bay seafood consumption report. Preliminary Report to Tacoma–Pierce County Health Department, Tacoma, Washington.

Puffer, H. W., S. P. Azen, M. J. Duda, and D. R. Young. 1981. Consumption rates of potentially hazardous marine fish caught in the metropolitan Los Angeles area. University of Southern California School of Medicine report to U.S. Environmental Protection Agency, Environmental Research Laboratory, EPA Grant R807 120010, Washington, D.C.

Rifkin, E., and J. LaKind. 1991. Dioxin bioaccumulation: key to a sound risk assessment methodology. Journal of Toxicology and Environmental Health 33:103–112.

Rupp, E. M., F. L. Miller, and I. C. F. Baes. 1980. Some results of recent surveys of fish and shellfish consumption by age and region of U.S. residents. Health Physics 39:165–175.

Sherman, W. R., R. E. Keenan, and D. G. Gunster. 1992. A reevaluation of dioxin bioconcentration and bioaccumulation factors for regulatory purposes. Journal of Toxicology and Environmental Health 37:177–195.

Soldat, J. K. 1970. A statistical study of the habits of fishermen utilizing the Columbia River below Hanford. Pages 302–308 *in* W. C. Reinig, editor. Environmental surveillance in the vicinity of nuclear facilities. C. C. Thomas, Springfield, Illinois.

Stansby, M. E., and H. S. Olcott. 1963. Composition of fish. Pages 343–349 *in* M. E. Stansby, editor.

803770

Industrial fishery technology. Chapman and Hall, London.

Turcotte, M.-D. S. 1983. Georgia fishery study: implications for dose-calculations. DuPont de Nemours and Co. report to U.S. Department of Energy, DE86-008041, Washington, D.C.

West, P., J. M. Fly, R. Marans, and F. Larkin. 1989. Michigan sport anglers fish consumption survey. Report to Michigan Toxic Substance Control Commission, Natural Resource Sociology Research Laboratory, Ann Arbor.

Westat, Inc. 1989. Investigation of possible recall/reference period bias in national surveys of fishing, hunting and wildlife-associated recreation. Report 14-16-009-87-008 to U.S. Fish and Wildlife Service, Arlington, Virginia.

803771

SELECTION OF FISH CONSUMPTION ESTIMATES FOR USE IN THE REGULATORY PROCESS

ELLEN S. EBERT, PAUL S. PRICE, AND RUSSELL E. KEENAN

ChemRisk — A Division of McLaren/Hart
Portland, Maine

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

1. Address all correspondence to: Ellen S. Ebert, ChemRisk — A Division of McLaren/Hart, Stroudwater Crossing, 1685 Congress Street, Portland, ME 04102. Tel: (207) 774-0012. Fax: (207) 774-8263.

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.

Journal of Exposure Analysis and Environmental Epidemiology, Vol. 4, No. 3, pp. 373-393

ISSN: 1053-4245

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;

803774

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

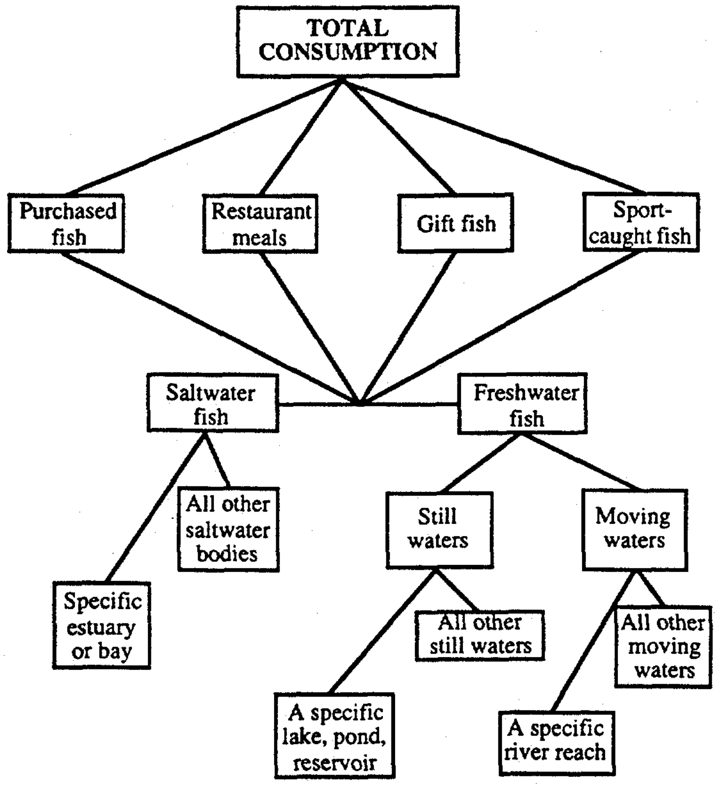

FIGURE 1. Total consumption of fish.

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

---

[2] Unpublished data.

803784

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 area 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

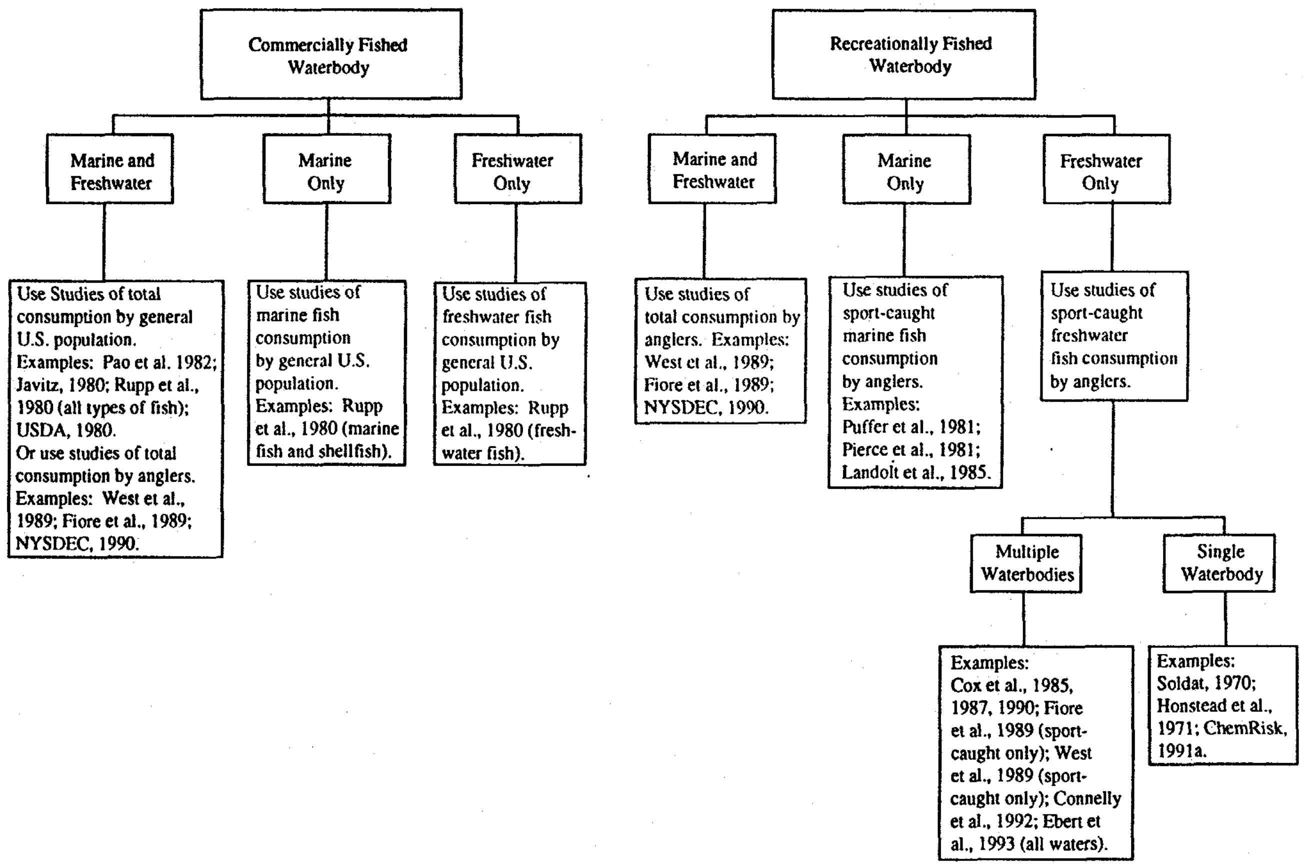

FIGURE 2. Selection of fish consumption rates based on type of waterbody and potentially exposed population.

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.

REFERENCES

CHEMRISK (1991a). Creel Survey for the West Branch of the Penobscot River. ChemRisk® A Division of McLaren/Hart, Portland, ME.

CHEMRISK (1991b). Consumption of Freshwater Fish from Maine Lakes and Ponds. ChemRisk®, A Division of McLaren/Hart. Portland, ME.

CONNELLY, N.A., KNUTH, B.A., and BISOGNI, C.A. (1992). Effects of the health advisory changes on fishing habits and fish consumption in New York sport fisheries. Human Dimension Research Unit, Department of Natural Resources, New York State College of Agriculture and Life Sciences, Fernow Hall, Cornell University, Ithaca, NY. Report for the New York Sea Grant Institute Project NO. R/FHD-2-PD.

COX, C., VAILLANCOURT, A., DE BARROS, C., and JOHNSON, A.F. (1985). "Guide to Eating Ontario Sport Fish" Questionnaire Results. Aquatic Contaminants Section, Water Resources Branch, Ontario, Canada.

COX, C., VAILLANCOURT, A., and JOHNSON, A.F. (1987). A Comparison of the Results from the "Guide to Eating Ontario Sport Fish" Questionnaires. Ontario Ministry of the Environment, Water Resources Branch, Ontario, Canada.

COX, C., VAILLANCOURT, A., and JOHNSON, A.F. (1990). The Results of the 1989 "Guide to Eating Ontario Sport Fish" Questionnaire. ISBN 0-7729-7084-X, Ontario Ministry of the Environment, Water Resources Branch, Ontario, Canada.

EBERT, E. S., HARRINGTON, N.W., BOYLE, K.J., KNIGHT, J.W., and KEENAN, R.E. (1993). "Estimating consumption of freshwater fish among Maine anglers." N. Am. J. Fish. Management 13:737–745.

FIORE, B.J., ANDERSON, H.A., HANRAHAN, L.P., OLSON, L.J., and SONZOGNI, W.C. (1989). "Sport fish consumption and body burden levels of chlorinated hydrocarbons: A study of Wisconsin anglers." Arch. of Environ. Health. 44:82–88.

HONSTEAD, J.F., BEETLE, T.M., and SOLDAT, J.K. (1971). A Statistical Study of the Habits of Local Fishermen and its Application to Evaluation of Environmental Dose. A Report to the U.S. Environmental Protection Agency by Battelle Pacific Northwest Laboratories, Richland, WA.

HUMPHREY, H.E.B. (1987). "The human population—An ultimate receptor for aquatic contaminants." Hydrobiologia 149:75–80.

JAVITZ, H. (1980). Seafood Consumption Data Analysis. EPA Contract 68-01-3887. Prepared by SRI International for the Office of Water Regulations and Standards, Washington, D.C.

KEENAN, R.E., FINLEY, B.L., and PRICE, P.S. (1994). "Exposure assessment: Then, now, and quantum leaps in the future." Risk Anal. 14:225-230.

LANDOLT, M.L., HAFER, F.R., NEVISSI, A., VAN BELLE, G., VAN NESS, K., and ROCKWELL, C. (1985). Final Report: Potential Toxicant Exposure among Consumers of Recreationally Caught Fish from Urban Embayments of Puget Sound. NOAA Technical Memorandum No. OMA 33. National Oceanic and Atmospheric Administration, Rockville, MD.

LANDOLT, M., KALMAN, D., NEVISSI, A., VAN BELLE, G., VAN NESS, K., and HAFER, F. (1987). Final Report: Potential Toxicant Exposure among Consumers of Recreationally Caught Fish from Urban Embayments of Puget Sound. NOAA Technical Memorandum NOS OMA 33. National Oceanic and Atmospheric Administration, Rockville, MD.

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION (NYSDEC). (1990). New York Statewide Angler Survey 1988. New York State Department of Environmental Conservation, Division of Fish and Wildlife, Albany, NY.

PAO, E.M., FLEMING, K.H., GUENTHER, P.M., and MICKLE, S.J. (1982). Foods Commonly Eaten by Individuals: Amount Per Day and Per Eating Occasion. Home Economics Report 44. U.S. Department of Agriculture, Washington, D.C.

PIERCE, D., NOVIELLO, D., and ROGERS, S. (1981). Commencement Bay Seafood Consumption Study. Tacoma-Pierce County Health Department, Seattle, WA.

PRICE, P.S., SU, S., and GRAY, M. 1994. "The effect of sampling bias on estimates of angler consumption rates." J. Expos. Anal. Environ. Epidem. 4:355–372

PUFFER, H.W., AZEN, S.P., DUDA, M.J., and YOUNG, D.R. (1981). Consumption Rates of Potentially Hazardous Marine Fish Caught in the Metropolitan Los Angeles Area. Grant No. R 807 120010. University of Southern California School of Medicine for Environmental Research Laboratory.

RICHARDSON, G.M. and CURRIE, D.J. (1993). "Estimating fish consumption rates for Ontario Amerindians." J. Exp. Anal. Environ. Epidem. 3:23–37.

RIFKIN, E. and LAKIND, J. (1991). "Dioxin bioaccumulation: Key to a sound risk assessment methodology." J. Toxicol. Environ. Health. 33:103–112.

RUPP, E.M., MILLER, F.L., and BAES, I.C.F. (1980). "Some results of recent surveys of fish and shellfish consumption by age and region of U.S. residents." Health Physics 39:165–175.

SOLDAT, J.K. (1970). "A statistical study of the habits of fishermen utilizing the Columbia River below Hanford." In: Environmental Surveillance in the Vicinity of Nuclear Facilities. (Reinig, W.C., ed.). Charles C. Thomas, Springfield, IL.

TURCOTTE, M-D.S. (1983). Georgia Fishery Study: Implications for Dose-Calculations. DuPont de Nemours & Co., Arkeu, South Carolina. DE86-008041. United States Department of Energy, Washington, DC.

U. S. DEPARTMENT OF AGRICULTURE (USDA). (1980). Food and Nutrient Intakes of Individuals in One Day in the United States: Spring 1977. Nationwide Food Consumption Survey 1977–1978. Preliminary Report No. 2. (cited in EPA 1989a.)

U.S. ENVIRONMENTAL PROTECTION AGENCY (U.S. EPA). (1989a). Exposure Factors Handbook. EPA/600/8-89/043. Office of Health and Environmental Assessment, Washington, D.C.

U.S. ENVIRONMENTAL PROTECTION AGENCY (U.S. EPA). (1989b). Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish: A Guidance Manual. EPA-503/8-89-002. Office of Marine and Estuarine Protection, Office of Water Regulations and Standards, Washington, D.C.

U.S. ENVIRONMENTAL PROTECTION AGENCY (U.S. EPA). (1991). Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance "Standard Default Exposure Factors". EPA 540/1-89/002. Office of Emergency and Remedial Response, Toxics Integration Branch, Washington, DC.

U.S. ENVIRONMENTAL PROTECTION AGENCY (U.S. EPA). (1992a). "Guidelines for exposure assessment." United States Environmental Protection Agency, Washington, DC. 57 Fed. Register 104:2288–22938.

U.S. ENVIRONMENTAL PROTECTION AGENCY (U.S. EPA). (1992b). "Estimating exposure to dioxin-like compounds." EPA/600/6-88/005B. Office of Research and Development, Washington, DC.

WEST, P.C., FLY, J.M., MARANS, R., and LARKIN, F. (1989). Michigan Sport Anglers Fish Consumption Survey. University of Michigan, Ann Arbor, MI.

WESTAT, INC. (1989). Investigation of Possible Recall/Reference Period Bias in National Surveys of Fishing, Hunting and Wildlife-Associated Recreation. Report #14-16-009-87-008. U.S. Fish and Wildlife Service, Arlington, VA.

THE EFFECT OF SAMPLING BIAS ON ESTIMATES OF ANGLER CONSUMPTION RATES IN CREEL SURVEYS

PAUL S. PRICE, STEAVE H. SU, AND MICHAEL N. GRAY

ChemRisk — A Division of McLaren/Hart
Portland, Maine

EPA guidance recommends that 30 grams per day be used to represent the consumption rate of fish caught from large bodies of water by a typical angler (EPA, 1989a). This estimate is based on the combined results of the Pierce et al. (1981) and Puffer et al. (1981) surveys of marine and estuarine anglers. An examination of these surveys demonstrates that the method used in both studies - - creel survey — oversamples frequent anglers and produces a distribution of consumption rates that overestimates intake rates of the total angler population using the surveyed waterbodies. Weighting the individual survey responses by the inverse of the angler self-reported fishing frequency corrects this bias and produces a more accurate characterization of the total population of anglers using the surveyed waterbodies. This approach is an extension of the methodology used by both Puffer et al. (1981) and Pierce et al. (1981) to estimate the size of the total angler populations. The results of the reanalysis of the Pierce et al. (1981) survey indicate that the median consumption rate for the total angler population is 1.0 g/d. The results of the Puffer et al. (1981) reanalysis indicate a median consumption rate for total angler population of 2.9 g/d. The recalculated distributions of consumption rates were found to be consistent with the results of other angler surveys that use survey methods that do not oversample frequent anglers. The angler intake rate of 30 g/d corresponds to roughly the 90th and 95th percentiles of the total angler populations in the Pierce et al. (1981) and Puffer et al. (1981) surveys, respectively. The results of this paper indicate that the current estimate of 30 g/d significantly overestimates consumption for typical marine and estuarine anglers.

1. Address all correspondence to: Paul S. Price, ChemRisk — A Division of McLaren/Hart, Stroudwater Crossing, 1685 Congress Street, Portland, ME 04102. Tel: (207) 774-0012. Fax: (207) 774-8263.

2. Abbreviations: EPA, United States Environmental Protection Agency; g, grams; g/d, grams per day; NYSDEC, New York State Department of Environmental Conservation; y, year; trips, one day fishing trips

Journal of Exposure Analysis and Environmental Epidemiology, Vol. 4, No. 3, pp. 355-372

ISSN: 1053-4245

803793

INTRODUCTION

The rate of consumption of self-caught fish is a critical parameter for many environmental risk assessments. Because persistent lipophilic compounds that are released to surface waterbodies may bioaccumulate in fish, often the most important route of human exposure to these chemicals is through fish consumption (Humphrey, 1983; EPA, 1984; Rifkin et al., 1991; Sherman et al., 1992). Because many surface waterbodies, and in particular most freshwaters, are not commercially fished, consumption of fish is limited to recreational anglers. While such individuals may only represent a fraction of the total population living near an affected body of water, they may represent the majority of risks posed by surface water contamination. Therefore, it is critical to accurately characterize the rate of fish consumption for recreational anglers. Currently, EPA guidance recommends that a rate of 30 grams per day be used to represent the ingestion rate of fish caught from large bodies of water by a typical angler (EPA, 1989a,b). This estimate is based on the combined results of the Pierce et al. (1981) and Puffer et al. (1981,1982) creel surveys (hereafter referred to as the Pierce and Puffer surveys) of marine and estuarine anglers.

Creel surveys are typically used by fisheries managers to evaluate angler participation, effort, and catch/harvest rates from an individual waterbody. Such surveys generally count and interview anglers observed fishing a specified body of water at a specified time. During these surveys, data are collected specific to the individual angler's fishing experience, such as the length of the trip, and the number, size, and species of fish targeted, caught, and harvested by the angler on the day of the interview (EPA, 1991). More recently, creel surveys have been expanded to collect details on the anticipated disposition and/or consumption of the harvested fish (ChemRisk, 1991; Ebert et al., 1993).

A key characteristic of creel surveys is that the probability of an angler being interviewed during the survey is a function of his or her frequency of fishing (Puffer et al., 1981). Anglers who fish frequently have a higher probability of being interviewed than anglers who fish infrequently. As a result, creel surveys tend to oversample the frequent anglers. In addition, the distribution of consumption rates in the anglers interviewed during a creel survey are likely to overestimate the distribution of consumption rates in the entire population of anglers that fish the surveyed waterbody.

In this paper, we investigate the effect of this bias on the estimates of fish consumption that are derived from the Puffer and Pierce surveys. First, we used the inverse of each angler's self-reported annual frequency of fishing to reweight the estimated fish intake rate of each of the surveyed anglers (hereafter referred to as the survey population). This was done to calculate the distribution of consumption rates in the entire angler population that fishes the surveyed body of water (hereafter referred to as the total angler population). This approach is an extension of the methodology used by both Puffer et al. (1981) and Pierce et al. (1981) to estimate the size of the total populations of anglers using the waterbodies they surveyed.

Background

Pierce et al. (1981) surveyed anglers during the months of July through September (summer season) and September through November (fall season) of 1980. More than 500 interviews with individual anglers and fishing parties were conducted at five locations on Commencement Bay in Puget Sound, Washington. For each angler interviewed, the survey collected information on the number of fish caught on the day of the interview, the average weight of each fish caught, the number of people in the angler's family/living group, and the angler's annual fishing frequency. Pierce et al. (1981) presented summary statistics on the number and total weight of each fish species caught, number of anglers, family/living group size, and angling frequency.

Puffer et al. (1981) investigated rates of fish consumption by Los Angeles Harbor anglers. The survey included interviews of more than 1,000 anglers as they fished at 12 locations along the harbor during the summer and fall of 1980. The survey clerks collected information on the number of fish the anglers caught on the day of the interview, the average weight of the fish harvested, the number of fish eaters in the angler's family/living group, and the angler's annual fishing frequency.

Neither the Puffer nor Pierce creel surveys asked the individuals for direct estimates of the amount of fish they consumed. Rather, the surveys collected data on the size of catch, the angler's frequency of fishing, and number of individuals sharing in the catch. These data, along with information on the number and size of fish caught, were used to estimate a typical fish consumption rate for the angler. Puffer et al. (1981) estimated consumption rates of the individual anglers interviewed using the following equation:

$$C = (K * N * W * F / 365) / E \qquad (1)$$

Where C is the estimated daily fish consumption rate (g/person-day); K is the average edible fraction of the fish caught by a surveyed angler; N is the number of fish caught on the day of the survey; W is the average weight of the fish caught on the day of the survey (grams); F is frequency of fishing during the year; and E is the number of fish eaters in the anglers family or living group. Table 1 presents the distribution of fish consumption rates in the Puffer survey population published in Puffer et al. (1981).

Pierce et al. (1981) did not attempt to develop estimates of the consumption rates for the individual anglers. However, in the 1989 *Exposure Factors Handbook* (EPA 1989b), EPA developed an estimate of the distribution of fish consumption rates based on the information provided in the final report. Because Pierce and co-workers did not include the raw data for each of the anglers surveyed and only reported the distribution of angler responses to survey questions, the Agency could not calculate the individual angler's consumption rate using the approach developed by Puffer (Eq. 1). EPA was forced to estimate the distribution of consumption rates based on an alternative approach that used the estimate of the average

803795

TABLE 1. Distribution of Fish Consumption Rates as Reported by Puffer et al. (1981)

Percentile	Consumption Rate (g/d)
5	2.3
10	4
20	8.3
30	15.5
40	23.9
50	36.9
60	53.2
70	79.8
80	120.8
90	224.8
95	338.8

amount of fish consumed by the surveyed anglers per fishing trip and the distribution of fishing frequencies given in the final study report. EPA estimated that the fish consumed by an average angler in the survey population was approximately 380 g/person per angling trip. The estimated distribution of annual consumption rates in the survey population was calculated using the equation:

$$C_F = 380 * F / 365 \qquad (2)$$

Where, C_F is the daily fish consumption rate (g/d) of all anglers with a fishing frequency of F (trip/y). The distribution of fish consumption rates calculated by EPA (1989b) using this method is given in Table 2.

TABLE 2. Distribution of Fish Consumption Rates for the Pierce Survey as Estimated in the EPA Exposure Factors Handbook (1989b)

Percentile[a]	Consumption Rate (g/d)
0-<11	1.04
11-<16	2.09
16- <22	6.27
22-<40	12.53
40-<91	54.31
91-100	381.19

[a] Approximate

To derive its recommended rates for anglers, EPA (1989b) used the distributions from the two surveys to derive fish consumption rates for a typical and a worst-case angler (Table 3). The recommended rate of 30 g/d for the typical anglers was based on the arithmetic average of the median consumption rates from the two surveys. 140 g/d was recommended as the "worst-case" consumption rate based on the arithmetic average of the 90th percentiles of the distributions of consumption rates in the two surveys.

TABLE 3. Rate Percentiles from Puffer and Pierce Surveys Used by EPA (1989b) to Derive Recommended Rates (g/d)

Survey	50th Percentile	90th Percentile
Puffer	37	225
Pierce	23[a]	54[a]
Average	30	140

[a] Estimated by EPA by interpolation

METHODS

Methodology

To calculate the distribution of consumption rates for the total angler populations represented by the two surveys, the estimated consumption rate of each individual angler surveyed was weighted by the inverse of the angler's self-reported fishing frequency. This approach is an extension of the methodology used by both Puffer et al. (1981) and Pierce et al. (1981) to estimate the relative sizes of the survey and total angler populations.

Both Puffer and Pierce recognized that their sample populations were only a fraction of the actual number of anglers using the surveyed waterbodies (total angler population). Both authors used the self-reported frequency of fishing to estimate the total angler population. The equation used was:

$$TAP = \sum_{i=1}^{k} N_F * 365 / F \quad (3)$$

Where, TAP is the total angler population; and N_F is the number of anglers who reported a fishing frequency of F (trips/y), and k is the number of fishing frequencies reported. Under this approach, each of the anglers surveyed is assumed to be a member of a population of anglers who fish the surveyed body of water at the same frequency as the surveyed individual but most of whom are not fishing on the day the creel survey was performed. The size of this population will on average be equal to 365/F. The sum of these populations is taken as an estimate of the number of anglers in the total angler population for the surveyed waterbody. Table 4 presents the sizes of the survey and total angler populations for the Puffer and Pierce studies as reported by their respective authors.

TABLE 4. Population Size for the Sampled and Total Angler Population in the Puffer and Pierce Surveys

Survey	Sample Population	Total Angler Population
Puffer	1,059	91,606
Pierce	508	3,391

In this analysis, the distribution of consumption rates in the total angler population is calculated in a similar manner. Each of the surveyed anglers is assumed to represent 365/F anglers with similar consumption rates who fish the surveyed body of water. The equation used is:

$$TN_A = N_{AF} * 365 / F \qquad (4)$$

where, TN_A is the total number of anglers with a consumption rate of A; and N_{AF} is the number of anglers with a consumption rate of A and a fishing frequency of F. The distribution of consumption rates in the combined populations, obtained by applying Equation 4 to all surveyed anglers, is taken as the distribution of consumption rates for the total angler population.

By a similar argument, the distribution of fishing frequencies in the total angler population can be estimated using the equation:

$$TN_F = N_F * 365 / F \qquad (5)$$

where, TN_F is the total number of anglers with a fishing frequency of F; and N_F is the number of surveyed anglers with a fishing frequency of F. The distribution of fishing frequency in the total angler population is thus the distribution of fishing frequency in the combined population obtained by applying Equation 5 to all frequency categories in the survey.

To calculate the distributions of consumption rate and fishing frequency in the total angler population, it is necessary to know the values of N_{AF} and N_F for each of the two surveys. The values of N_{AF} can be developed from the data on individual anglers. The values of N_F used in this paper are taken from the original papers (Puffer et al., 1981; Pierce et al., 1981) wherever possible.

Analysis of the Two Creel Surveys

In order to obtain information on N_{AF} values for the two surveys, we contacted the original authors of the two studies and requested copies of the raw data. The raw data for the Pierce et al. survey were available from the Tacoma-Pierce County Health Department, Tacoma, Washington, in the form of paper copies of the original, completed survey forms.

Copies of a total of 687 interviews were received from the Tacoma-Pierce County Health Department. This number exceeds the number of anglers (508) reported to have been surveyed by Pierce et al. (1981). Many of the survey forms obtained were not usable due to missing data and other problems. This suggests that Pierce et al. (1981) performed some screening of the completed forms before they performed their analyses. Unfortunately, there was no indication of which survey forms had been included by Pierce et al. in their analysis and no information on the criteria used by Pierce et al. to select forms for inclusion in the analysis. Attempts to contact the original authors were unsuccessful. Therefore, we developed and used the following criteria for including survey responses in this analysis:

- All forms that contained incomplete data (with the exception of the fish weight and length data discussed below) were excluded;
- all forms that reported the catch for groups (rather than individual anglers) were excluded;
- all anglers that reported practicing catch and release (fish were not consumed) were excluded; and
- anglers who only consumed shellfish were excluded.

Using these criteria, we identified a total of 451 anglers appropriate for our analysis.

Data on fish consumption rates and other relevant parameters were extracted from the Pierce survey forms and entered into a database. Data taken from the survey forms included: interview number; number of individuals in the angler's living group; use of fish caught; frequency of fishing; fish species caught; number of fish caught; and species-specific average fish weights. Because the present analysis focuses on consumption of fish only, the consumption of crustaceans (crabs) was not considered in this analysis.

Approximately 3.5% of the survey forms included one or more fish without weight data. In addition, a few fish with missing weight data were also missing length data. We developed estimates of mass for these fish based on simple regression models of the relationship between species-specific fish mass measurements and lengths. These regression models were fitted to the fish in the survey that did report lengths or weights. In the few instances where the lengths of fish were also missing, the lengths reported for the same species in the same creel were used in the length-mass regression estimates.

Based upon the data extracted from the survey forms, we estimated a consumption rate for each angler using Equation 1. In developing these estimates, we used the same assumption of edible fraction of fish as reported by Pierce et al. (1981). These consumption rates and the reported fishing frequencies were used to determine the N_{AF} and N_F. The values of N_{AF} and N_F were in turn used to estimate the distribution of consumption rates and fishing frequencies in the total angler population, using Equations 4 and 5.

Unlike the Pierce survey, the raw data for the Puffer study have not been preserved (personal communication with Dr. Harold Puffer). No electronic or paper copies of extracted "raw" data from the survey forms were preserved, and only 350 of the "completed survey" forms (of the more than 1,000 original forms) are still available. Upon a review of the available forms, we determined that a meaningful analysis of the Puffer et al. raw data was not possible, given that less than one-third of the forms were preserved and the remaining forms could not be assumed to be a random sample of the original survey forms. Therefore, the only data available on the study are contained in the summary of the survey results in Puffer et al. (1981). This report on the Puffer survey does contain the distribution of angler frequencies from the N_F. Based on these data, we estimated the distribution of angling frequencies in the total angler population using Equation 5.

As demonstrated by EPA's *Exposure Factors Handbook* (EPA, 1989b), it is possible to obtain an estimate of the distribution of fish consumption rates in a population based on the average amount of fish consumed per fishing trip and the distribution of fishing frequencies (see Equation 2). We calculated the average amount of fish consumed per angler trip in the Puffer survey based on the mean consumption rate and fishing frequency of the anglers in the Puffer survey. The means of these parameters were estimated based on the reported distribution of consumption rates and frequencies (Puffer et al., 1981). The mean consumption rate was estimated to be 91 g/d. The average frequency was 63 trips per year. The average consumption rate per trip is therefore 522 g/person-trip. Using this estimate and the distribution of fishing frequencies in the total angler population, we developed a distribution of consumption rates for the Puffer survey.

Because different approaches were used to estimate the distributions of total angler population fish consumption rates for the Puffer and Pierce surveys, it is important to determine if the two different methods produce different estimates of the fish consumption rates. This was determined by applying both approaches to the Pierce survey results. The two resultant distributions of total angler population fish consumption rates were then evaluated for consistency.

RESULTS

Pierce et al.

The results of our reanalysis of the Pierce survey data are presented in Table 5 along with the results of Pierce's original analysis as reported in Pierce et al. (1981). In general, our estimate of the size of the survey population was smaller, and the surveyed anglers were estimated to consume more fish than the Pierce estimates. Another distinction between our reanalysis and the original analysis is that our study used all 15 angling frequency responses in the completed Pierce survey forms, while Pierce grouped the anglers into six frequency categories (see Table 5).

TABLE 5. Comparison of Survey Populations as Estimated from the Reanalysis of the Pierce Survey with the Results for the Survey Population Reported in Pierce et al. (1981)

Parameters	Pierce et al. (1981)	Reanalysis (Consuming Anglers)
Number of Anglers		
Summer	304	225
Fall	204	226
Total	508	451
Total Mass of Fish Caught	2,700 kg	3,300 kg
Average Family Size	3.74	3.65
Number of Trips/Year	Percent of Anglers	
1	10.85	9.76
2	5.40	5.99
3		0.22
4		0.22
6	5.25	3.77
8		0.22
12	18.45	19.07
24		1.11
36		0.44
52	51.30	44.79
93		0.22
104		3.99
156		3.33
208		1.33
365	9.40	5.45

The cumulative distributions of the angling frequencies and daily fish consumption rates for the survey population and total angler population in our reanalysis of the Pierce survey data are presented in Figures 1 and 2. Because the exposure frequencies for individual anglers were evaluated using rough categories of frequency, the distributions can only be specified for a limited number of points on the distribution. The distributions of angling frequencies (Figure 1) show a disproportionate number of anglers at the higher frequencies, e.g., more than 50% of respondents fish more than once a week in the survey population, while less than 6% of the total angler population fish this often. The distribution of angler consumption rates in the survey and total angler population show a similar shift. In the survey population, the median consumption rate is 19 g/d. In the total angler population, less than 6% of the population has a consumption rate of 19 g/d or more.

803801

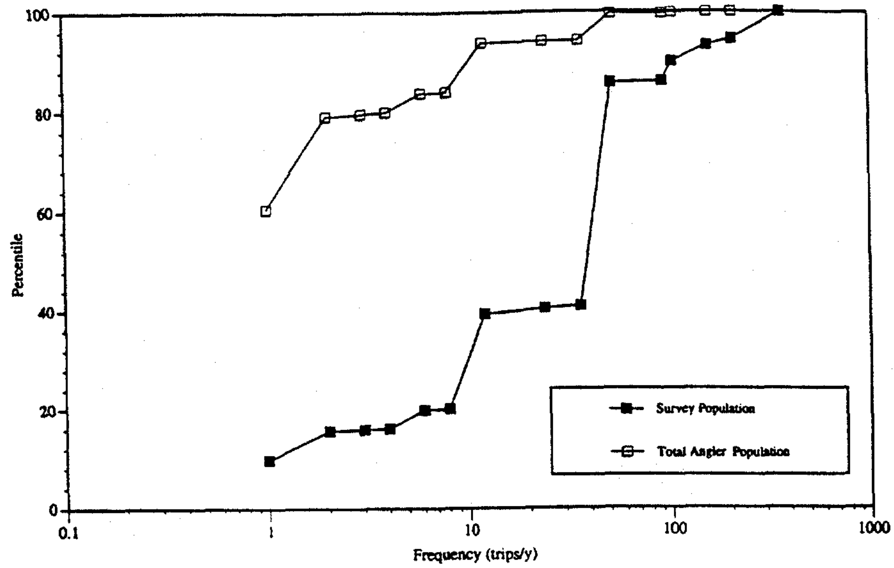

FIGURE 1. Comparison of the estimated cumulative distribution of angling frequencies for the survey population with the total angler population from the reanalysis of the Pierce survey.

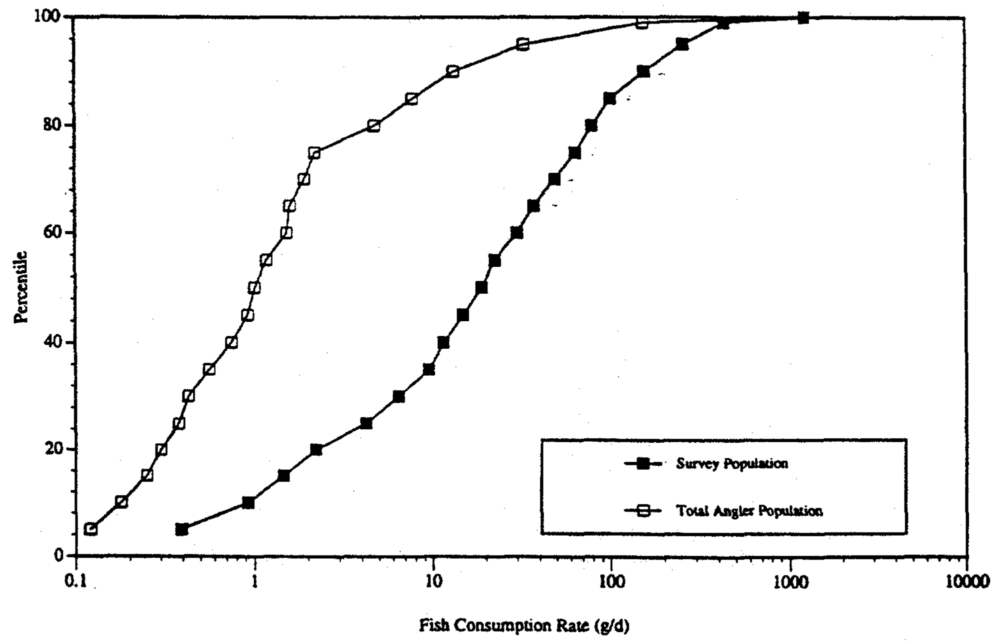

FIGURE 2. Comparison of the estimated cumulative distribution of fish consumption rates for the survey population with the total angler population from the reanalysis of the Pierce survey.

Puffer et al.
The cumulative distribution of angling frequencies for the survey and total angler populations in the Puffer et al. (1981) survey are presented in Figure 3. The distribution of angling frequencies in the survey population show a disproportionate number of anglers at the higher frequencies with approximately 50% fishing more than once a week. However, in the total angler population, less than 1% of the population fishes with this or greater frequency.

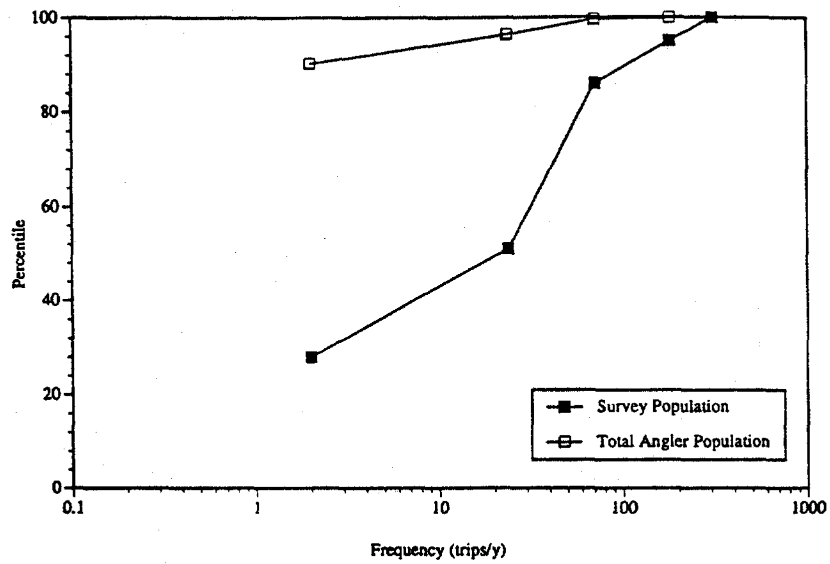

FIGURE 3. Comparison of estimated cumulative distributions of angling frequency in the survey population with the total angler population from the reanalysis of the Puffer survey.

The cumulative distribution of angler consumption rates for the total angler and survey populations derived from the Puffer et al. (1981) data is given in Figure 4. The distribution of survey population rates are taken directly from Puffer et al. (1981). The distribution of consumption rates in the total angler population is derived from the distribution of fishing frequencies for the total angler population. Because the fish consumption rate estimates in the total angler population of the Puffer survey (Figure 4) are based on angling frequency data, the consumption rate curve does not appear to be as smooth as the curve for the Pierce data (Figure 2).

The differences in the consumption rate distributions for the two populations show the same pattern as the Pierce survey results. The median consumption rate in the survey population is 36.9 g/d. In the total angler population, less than 5% of the population has a consumption rate that is greater than or equal to this value.

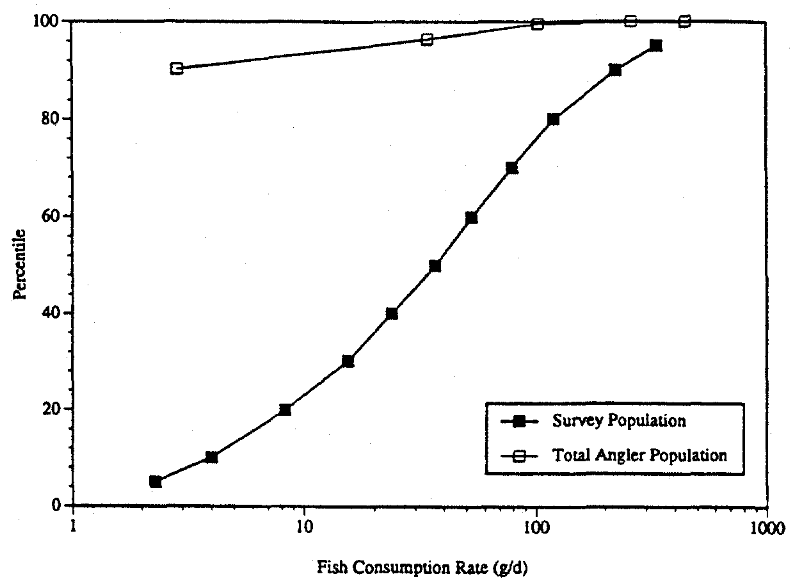

FIGURE 4. Cumulative distributions of fish consumption rates for the survey population with the total angler population from the reanalysis of the Puffer survey.

Table 6 presents the estimated consumption rates for the median and 90th percentiles for the survey and total angler populations derived from the reanalyses of the Pierce and Puffer survey data. In the Puffer survey, the values for the median are taken from the lowest frequency group

TABLE 6. Selected Percentile Consumption Estimates (g/d) for the Survey and Total Angler Populations Based on the Reanalysis of the Puffer and Pierce Data

	50th Percentile	90th Percentile
Survey Population		
Puffer	37	225
Pierce	19	155
Average	29	190
Total Angler Population		
Puffer	2.9[a]	35[b]
Pierce	1.0	13
Average	2.0	24

[a] Estimated based on the average intake for the 0-90th percentile anglers.
[b] Estimated based on the average intake for the 91st-96th percentile anglers.

803804

(less than once a month) that comprises 90% of the total angler population. The 90th percentile is conservatively estimated based on the estimated consumption rate for the next lowest frequency (1-3 times per month) that represents the 91st to the 96th percentiles of the total angler population. In both surveys, the medians and the 90th percentiles of the total angler population are one to two orders of magnitude lower than the equivalent values for the survey populations.

Figure 5 presents two estimates of the distribution of consumption rates for the total angler population in the Pierce et al. (1981) survey. As the figure indicates, the cumulative distribution produced by using the average fish consumption per fishing trip approach overestimates consumption rates for anglers with the lowest consumption rates. However, the two approaches produce similar estimates for the upper portion of the consumption distribution.

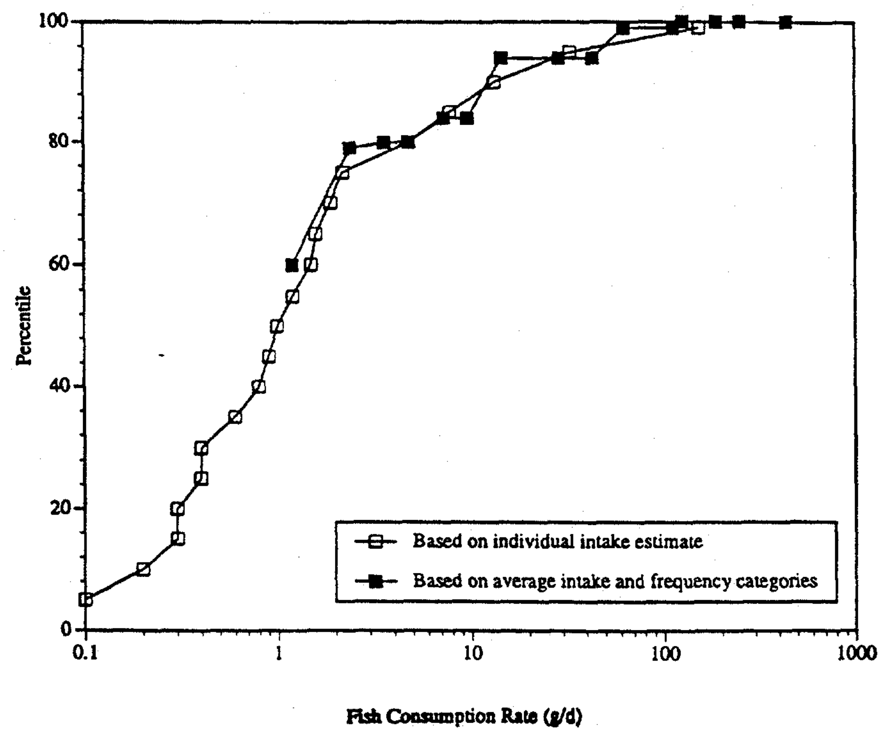

FIGURE 5. A comparison of individual and frequency category-based estimates of the cumulative distribution of fish consumption rates in the total angler population from the Pierce survey.

DISCUSSION

The primary finding of the analysis presented in this paper is that the distribution of consumption rates derived for a survey population differ substantially from the distribution of consumption rates derived for the total population of anglers using a given waterbody. Total angler populations have much lower fishing and consumption rates than survey populations. This difference occurs because creel surveys oversample more frequent anglers and the intakes of the surveyed anglers provide a biased estimate of the total angler population's intake.

This finding of sharply lower intakes is not due to our reanalysis of the Pierce survey results. Our reanalysis of the Pierce survey data resulted in slightly higher estimates of intake for the survey population than EPA's analysis (EPA, 1989b) (see Tables 3 and 6), due to higher estimates of total catch and lower estimates of the number of anglers. It is not clear why we derived higher estimates of fish caught. The smaller number of anglers included in our analysis is probably due to the elimination of anglers practiced catch and release or who only consumed shellfish.

This paper used two different methods of estimating the distribution of consumption rates for the total angler population. The first approach (Equation 4) includes information on the inter-individual variation in the number of fish caught, the size of the fish, and the number of individuals sharing the fish. This approach was used to reevaluate the Pierce survey results. The second approach (Equation 5) is frequency-based and does not consider these sources of variation. It uses an estimate of the average fish consumption rate per angler trip. This second approach was used to analyze the Puffer survey. The second approach would be expected to underestimate the variation in the distribution of consumption rates because it would not include the variations in size of catch and the number of individuals sharing the catch.

In order to investigate the impact of using the two different approaches, we applied both approaches to the Pierce survey results. Figure 5 presents the resulting distributions of angler consumption rates in the total angler population from the two approaches. As the Figure indicates, the second approach's inability to fully characterize the extremes in consumption rates is clearly apparent in the lower end of the consumption rate distribution. However, the difference between the two estimates appears to be minimal for the upper end of the distribution. This suggests that the use of the second approach, while theoretically less desirable, provides a reasonable estimate of consumption rates for the "typical" and "high end" anglers.

The information on N_F for the two surveys is somewhat limited by the relatively coarse measurement of self-reported fishing frequency. As Table 7 indicates, both surveys asked for the frequency of fishing in terms of once a day, once a week, once a month, etc. As a result, the estimates of consumption rate and frequency developed using Equations 4 and 5 do not appear as smooth distributions. In addition, it is difficult to estimate the average frequency of angling for some categories. For example, there is considerable uncertainty in the actual frequency for individuals in the Puffer survey who reported that they fish less than once a month. In this analysis, we used the average frequency proposed for each of the frequency categories by the original authors wherever possible (see Table 5). This problem is exacerbated in the estimates of frequency for the total angler population. In both the Puffer and Pierce surveys, more than 66% of the total angler populations fall into the lowest frequency category and only a single estimate of fishing frequencies can be made for these large portions of the populations. This absence of data on the infrequent angler is directly related to the bias in the creel survey methodology toward the frequent angler.

TABLE 7. Estimates of Average Angling Frequencies (trips/y) for Angling Frequency Categories Reported in Puffer et al. (1981) and Pierce et al. (1981)

Category	Average Angling Frequency
Puffer	
Infrequnct (<1/mo)	2
1-3 times/month	24
1-2 times/week	72
3-4 times/week	182
5-7 times/week	312
Pierce	
Yearly	1
2 times/year	2
3 times/year[a]	3[b]
Every 3 months[a]	4[b]
Bimonthly	6
8 times/year[a]	8[b]
Monthly	12
2 times/month[a]	24[b]
3 times/month[a]	36[b]
Weekly	52
Daily during summer[a]	93[b]
2 times.week[a]	104[b]
3 times/week[a]	156[b]
4 times/week	208[b]
Daily	365

[a] Not included in the original Pierce et al. (1981) report but reported by respondents on original survey intake forms.
[b] Estimated by the current authors.

There are two major implications for the findings in this paper. First, current EPA policy on exposure assessment calls for the evaluation of the dose rates received by a population in terms of the "typical" and "high end" exposure rates (EPA, 1991). These rates are to be established for the total angler population exposed to the contaminant. Use of point estimates of consumption by "typical" and "high end" anglers in a survey population to characterize the consumption rates in the total angler population will result in a significant overestimation of consumption rates. A comparison of Table 3 and Table 6 indicates that the estimates of the typical angler derived by EPA (1989b) may be high by one to two orders of magnitude. In fact, the estimate of typical angler consumption, 30 g/d, roughly corresponds to the 95th and 90th percentiles of the total angler populations in the Pierce and Puffer surveys, respectively.

Second, the resulting distribution of consumption rates for the total angler population is expected to more closely agree with the results of other angler survey methods that randomly select individuals from a defined population of anglers (e.g., all individuals with fishing licenses). Examples of such surveys include Ebert et al. (1993), West et al. (1989), and Connelly et al. (1992). These surveys do not have the bias toward oversampling frequent anglers that occurs with creel surveys. As a result, the distribution of consumption rates from these types of surveys are expected to be comparable to the distribution for the total angler population and not the survey population of a creel survey. Figure 6 presents a comparison of the distribution of consumption rates from Ebert et al. (1993) with the estimated distributions for the survey and total angler populations of the Pierce survey. As the figure demonstrates, the consumption rate distribution for the total angler population agrees much more closely with the Ebert et al. (1993) distribution than does the distribution for the survey population. The Connelly et al. (1992) and West et al. (1989) surveys reported intake data that are similar to Ebert et al. (1993). The consistency between the Pierce total angler results and the results of the Ebert et al. (1993), Connelly et al. (1992), and West et al. (1989) is in spite of significant differences, in the types of water surveyed (salt water versus freshwater) and the region of the country (west coast versus upper midwest and the northeast), which would lead one to predict significant differences in consumption behavior. It appears, however, that performing the evaluation on the same total angling population basis eliminates much of the reported variation in the results of angler surveys.

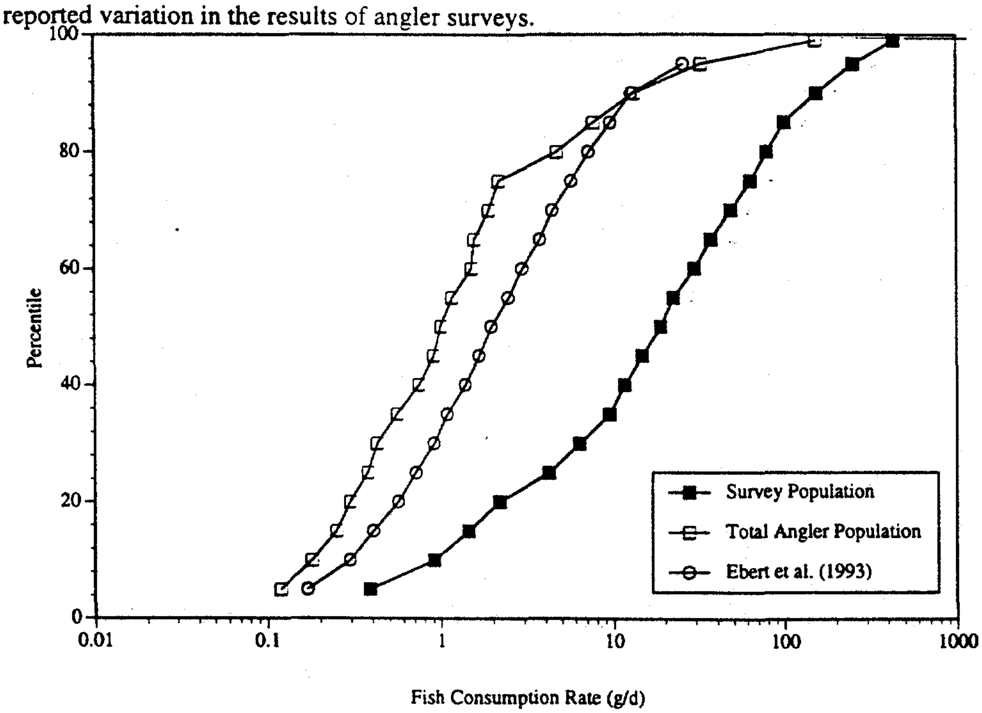

FIGURE 6. Comparison of the estimated cumulative distributions of fish consumption rates for the survey and total angler populations from the reanalysis of Pierce survey (1981) and the results of Ebert et al. (1993).

In summary, evaluation of creel surveys must take into consideration the inherent bias towards oversampling the frequent angler. Estimates of fish consumption rates derived from data collected from creel surveys should be adjusted before they are used to estimate fish consumption rates for total populations of anglers using a given fishery. The results of creel surveys must also be adjusted before they can be directly compared to the results of other types of angler surveys.

ACKNOWLEDGEMENTS

To Todd Abel for his diligence in obtaining the raw data and to Russell Keenan and Ellen Ebert for their thoughtful reviews. This work was supported by General Electric Corporation.

REFERENCES

CHEMRISK (1991). Creel Survey for the West Branch of the Penobscot River. ChemRisk® A Division of McLaren/Hart, Portland, ME.

CONNELLY, N.A., KNUTH, B.A., and BISOGNI, C.A. (1992). Effects of the Health Advisory Changes on Fishing Habits and Fish Consumption in New York Sport Fisheries. Human Dimension Research Unit, Department of Natural Resources, New York State College of Agriculture and Life Sciences, Fernow Hall, Cornell University, Ithaca, NY. Report for the New York Sea Grant Institute Project NO. R/FHD-2-PD. September.

EBERT, E. S., HARRINGTON, N.W., BOYLE, K.J., KNIGHT, J.W., and KEENAN, R.E. (1993). "Estimating consumption of freshwater fish among Maine anglers." N. Am. J. Fish. Management 13:737-745.

HUMPHREY, H.E.B. (1983). "Chapter 21: Population studies of PCBs in Michigan residents." In: PCBs: Human and Environmental Hazards. (D'Itri, F.M. and M.A. Kamrin, eds.). Butterworth Publishers, Boston, MA.

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION (NYSDEC) (1990). New York Statewide Angler Survey 1988. New York State Department of Environmental Conservation, Division of Fish and Wildlife, Albany, NY.

PIERCE, D., NOVIELLO, D., and ROGERS, S. (1981). Commencement Bay Seafood Consumption Study. Tacoma-Pierce County Health Department, Seattle, WA. December.

PUFFER, H.W., AZEN, S.P., DUDA, M.J., and YOUNG, D.R. (1981). Consumption Rates of Potentially Hazardous Marine Fish Caught in the Metropolitan Los Angeles Area. Grant No. R 807 120010. University of Southern California School of Medicine for Environmental Research Laboratory, U.S. Environmental Protection Agency.

PUFFER, H.W., DUDA, M.J., and AZEN, S.P. (1982). "Potential health hazards from consumption of fish caught in polluted coastal waters of Los Angeles County." N. Am. J. Fish. Management 2:74-79.

RIFKIN, E. and LAKIND, J. (1991). "Dioxin bioaccumulation: Key to a sound risk assessment methodology." J. Toxicol. Environ. Health 33:103-112.

SHERMAN, W.R., KEENAN, R.E., and GUNSTER, D.G. (1992). "Reevaluation of dioxin bioconcentration and bioaccumulation factors for regulatory purposes." J. Toxicol. Environ. Health 37:211-229.

U.S. ENVIRONMENTAL PROTECTION AGENCY (U.S. EPA) (1984). Ambient Water Quality Criteria for 2,3,7,8-Tetrachlorodibenzo-p-Dioxin. Office of Water Regulations and Standards.

U.S. ENVIRONMENTAL PROTECTION AGENCY (U.S. EPA) (1989a). Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual (Part A). EPA/540/1-89/002. Office of Emergency and Remedial Response, Washington, DC. December.

U.S. ENVIRONMENTAL PROTECTION AGENCY (U.S. EPA) (1989b). Exposure Factors Handbook. EPA/600/8-89/043. Office of Health and Environmental Assessment, Washington, DC. July.

U.S. ENVIRONMENTAL PROTECTION AGENCY (U.S. EPA) (1992). Final Guidelines for Exposure Assessment. 57 FR 104:22888-22938. Washington, DC. May 29.

WEST, P.C., FLY, J.M., MARANS, R., and LARKIN, F. (1989). Michigan Sport Anglers Fish Consumption Survey. University of Michigan, Ann Arbor, MI. May.

NOTE: Pages 803811 & 803812 of this Administrative Record have been intentionally left blank for pagination purposes.