9 Fish Consumption

9.1 Introduction

The “Hot Spots” (AB-2588) risk assessment process addresses contamination of bodies of water near facilities emitting air pollutants. The consumption of fish from contaminated bodies of water can be a significant exposure pathway for persistent bioaccumulative organic compounds and some heavy metals. Sport fishing in freshwater lakes and ponds is the primary concern for this exposure pathway, as deposited contaminants have the greatest potential to concentrate in these types of water bodies. Although regional air contaminants depositing into the ocean, bays and estuaries are a significant problem, the risks predicted from a single source are expected to be relatively insignificant due to tidal flows and dilution. Possible exceptions could be estuaries, salt marshes or sloughs with very low tidal flow that lead to accumulation of pollutants from nearby emission sources.

Commercial store-bought fish generally come from a number of sources. Consequently, the health risks of concern are due to noncommercial, or sport, fishing. The sport fish consumption rate is a critical variate in the assessment of potential health risks to individuals consuming fish from waters impacted by facility emissions. Other synonymous terms used for sport fishing include “self-caught fish” and “wild-caught fish”. The term “angler” or “sport fisher” refers to persons who catch sport fish or shellfish. These groups may include subsistence fishers.

Estimates of sport fish consumption by fishers tend to be greater than estimates of commercial fish consumption rates for the general population (Puffer et al., 1982a; Puffer et al., 1982b; SCCWRP and MBC, 1994; OEHHA, 2001). The higher intake rate of sport fish consumption by fishers creates a sensitive subpopulation relative to the general population when a facility’s emissions impact a fishable body of water. For this reason, consumption rates that apply to the general sport fisher population, rather than per capita estimates of fish consumption, are used here to characterize fish consumption by the subpopulation that is at risk from consuming fish contaminated by air emissions from stationary sources.

Sport fish consumption rates may also vary by geographic location and for specific subpopulations. The U.S. EPA recommends using data on local consumption patterns and population characteristics whenever possible (U.S. EPA, 2000). For instance, subsistence fishers, as well as certain cultural groups, can have particularly high consumption rates relative to the general population (Harnly et al., 1997; SFEI, 2000; U.S. EPA, 2000). Use of national averages can seriously underestimate risks to these subpopulations.

Because freshwater bodies such as lakes and ponds have the greatest potential for concentrating deposited contaminants, the ideal fish consumption study to use for the Hot Spots program would be a study of California freshwater sport fish consumption. Unfortunately, there are no such studies available. However, comprehensive studies have been conducted in California surveying consumption rates of saltwater or Central Valley Delta fishers (Puffer et al., 1982a; Puffer et al., 1982b; SCCWRP and MBC, 1994; Wong, 1997; SFEI, 2000; Shilling et al., 2010). One strength of the California marine surveys is that the survey population is ethnically diverse, which may better approximate the consumption patterns for the California population, relative to studies that surveyed more homogeneous populations.

The application of the results of an ideal single fish consumption study conducted elsewhere to an impacted water body will always be uncertain because factors such as individual water body productivity, size, and local angler water body preferences will influence fish consumption. Conducting a site-specific sport fish consumption survey, in most cases, would not be a cost-effective alternative to use of the values presented in this chapter. Thus, OEHHA encourages the description of factors in the risk assessment which might significantly reduce or increase the estimated quantity of sport fish consumed for the consideration of the risk managers.

9.2 Recommendations for Angler-Caught Fish Consumption Rates

Recommended point estimates for angler-caught fish consumption rates are shown in Table 9.1. The fish consumption estimates are used to calculate individual cancer risk and noncancer chronic risk to those who eat sport (angler-caught) fish. Under the “Hot Spots” program, these consumption estimates apply principally to the general freshwater fishing population and encompass consumption of all sport fish species at a given location.

The risks should be presented using the high-end estimate in Tier 1 risk assessments, if the fish ingestion pathway is a dominant pathway. As noted in Chapter 1, dominant pathways are defined as the two pathways contributing the most to cancer risk when high-end estimates of intake are used in the risk calculation. The risks estimated from the average value would be used where fish ingestion is not a dominant pathway and may also be presented for comparison in assessments where fish ingestion is a dominant pathway.

However, if high fish-consuming groups including ethnic groups and/or subsistence fishers are known to be present, OEHHA recommends that the intake rate at the 95th percentile be used to reflect the upper bound estimate of consumption rates for these subpopulations, and when aiming to protect the target population as a whole.

Table 9.1 Point Estimate Values for Sport Fish Consumption by Age Group

	Third Trimester	0 <2 Years	2<9 Years	2<16 Years	16<30 Years	16-70 Years
	Consumption rates in g/day					
Average	-	2.1	7.9	13.3	28.8	28.8
High End[a]	-	6.6	25.4	42.9	92.4	92.4
	Consumption rates normalized by body weight, in g/kg-day					
Average	0.38	0.18	0.36	0.36	0.38	0.36
High-End[a]	1.22	0.58	1.16	1.16	1.22	1.16

[a] High end fish consumption values are the 95th percentiles. OEHHA recommends using the g/kg-day values.

Distributional analysis rather than single point estimates of fish consumption rates may be used to describe exposure within a population. Using a stochastic analysis will allow a more complete characterization of the variability in consumption in a population.

OEHHA recommends that the avidity-bias corrected distribution derived from the San Francisco Bay study (see Section 9.5) be used in Tier 3 and 4 risk assessments. The data in Table 9.2, expressed in g/kg-d, were obtained by dividing the adult fish consumption lognormal distribution data (in g/day) in Table 9.6 by the mean body weight of 80.0 kg derived in Section 10 for adults age 16-70 years. This was necessary because individual body weights were not collected in the fish consumption surveys.

Table 9.2. Empirical Distribution for Avidity Bias Adjusted Sport-Caught Fish Consumption Expressed in g/kg-day

Mean	**Percentiles**									
	10th	**20th**	**30th**	**40th**	**50th**	**60th**	**70th**	**80th**	**90th**	**95th**
Third trimester, 2<9, 2<16, 16<30 and 16-70-year age groups										
0.36	0.06	0.09	0.12	0.16	0.21	0.28	0.36	0.50	0.79	1.16
0<2-year age group										
0.18	0.03	0.05	0.06	0.08	0.11	0.14	0.18	0.25	0.40	0.58

As discussed below, there were no data available to clearly ascertain sport fish consumption rates of children. Estimates from studies for children in households of anglers indicate both potentially higher consumption rates than the anglers themselves (Mayfield et al., 2007; Shilling et al., 2010), and lower consumption rates than the anglers themselves (US EPA, 2002). We therefore assumed that sport fish consumption rate for adults 16-70 years of age would be proportional to body weight for the child age groupings of 2<9 and 2<16-year olds. Multiplying the adult consumption rate point estimates in g/kg-day by the time-weighted average body weight of 21.9 kg from Section 10 for the 2<9 year olds yields a mean and high-end fish consumption rate of 7.9 and 25.4 g/day, respectively. Performing the same calculation for the 2<16 age group with an average body weight of 37.0 kg results in a mean and high-end fish consumption rate of 13.3 and 42.9 g/day, respectively.

For the 0<2 age group, no fish consumption is expected in the first year, and fish consumption during the second year was assumed proportional on a gram per kg body weight basis to that of older children and adults. Thus, the fish consumption rate is based on the mean body weight of children during the second year (11.4 kg for 1<2 year age group) and divided by two to represent the first 2 years after birth. The resulting mean and high-end fish consumption rates are 2.1 and 6.6 g/day, respectively (See Table 9.1 above).

Fetal exposure via the mother's consumption of fish during the third trimester is represented in g/kg-day only; no estimate was determined based on g/day. To account for the third trimester of fetal exposure we assumed sport fish consumption for both the fetus and the mother will be the same during this three-month period using the sport fish consumption rate of 0.38 g/kg-day for adults age 16<30 years.

9.3 List of "Hot Spots" Chemicals for Which Evaluation of the Fish Pathway Is Recommended

The subset of organic and metal compounds that exhibit multipathway exposure are semi-volatile or nonvolatile, and are therefore partially or wholly in the solid or liquid phase and subject to deposition on water bodies. Fate and transport of the deposited chemical are estimated in order to assess the impact on fish that humans may catch and consume. The basis for the selection of these compounds as Hot Spots multipathway substances can be found in Appendix E. If the chemical has a long half-life and accumulates in fish, the multipathway analysis becomes more important. Below are the compounds on the Air Toxics "Hot Spots" list for which evaluation of the fish pathway is recommended:

Organic Compounds
Diethylhexylphthalate
Hexachlorobenzene
Hexachlorocyclohexanes
Pentachlorophenol
Polychlorinated biphenyls
Polychlorinated dibenzo-p-dioxins and dibenzofurans
Polycyclic aromatic hydrocarbons

Inorganic Metals and Semi-Metals
Arsenic & arsenic compounds
Beryllium & beryllium compounds
Cadmium & cadmium compounds
Soluble compounds of hexavalent chromium
Lead & inorganic lead compounds
Inorganic mercury
Nickel & nickel compounds
Selenium & selenium compounds

9.4 Algorithm for Dose via Fish Ingestion

In the Air Toxics "Hot Spots" program, the concentration of a chemical in fish, Cf, is a product of the modeled concentration in water, Cw, and the bioaccumulation factor (BAF) for the chemical of concern.

$$Cf = Cw \times BAF \qquad \textbf{(Eq. 9-1)}$$

where: Cf = concentration in fish (μg/kg)

Cw = concentration in water (μg/kg)

BAF = chemical-specific bioaccumulation factor for fish

Bioaccumulation refers to the uptake and retention of a chemical by an aquatic organism such as fish from all surrounding media (e.g., water, food, sediment). A BAF is the ratio of the chemical concentration in the fish tissue to the concentration in water, taking into account uptake through contaminated food, sediment and water. There are a number of factors that can affect the BAF of a chemical in fish. Appendix I presents the derivation of the BAF for each chemical, and provides a brief discussion of the various factors influencing the BAF in fish.

Airborne contaminants can deposit directly into a body of water or be carried there by runoff. As discussed in chapter 8, the Air Toxics "Hot Spots" algorithm only considers direct deposition onto the surface of the water body. OEHHA has not currently endorsed a modeling approach for runoff. If runoff into a water body is thought to significantly impact risk from a particular facility, the risk assessor should include discussion of this problem. The concentration in the water in the model below is a function of what is directly deposited into the body of water. This is calculated as follows:

$$Cw = Dep\ (SA)\ (365)\ /\ (WV)\ (VC) \qquad \textbf{(Eq. 9-2a)}$$

and

$$Dep = GLC \times \text{dep-rate} \times 86{,}400 \qquad \textbf{(Eq. 9.2b)}$$

where: Cw = concentration in water due to direct deposition (μg/kg)

Dep = amount deposited/day (μg/m2/day) = GLC x dep-rate x 86,400

GLC = modeled ground level concentration (μg/m^3)

dep-rate = vertical rate of deposition (m/sec)

86,400 = seconds/day

SA = surface area of water body (m^2)

365 = days per year

WV = water volume (L = kg)

VC = number of volume changes per year

The deposition rate is assumed to be 0.02 m/sec for a controlled source and 0.05 m/sec for an uncontrolled source (see Chapter 2). The terms SA, WV, and VC are site-specific factors; values for these terms need to be ascertained by the risk assessor.

Calculating dose of contaminant via fish ingestion requires an estimate of the fish concentration and the amount of fish an individual consumes. The following equation can be used to calculate dose via ingestion of contaminated fish:

$$DOSEfish = (Cf \times Ifish \times GI \times Fsf \times EF \times (1 \times 10^{-6}) \qquad \textbf{(Eq. 9-3)}$$

where:

DOSEfish	=	dose of contaminant via ingestion of fish (mg/kg BW-day)
Cf	=	concentration in fish (μg/kg)
Ifish	=	sport fish ingestion rate (g/kg BW-day)
GI	=	gastrointestinal absorption fraction, unitless
Fsf	=	fraction of sport fish caught at contaminated site, unitless
EF	=	exposure frequency (days/365 days)
1×10^{-6}	=	conversion factor (μg/mg) (kg/gm)

The value of Cf is calculated using equations 9-1 and 9-2. The default gastrointestinal absorption fraction is 1. There are currently no data to support a value different from 1 for any of the chemicals that are evaluated for this pathway. The factor, Fsf, is a site-specific factor; the risk assessor must evaluate site-specific data to ascertain what fraction of the sport fish consumed by an individual comes from the impacted body of water. If such data are unobtainable, then Fsf should be set to 1. We provide both point estimates and a distribution of sport fish consumption rates normalized to body weight in this chapter. The exposure frequency (EF) is set at 350 days per year (i.e., per 365 days) to allow for a two week period of time away from home (US EPA (1991).

For cancer risk, the risk is calculated for each age group using the appropriate age sensitivity factors (ASFs) and the chemical-specific cancer potency factor (CPF) expressed in units of $(mg/kg\text{-}day)^{-1}$.

$$RISKfish = DOSEfish * CPF * ASF * ED/AT \qquad \textbf{(Eq. 9-4)}$$

RISK is the predicted risk of cancer (unitless) over a lifetime as a result of the exposure, and is usually expressed as chances per million persons exposed (e.g., 5×10^{-6} would be 5 chances per million persons exposed).

The dose-response phase of a cancer risk assessment aims to characterize the relationship between an applied dose of a carcinogen and the risk of tumor appearance in a human. This is usually expressed as a cancer potency factor, or CPF, in the above equation. The CPF is the slope of the extrapolated dose-response curve and is expressed as units of inverse dose $(mg/kg\text{-}d)^{-1}$.

Exposure duration (ED) is the number of years within the age groupings. In order to accommodate the use of the ASFs (OEHHA, 2009), the exposure for each age grouping must be separately calculated. Thus, the ED is different for each age grouping. The ASF, as shown below, is 10 for the third trimester and infants 0<2 years of age, is 3 for children age 2<16 years of age, and is 1 for adults 16 to 70 years of age.

ED =	exposure duration (yrs):	
	0.25 yrs for third trimester	(ASF = 10)
	2 yrs for 0<2 age group	(ASF = 10)
	7 yrs for 2<9 age group	(ASF = 3)
	14 yrs for 2<16 age group	(ASF = 3)
	14 yrs for 16<30 age group	(ASF = 1)
	54 yrs for 16-70 age group	(ASF = 1)

AT, the averaging time for lifetime cancer risks, is 70 years in all cases. To determine lifetime cancer risks, the risks are then summed across the age groups:

$$RISKfish_{(lifetime)} = RISKfish_{(3rdtri)} + RISKfish_{(0<2\ yr)} + RISKfish_{(2<16\ yr)} + RISKfish_{(16\text{-}70yr)}$$ **(Eq. 9-5)**

As explained in Chapter 1, we also need to accommodate cancer risk estimates for the average (9 years) and high-end (30 years) length of time at a single residence, as well as the traditional 70 year lifetime cancer risk estimate. For example, assessing risk in a 9 year residential exposure scenario assumes exposure during the most sensitive period, from the third trimester to 9 years of age and would be presented as such:

$$RISKfish_{(9\text{-}yr\ residency)} = RISKfish_{(3rdtri)} + RISKfish_{(0<2\ yr)} + RISKfish_{(2<9\ yr)}$$ **(Eq. 9-6)**

For the 30-year residential exposure scenario, the risk for the 2<16 and 16<30 age groups would be added to the risks from exposure during the third trimester and from ages 0<2 yr. For 70 year residency risk, Eq 9-5 would apply.

The fetus can be exposed via the mother's consumption of fish during the third trimester of pregnancy. Fetal exposure during the third trimester via fish consumption by the mother is taken into account in the final determination of the point estimate values presented in Section 9.2. For the 0<2 yr age group, no fish consumption by the infant is expected from birth to one year of age.

9.5 Studies Evaluated for Sport Fish Consumption Rate

In order to determine the dose of a contaminant via ingestion of fish, reasonable point estimates and distributions for the rate of California sport fish ingestion are required. The most comprehensive studies of noncommercial fish consumption in California are the Santa Monica Bay Seafood Consumption Study (SCCWRP and MBC, 1994) and the San Francisco Bay Seafood Consumption Study (SFEI, 2000). These studies were undertaken to describe the demographic characteristics of anglers that fish the Santa Monica Bay and San Francisco Bay, to assess their sport seafood consumption rates, and to identify ethnic subgroups that may have high rates of seafood consumption.

Other California fish consumption studies that provide estimates of fish consumption rates are also reviewed here. Since comprehensive freshwater fish consumption rate studies in California are lacking, the best freshwater fish studies performed elsewhere in the U.S. are also summarized. Studies that discussed consumption of sport fish by household members are also summarized. Household members may represent a more sensitive subgroup of people consuming contaminated sport fish brought home by anglers. Sensitive household members include children and pregnant and lactating women.

9.5.1 Marine and Delta Fish Consumption Studies

9.5.1.1 1998-1999 San Francisco Bay Seafood Consumption Study

Between July 1998 and June 1999, the California Department of Health Services conducted over 150 fishing site visits and approached over 1700 San Francisco Bay (SF Bay) anglers (SFEI, 2000). The sites chosen for interviews included public piers and adjacent beaches or banks, public boat launches, and party boats. Anglers were asked how many times they ate Bay fish in the four weeks prior to being interviewed - a time period within which anglers were assumed to have reasonably accurate recall. Anglers were also asked the portion size of the meal compared to a plastic model of an eight-ounce fish fillet. The portion size question was asked only once and was used to calculate all fish consumption rates. Angler fish-consumption rates were determined by multiplying the two variables, meal frequency and portion size, and converted to grams per day (g/d). Consumption rates are described primarily for two populations, consumers and recent consumers. Consumers are anglers who reported eating Bay fish. Recent consumers are a subset of consumers who reported consuming Bay fish in the last four weeks.

Of 1738 eligible (i.e., not previously interviewed) anglers interviewed, 501 individuals identified as recent consumers provided adequate information for deriving a consumption rate. The researchers had determined a sample size of 500 recent consumers would be needed to derive a reasonably precise mean consumption rate (i.e., 95% confidence interval of ± 10% around the geometric mean consumption rate and 95% confidence interval of ± 15% around the upper percentiles). The mean and 95th percentile for fish consumption rate among recent consumers based on 4-week recall was 28 and 108 g/d, respectively.

The SF Bay report also included a distribution of consumption rates for recent consumers adjusted for avidity bias (See section 9.8.2.1 for discussion on avidity bias). In on-site surveys such as the SF Bay study, avid anglers are over-represented in the sample and infrequent anglers are under-represented, resulting in avidity bias. This bias occurs because an individual who fishes frequently has a greater chance of being interviewed than a person who fishes infrequently. Thus the distribution will over-represent the consumption of frequent fishers. Further information about avidity bias is discussed below. The mean and 95th percentile for the avidity adjusted fish consumption rate among recent consumers based on 4-week recall was 23 and 80 g/d, respectively.

Although less reliable than the four week recall, consumers (n=1019) were asked to report the number of times they ate Bay fish in the past 12 months. The unadjusted mean and 95th percentile for fish consumption rate based on 12-month recall was 11 and 44 g/d, respectively. Consumption rates for the 12-month period prior to the interview could not be adjusted for avidity bias due to insufficient fishing frequency data over the same time period.

Due to historic mercury contamination in the region, the SF Bay report also surveyed angler households for pregnant or lactating women. The developing fetus and infants are particularly sensitive to mercury contamination. The SF Bay report found that only 2% of anglers reported that pregnant or lactating women in their household ate SF Bay sport-caught fish. However, 46% of anglers reported that women of childbearing age (18-45 years) in their household ate SF Bay sport-caught fish, and 13% reported that children younger than six years of age ate SF Bay sport-caught fish.

9.5.1.2 1991-1992 Santa Monica Bay Seafood Consumption Study

For the Santa Monica Bay study, surveys were conducted at 29 sites on 99 days, from September 1991 to August 1992 (SCCWRP and MBC, 1994; Allen et al., 1996). Fishers on piers and jetties, private boats, party boats, and beaches were interviewed using a questionnaire. The fish consumption estimates applied only to consumption of Santa Monica Bay sport fish, and did not include consumption of fish from all sport and commercial sources. Anglers were questioned about consumption of eight commonly consumed species of fish as well as about fish they had in hand. Anglers were also asked to estimate how much fish he/she consumed per meal, compared to a wood model representing a 150 gram (0.33 pound) portion of a fish fillet. Similar to the SF Bay study, fishers were asked the number of times they had consumed sport fish in the 4 weeks prior to the interview, but unlike the SF Bay study, the frequency of fish consumption was increased by one meal to account for consumption of catch present at the time of the interview. Fishers who had eaten any of the 8 species in the survey in the 4 weeks prior to the interview were included in consumption rate estimates. Of the 1,243 fishers interviewed, 554 provided information that could be used for calculating consumption rates. Average daily sport fish consumption rates (g/day) were calculated by multiplying the fisher's estimate of the typical meal size relative to the model, by the frequency of consumption in the four weeks prior to the interview, divided by 28 days. The mean and 95th percentile consumption rates for the overall surveyed population were 49.6 and 161 g/d, respectively.

OEHHA utilized a basic inverse-weighting scheme to adjust the fish consumption rate data for avidity bias, resulting in a mean of 29.4 g/d (OEHHA, 2000). Additionally, the analysis adjusted for four separate factors producing potential bias in the sampling procedure (i.e., number of times fished, frequency of site selection, proportion of successful interviews, and week days versus weekend days sampled). The four-factor corrected mean was 30.5 g/d, and differed from the avidity-corrected mean by only 3%. The four-factor adjusted high end (95th percentile) fish consumption rate estimate was 85.2 g/d.

9.5.1.3 1980 Los Angeles Metropolitan Area Survey

In 1980, an intercept survey was conducted in the Los Angeles metropolitan area (including Santa Monica Bay) to assess noncommercial fish and shellfish consumption rates by local fishers, and to identify subgroups that have significantly larger consumption rates (Puffer et al., 1982a; Puffer et al., 1982b). The intercept survey method surveys fishers at a fishing site or sites about fish consumption, catch or other questions of interest. During the one-year study period, a total of 1,059 fishers were interviewed at 12 sites, including piers, jetties, and party boats. Average daily consumption rates were estimated based on the number of fish in the catch, the average weight of the fish in the catch, the edible portion of the species, the number of fish eaters in the family and the frequency of fishing per year. The fish consumption rate data were presented as a cumulative percentile distribution, with a median of 37 g/d and 90^{th} and 95^{th} percentiles of 225 and 339 g/d, respectively. Mean estimates of fish consumption were not presented.

While this study was quite extensive, there were several limitations. Consumption data were collected from over 1,000 individuals representing various ethnic groups in the survey population (i.e., Caucasian, Black, Mexican-American, and Oriental/Samoan), but only English speaking fishers were included in the study. The Santa Monica and SF Bay Seafood Consumption Studies interviewed a number of different ethnic groups in their native languages. In addition, the survey did not ask fishers for direct estimates of the amount of fish they consumed, correction for avidity bias was not performed, and no recall was included of sport fish consumption over a previous period of time.

Price et al. (1994) attempted to correct for avidity bias using the general assumption that sampling probability is proportional to the inverse of fishing frequency. The adjusted consumption rate distribution was considerably lower than that obtained by Puffer et al. studies; the median and 90^{th} percentile were estimated at 2.9 and 35 g/d, respectively. U.S. EPA (1997) notes that an avidity-correction assumption is not completely valid, as interviewers visited sites numerous times and anglers were not interviewed more than once. However, U.S. EPA (1997) does state that the estimates of Price et al. (1994) are probably better estimates of the fish consumption of the entire population that fishes the area than the non-adjusted survey results.

9.5.1.4 1988-1989 San Diego Bay Health Risk Study

The San Diego Department of Health Services conducted a survey of fishers fishing the San Diego Bay (SDCDHS, 1990) to identify the demographics of this fisher population and to characterize their noncommercial fish consumption patterns. The authors derived an overall bay-wide fishing population mean of 31.2 g/d. Only 59 fishers provided all of the necessary data for calculating individual noncommercial fish consumption rates and subsets of the 59 interviews were used to calculate species and ethnic-specific rates. Thus, there is more uncertainty about the fish consumption values because of the small number of subjects in the study population, particularly for the subsets for specific species and influence of ethnicity. In addition, the consumption rate overestimates consumption in the general fishing population because the rate only includes fishers who were known to catch and consume fish year-round.

9.5.1.5 1993 San Francisco Bay Seafood Consumption and Information Project

In an earlier study of fish consumption habits of people fishing in San Francisco Bay, Wong (1997) conducted personal interviews with approximately 200 people fishing or crabbing from ten public piers during September to November 1996. A fish fillet model, representing 150 grams, was used to assist with estimating the amount of fish consumed per meal. Sixty-two respondents (29 percent) reported consumption of SF Bay fish in the 7-day period preceding the interview. A calculated median consumption rate of 32 g/d was determined for anglers that ate fish and/or shellfish from SF Bay. This study was not corrected for avidity bias.

9.5.1.6 2010 California Central Valley Delta Fish Consumption Study

A fish consumption survey was conducted in the California Central Valley Delta (including the Sacramento-San Joaquin Rivers Delta) where a high rate of subsistence fishing of potentially mercury-contaminated fish occurs (Shilling et al., 2010). This study reflects a region where both freshwater and anadromous fish are caught. Anglers were chosen for interviews as they were encountered along the riverbank by surveyors. Shore anglers (n=373) were interviewed during biweekly to monthly site visits between September 2005 and June 2008. Anyone reporting that they had been previously interviewed was not interviewed again. Fish consumption rates (g/d) were calculated for each individual based on 30-day recall of how much and how often individual types of fish were eaten. Fish fillet models were used representing 1.5, 4.5, and 7.5 oz cooked weights of fish fillet for the estimate of actual fish consumption rates.

The arithmetic mean and median consumption rates of locally caught fish were 27.4 and 19.7 g/day, respectively, for anglers. There were no statistically significant differences in consumption rates among age groups (18-34, 35-49, and >49 years of age). The 95th percentile rate of locally caught fish (126.6 g/d) was also determined to represent the majority of the fish consuming population. Note that this distribution is not normally distributed. The arithmetic mean and median consumption rates of locally caught fish for children (n=174, age unspecified) in households of anglers were 35.3 and 22.2 g/day, respectively. This study was not corrected for avidity bias.

In addition to interviewing shore anglers, interviews were conducted with selected members of the local South East Asian community in which it was known that a member of their extended family fished. The mean corresponding consumption rate for locally-caught fish from the community member survey was 55.2 g/day, which was higher than the corresponding rate for anglers in the field. Because this portion of the study was a community-based, rather than angler-based, survey of an ethnic group known for high consumption of locally-caught fish, it does not represent an overall California fish consumption rate.

9.5.2 Freshwater Fish Consumption Studies

9.5.2.1 Washington King County Lakes Study

A survey was conducted at three Washington state freshwater lakes from June 2002 to May 2003 (Mayfield et al., 2007). A total of 212 anglers were interviewed and asked to estimate their typical meal size from a visual aid (6, 8, 10, and 12 oz. fillets) and how often they had consumed fish they caught from the lakes in the previous month. Surveyors also asked the anglers to provide the same information for any children (i.e., <18 years) who also consumed their catch. Forty-six percent of anglers reported sharing their catch with children. The mean consumption rate was 10 and 7 g/d for anglers and their children, respectively. The 95th percentiles were 42 and 29 g/d for anglers and the children of anglers, respectively. Although many anglers reported consuming fish from King County Lakes, many had not consumed any fish in the previous month. Therefore, the median consumption rate was zero.

9.5.2.2 Michigan Freshwater Fish Consumption Studies

The University of Michigan conducted a stratified random mail survey of 2600 Michigan residents with annual fishing licenses during the period of January to June 1988 (West et al., 1989a; 1989b; 1989c). Those with one day fishing licenses from both in state and out of state were excluded thus eliminating some infrequent fishers. Fish meals included self-caught, market, restaurant, and gift fish. Fish consumption information was gathered from all members of the household for a 7-day recall period and included only those individuals who responded that they ate fish. However, all responses were tabulated in one of only three meal sizes, 5, 8, and 10 oz. Because the overall response rate was only 47.3 percent, the authors adjusted the population mean value of 18.3 g/d downward by 2.2 g/d to account for nonresponse bias, thus deriving a mean rate of 16.1 g/d. Derivation of the adjustment factor was based on a follow-up telephone survey of respondents and nonrespondents (West et al., 1989b). The researchers did not generate a distribution. The probability of being contacted in this study was not dependent on the frequency of fishing; therefore, the avidity bias found in intercept surveys is not present in the data. However, the authors noted that the sampled population may not have represented subsistence fishers because it was selected from licensed anglers only.

Murray and Burmaster (1994) used the raw data of West et al. studies to generate a distribution for total fish and self-caught fish among adults only, providing 12 empirical distributions for eight population subgroups. Fish consumption rate estimates were derived for persons who consumed self-caught fish during the recall period, resulting in a consumption rate based on a population that more frequently consumes fish. This study represents the most comprehensive analysis of freshwater sport fish consumption by anglers. Table 9.3 includes empirical distribution data for average daily fish consumption rate in the four adult subgroups that are most relevant for the California “Hot Spots” program. The Great Lakes fish population groups refer to anglers and family members who only ate self-caught fish from the Great Lakes. These groups may be analogous to sport fishers in California that fish only from one or a few lakes in a defined area that are impacted by pollutants. The self-caught fish population groups refer to groups that caught and consumed fish caught anywhere in Michigan.

Table 9.3. Average Daily Fish Consumption Rates in g/day of Adults for Four Subgroups from Murray and Burmaster (1994)

Population group[a]	Distribution for fish consumption type	N	Fraction as % of adults[b]	Mean	SD	Percentile	
						50th	95th
Anglers/ate self-caught fish	Self-caught fish	191	0.08	45.0	23.7	32.7	98.0
All/ate self-caught fish	Self-caught fish	418	0.18	42.3	22.3	32.7	98.0
Anglers/ate Great Lakes fish	Great Lakes fish	89	0.04	40.9	19.9	32.7	81.6
All/ate Great Lakes fish	Great Lakes fish	188	0.08	38.5	19.0	32.7	81.6

[a] The first two rows refer only to fish consumption of self-caught fish for anglers only (anglers) or the anglers plus adult family members (all). The last two rows refer to fish consumption of only self-caught fish from the Great Lakes for anglers only (anglers) or the anglers plus adult family members (all).
[b] This column represents the percentage of general population (i.e., Michigan adults) that ate self-caught fish.

Murray and Burmaster (1994) found that a lognormal model fit the empirical data well and provided parametric compound distributions for use in Monte Carlo simulations.

9.5.2.3 1992-1993 Freshwater Fish Consumption by Alabama Anglers

A statewide survey was conducted from August 1992 to July 1993 to estimate daily fish consumption of freshwater fish harvested by anglers fishing from 29 locations throughout Alabama, including tailwater sites, reservoirs, and river drainages (Meredith and Malvestuto, 1996). A total of 1,586 anglers were interviewed at the completion of fishing activity. Of the total anglers interviewed, 1,303 anglers reported consumption of fish from the study areas. Serving size was estimated by equating the entire surface (palm side) of the flat open hand to a single 113 g (4 ounce) serving. To estimate fish consumption rates, anglers were asked to estimate the number of fish meals eaten in the past month consisting of fish caught at the study sites (“site meals”) and those caught at all lakes and rivers in Alabama, including study sites (“all meals”). Only anglers indicating they consumed fish from the study sites were included in the analysis. The mean annual consumption rate estimated by this method was 30.3 g/d for site meals and 45.8 g/d for all meals.

9.5.3 Studies of Household Members Who Eat Sport-Caught Fish

Determining the consumption rate of sport fish eaten by others in angler households was beyond the scope of most studies summarized above. Some studies have shown that people who do not go fishing eat sport-caught fish given to them by friends and family, but possibly at reduced rates compared to the anglers themselves (Toth and Brown, 1997; Burger, 2000; Nadon et al., 2002; Mayfield et al., 2007). The household members of anglers are of particular interest because the anglers are predominantly male, and may bring home fish to household members that are at higher risk from consuming contaminated sport-caught fish (i.e., pregnant and lactating women, women who are of childbearing age, and children). Table 9.4 below presents the data from studies that did estimate consumption rates for household members that eat freshwater sport-caught fish.

Table 9.4. Freshwater Sport Fish Consumption Rates by Household Members of Anglers

Group	N	Consumption rate (g/day)	Consumption rate (g/kg-day)	Reference
Children		Arithmetic Means	Arithmetic Means	
1-5 yrs	121	5.63	0.369	U.S. EPA (2002) [a]
6-10 yrs	151	7.94	0.276	
11-20 yrs	249	7.27	0.123	
<18 yrs	81	7	0.19	Mayfield et al. (2007)
Not Specified [b]	174	35.3	0.95[c]	Shilling et al. (2010)
Women				
All ages (<17-50+)	80	10.5 [d]	0.14 [d]	Silver et al. (2007)
<17 yrs	5	13.9		
Pregnant	6	12.8		
lactating	11	10.2		
18-49 yrs	217	33.0	0.44	Shilling et al. (2010)

[a] U.S. EPA values are based on treatment of data from West et al. (1989a)
[b] Child age range not specified, but can be inferred from the study to mean <18 years of age.
[c] Based on average body weight of 37.0 kg for children 2<16 yrs of age from Table 10.1
[d] Only geometric mean consumption rates were available

9.5.3.1 U.S. EPA analysis of West et al. (1989a) child fish consumption data subset

The U.S. EPA (2002) child fish consumption rates presented in Table 9.4 were obtained from the raw data by West et al. (1989a) to estimate freshwater recreational fish consumption rates for household members of anglers, based on the 7-day recall data. The household members were divided into three age groups, age 1-5, 6-10, and 11-20 years. The analysis was restricted to individuals who ate fish and who resided in households reporting some recreational fish consumption during the previous year.

Since the study was a stratified random mail survey of Michigan residents with annual fishing licenses, the study was not dependent on the frequency of fishing and did not need to be corrected for avidity bias.

Using an average adult body weight of 80.0 kg from Table 10.1of this document, the average adult angler consumption rate on a per kg body weight basis is 0.56 g/kg-day (45.0 g/day from Table 9.1 ÷ 80.0 kg). Comparing the child consumption rates in Table 9.4 to that of adult anglers who ate self-caught fish, this study suggests that the children in households of anglers eat less on a per body weight basis than the adult anglers.

9.5.3.2 Child sport fish consumption rate for the Washington King County Lakes Study

The Washington state freshwater fish consumption study recorded a mean consumption rate of 7 g/day for children (<18 years) of anglers interviewed (Mayfield et al., 2007). However, this study was not corrected for avidity bias, and included persons who did not consume sport fish during the 30-day recall period. Not accounting for avidity may overestimate consumption, while including anglers and their children who did not consume sport fish in the last month may underestimate the consumption rate of persons who frequently consume sport fish.

Using a mean body weight of 37.0 kg for children age 2<16 years, and 80.0 kg (age 18<75) for the mean body weight of adults, the sport fish consumption rates on a per kg body weight basis are 0.19 g/kg-day for children (7 g/d ÷ 37.0 kg) and 0.13 g/kg-day for adults (10 g/d ÷ 80.0 kg). The Washington state freshwater fish consumption data suggest that, if corrected for differences in body weight, children of anglers may consume as much fish, or more, on a per kg body weight basis as the anglers themselves. However, when compared to avidity-adjusted average adult angler consumption rates corrected for body weight from the S.F. Bay study (0.36 g/kg-day, see Table 9.1), the child consumption rate from the Washington study is only about half that of the adult S.F. Bay anglers.

9.5.3.3 California sport fish consumption survey among low-income women

The only study that investigated sport-caught fish consumption rates among a California population at increased risk (and presumably household members of an angler) was a survey of low-income women at a Special Supplemental Nutrition Program for Women, Infants and Children (WIC) clinic in the California Sacramento-San Joaquin Delta region (Silver et al., 2007). Of 500 eligible women participating in the survey, 80 (16%) reported eating sport fish in the last 30 days. These participants were asked about consumption frequency, portion size of cooked meals, and source of the fish. To assist with recall of portion size, fish fillet “portion models” were shown corresponding to 1.5, 3.0, 4.5, and 7.5 oz weight. The geometric mean sport fish consumption rate among this group was 10.5 g/d. Hmong and Cambodian women consumption rates showed a higher consumption trend but were not statistically significantly different.

Comparison of this geometric mean sport fish consumption rate for women in angler households with the geometric mean sport fish consumption rate among anglers in the

SF Bay and Santa Monica Bay studies suggests household members eat less sport-caught fish than the anglers themselves. The unadjusted geometric mean sport fish consumption rate for the SF Bay study and Santa Monica Bay study were 16.5 and 23.6 g/d, respectively. However, these consumption rates did not account for gender body weight differences and the predominance of male anglers in surveys (e.g., 92% of interviewed anglers in the SF Bay study were male), which would bring sport fish consumption rates among anglers and women household members closer together. Using mean body weight data by gender summarized in Table 10.2, the SF Bay and Santa Monica Bay mean consumption rates were divided by the average body weight of adult males (88.3 kg, age 20 yrs and above) and the WIC mean consumption rate divided by the average body weight for adult females (74.7 kg, age 20 yrs and above). Consumption rates on a per body weight basis yields values of 0.19, 0.27 and 0.14 g/kg-day for the SF Bay, Santa Monica Bay and WIC fish consumption studies, respectively.

9.5.3.4 California Central Valley Delta study of household fish consumption

The household consumption rates of women and children in the study by Shilling et al. (2010) are considerably higher compared to the household members in other studies. This may be due to the high number of subsistence fishers in this study, and that a majority of the anglers reported catching fish in order to feed their families. This study did not correct the consumption rate for avidity bias, so consumption rate may be overestimated.

Comparing the anglers with their family members, the consumption rates of children and women in households of anglers were not statistically significantly greater than the anglers themselves ($P < 0.05$, *t*-test). The study reported average consumption rates of 26.4, 33.0, and 35.1 g/day for male anglers, women in households of anglers, and children in households of anglers, respectively. However, when OEHHA divided the consumption rates by average body weights for men (88.3 kg), women (74.7 kg) and children (37 kg for 2 to <16 yrs), the fish consumption on a per body weight basis was 0.30, 0.44, and 0.95 g/kg-day, respectively. The results from this study suggest that household members of anglers, many of which are subsistence fisherman that fish mainly to feed their families, have a greater fish consumption rate than the anglers themselves.

9.5.3.5 Household sport fish consumption frequency surveys

A nationwide telephone survey of fish consumption patterns found that the presence of a fishing license in the home was a significant predictor of sport-caught fish ingestion by family members, including children and their mothers (Imm et al., 2007). Families with a fishing license in the home were more likely to eat sport-caught fish than families without a fishing license in the home. Forty-seven percent of children (2-17 years of age) who lived with a licensed angler ate sport-caught fish, with an average of 16 sport-caught fish meals (median = 8 meals; maximum = 240 meals) per year. A nationwide survey of 3015 women of childbearing age (ages 18-45) reported that 29% of participants had consumed sport fish in the previous 12 months (Anderson et al., 2004). Among those reporting sport fish consumption, the median and mean number of sport-caught fish meals for the past 12 months were 6 and 16, respectively. Neither study collected data on portion sizes of fish meals to estimate consumption rate.

9.6 Comparison of Marine Fish Consumption Rates among California Studies

Fish consumption rates for four California fish consumption studies, the SF Bay study, the Santa Monica Bay study, the Save the Bay Study (Wong, 1997), and the Central Valley Delta study (Shilling et al., 2010) are shown in Table 9.5 for comparison. The data from the SF Bay and Santa Monica Bay studies are presented both adjusted and unadjusted for avidity bias as discussed under section 9.8.2.1. Differences among the consumption rates could be explained by the different study methodologies used by the studies.

For example, the unadjusted geometric mean consumption rate from the Santa Monica Bay study is about 50 percent higher than the unadjusted rate derived from the SF Bay study, and the difference was found to be statistically significant. In the Santa Monica study, the frequency of consumption was increased by one to account for consumption of any fish in hand at the time of the interview. Fish in hand at the time of interview was not included in the SF Bay consumption rate estimates. This factor was thought to explain the higher consumption rates of the Santa Monica Bay study (SFEI, 2000). Another difference between the two studies was that the Santa Monica Bay study used a 5.3 ounce (150 g) portion model while the SF Bay study used an 8 ounce (227 g) portion model. The model size appears to have influenced the responses in both studies. Whether the different model sizes would widen or narrow the consumption rate difference between the two studies is not known.

In the Save the Bay study, the median consumption rate (32 g/d) was considerably higher than the unadjusted consumption rates of the other two California studies. However, only 7-day recall of fish consumption was surveyed among interviewed anglers. This short recall period creates an even smaller subset of all anglers compared to the 4-week recall used in the California studies, and also selectively includes anglers with the highest consumption rates.

Other factors unrelated to methodologies that may contribute to consumption rate differences among studies include differences in climate, fishery production, year of study, and demographic characteristics. As noted in Section 9.5.3.4, the California Central Valley Delta study by Shilling et al. (2010) contained a high number of subsistence anglers that reported catching fish in order to feed their families. This study also did not correct the consumption rate for avidity bias. Even so, consumption rates among the Central Valley Delta anglers are similar to avidity-adjusted rates in Table 9.3. This study suggests that a greater proportion of this population of subsistence anglers gives the fish they catch to their families, and this may account for the high consumption rate of household family members shown in Table 9.4.

Table 9.5 Comparison of Consumption Rates (in g/day) for the San Francisco Bay Seafood Consumption Study, Santa Monica Bay Study, Save the Bay Study and the Central Valley Delta Study[a]

	Adjusted SF Bay Study[b]	Adjusted Santa Monica Study[c]	Unadjusted SF Bay Study[b]	Unadjusted Santa Monica Study[c]	Save the Bay Study[d]	Central Valley Study[e]
Respondents	n=1152	[f]	n=1331	n=1244	n=222	[f]
Population used to derive consumption rate (% of respondents)	n=465 (40%)	[f]	n=501 (38%)	n=555 (45%)	n=62 (27%)	n=373 ([f])
	4-week recall	4-week recall	4-week recall	4-week recall	7-day recall	4-week recall
Mean (Standard Deviation)	23.0 (32.1)	30.5 (45)	28.0 (39.5)	49.6 (111.1)	[f]	27.4 ([f])
Geometric Mean	14.0	[f]	16.5	23.6	[f]	[f]
50th Percentile	16.0	15.0	16.0	21.4	32	19.7
90th Percentile	48.0	62.4	56.0	107.1	[f]	[f]
95th Percentile	80.0	85.2	108.0	161	[f]	126.6

[a] Table modified from SFEI (2000)
[b] SFEI, 2000; [c] Allen et al. (1996); [d] Wong, 1997; [e] Shilling et al. (2010)
[f] Not reported

9.7 Comparison of Freshwater and Marine Fish Consumption Rate Studies

Although the California fish consumption rate studies are derived from a population fishing from marine water bodies, a similar distribution of consumption rates also occurred from data obtained of populations fishing from freshwater bodies. For example, Murray and Burmaster (1994) calculated mean rates for non-avidity-biased consumption of Michigan sport-caught freshwater fish by anglers as 45.0 g/d for self-caught fish in general, and 40.9 g/d for anglers consuming fish from the Great Lakes, in particular. Meredith and Malvestuto (1996) reported an avidity-biased consumption rate of 30.3 g/d for specific study sites in Alabama, and 45.8 g/d for all sport-caught meals caught in the state. These mean values fall between the adjusted mean for the SF Bay study (23.0 g/d) and the unadjusted mean for the Santa Monica Bay study (49.6 g/d) shown in Table 9.5. These saltwater and freshwater studies were comparable in many study parameters and in analytical evaluation and, thus, can be reasonably used to support angler-caught freshwater fish consumption estimates in California.

The Washington King County Lakes study (Mayfield et al., 2007) exhibited a lower mean angler consumption rate of 10 g/day for freshwater fish compared to the Alabama and Michigan studies. The lower consumption rate in the Washington study is likely due to differences in methodology. Anglers that had not eaten sport fish in the previous month were included in the consumption rate analysis, whereas the Alabama and Michigan studies excluded anglers who had not eaten sport fish in the previous month. Thus, the Alabama and Michigan studies target the angler population that are the most frequent consumers of sport fish.

A more analogous comparison to the Washington King County Lakes study might be made with the unadjusted mean fish consumption rate based on 12-month recall in the SF Bay study. A lower mean consumption rate of 11.0 g/d was recorded for this group, which includes frequent (i.e., consumed sport fish in the last 4 weeks) and infrequent (i.e., consumed sport fish in the previous year, but not in the previous 4 weeks) anglers. The Washington King County Lakes mean consumption rate of 10 g/d is similar, using the assumption that this consumption rate includes both frequent and infrequent anglers that probably consumed sport fish in the previous year.

9.8 Determination of Fish Consumption Distribution

9.8.1 Choice of Study

The data from the San Francisco Bay Seafood Consumption Study (SFEI, 2000) were determined to be the most comprehensive and appropriate report for our estimation of average daily sport fish consumption in California. The SF Bay study was chosen over the other major California fish consumption studies in Table 9.5 because it represents the most recent well-conducted study of a California population. The SF Bay study applies to salt water sport-caught fish, whereas the “Hot Spots” program primarily applies to consumption of contaminated fresh water sport fish. However, as discussed above, comparable fish consumption rates have been observed for both marine and fresh water angler populations. If comprehensive and reliable data become available which describe consumption of freshwater sport fish in California, the current consumption rate values will be revisited

The Central Valley Delta fish consumption study by Shilling et al. (2010) was considered. This study contained a high number of subsistence anglers and did not correct for avidity bias. However, the mean consumption rate of 27.4 g/day for all anglers, and the body weight adjusted value of 0.33 g/kg-day compared well to the SF Bay study avidity-corrected average consumption rates of 28.8 g/day and 0.36 g/kg-day, respectively, for adults (see Table 9.1).

9.8.2 Statistical Correction for Unequal Sampling Probabilities

Samples obtained from on-site surveys, such as the SF Bay and Santa Monica Bay fish consumption rate studies, can provide estimates of the distribution of fish consumption rates for the total angler population being sampled. In order to obtain unbiased estimates for the total angler population in the SF Bay study, the estimates were (1) adjusted for sources of unequal sampling probabilities in fishing frequency, leading to avidity bias, and (2) examined for the effect of interview decliners on the consumption rate estimate.

9.8.2.1 Avidity Bias

How frequently anglers go fishing (i.e., their avidity) can vary widely among anglers. Some may fish daily while others may fish only once per year. In on-site surveys, how often an angler goes fishing determines how likely he or she will be included in the survey. Generally, avid anglers will be over represented in the sample and infrequent anglers will be under represented, resulting in avidity bias (Price et al., 1994; U.S. EPA, 1997; OEHHA, 2001).

Avidity bias presents a concern when an angler’s avidity is correlated with important parameters that are being studied, such as consumption rate. If no correlation exists, there is no bias and data adjustments will not change the results. However, if correlation exists, the sample will not accurately reflect the overall angler population. Adjusting for avidity bias allows for the results to more closely reflect general exposure of the target population of the study (i.e., San Francisco Bay anglers), and to determine a point estimate for the California fish consumption rate.

In the SF Bay study, sample data were adjusted for avidity bias by weighting the respondents in proportion to the inverse of their sampling probability during the four weeks prior to the interview. The algorithm for the statistical adjustment for avidity bias can be found in the report. For cases where the population of concern for risk assessment is the general fishing population and fish is not a major exposure pathway, as can be expected in most cases under the “Hot Spots” program, the adjusted (weighted) results that correct for avidity bias are recommended. However, if the fishing population of concern are fishers that consume sport fish on a regular and frequent basis (i.e., at least once per month), the unadjusted values are considered most relevant (OEHHA, 2001). For risks associated with a single fish species from a water body (i.e., single pathway exposures where fish consumption is a major pathway), it has been recommended that the unadjusted values representing the median and the 90^{th} percentile be used to characterize the population at risk (SCCWRP and MBC, 1994; OEHHA, 2001)

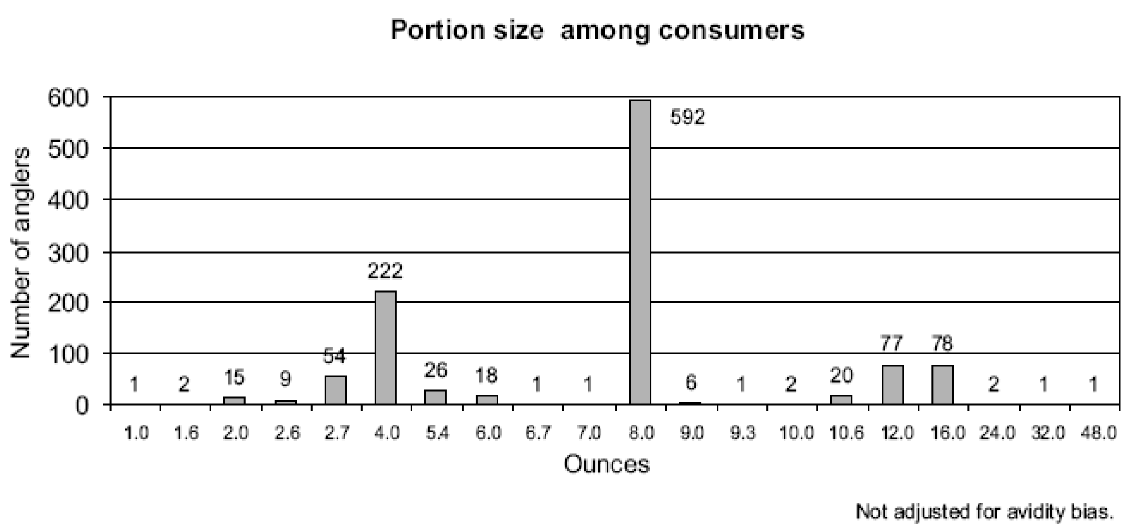
9.8.2.2 Influence of Interview Decliners on the Fish Consumption Rate

Anglers who declined to be interviewed for the SF Bay study represented 23% (n=407) of the net attempted interviews. Lacking data on nearly one fourth of the sample may have introduced some bias. As a worst-case scenario, it was assumed that all decliners had recent consumption (in the last four weeks) of Bay fish, to ensure that the influence of decliners did not result in an underestimation of overall consumption rates of recent consumers. Because ethnicity was the only demographic variable that showed a significant influence on consumption rate, the sample was adjusted to account for ethnic differences between the decliners and interviewed anglers. This was done by assuming that decliners of a certain ethnic group had the same consumption rate as recent consumers interviewed in the same ethnic group. Although any bias associated with anglers who declined to be interviewed is not quantifiable, the analysis using reasonable assumptions about this group revealed that the 23% of anglers from whom the researchers could not directly obtain consumption data were unlikely to influence the overall derived consumption estimates.

9.8.3 Graphical and Statistical Presentation of Consumption Rate Distributions

Figure 9-1 shows the portion size responses among consumers from the SF Bay study (SFEI, 2000) as a distribution. Portion size responses for consumers and recent consumers (i.e., anglers who reported consuming SF Bay fish in the last four weeks) were similar. In general, anglers gave portion size responses in multiples or fractions of the 8-ounce fish fillet model they were shown during the interview. Just over half of consumers reported that the 8-ounce model was equal to the amount they eat at one time, and the overall mean portion size for consumers was 7.7 ounces.

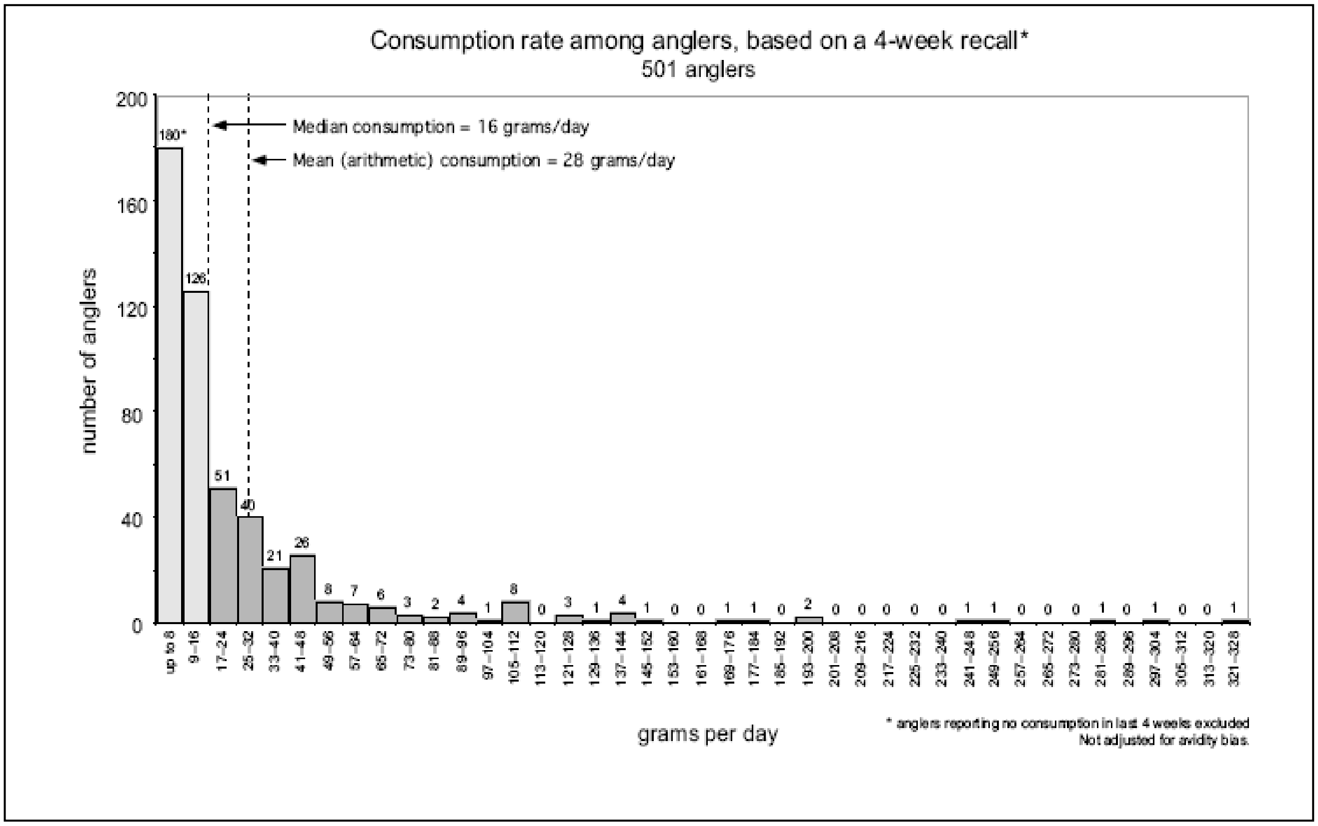
Figure 9



(Reprinted from SFEI, 2000)

Multiplying portion size by meal frequency responses provided by the anglers during the interview gives the consumption rate. Figure 9-2 shows the raw (untransformed) data for consumption rate distribution for recent consumers.

Figure 9-2



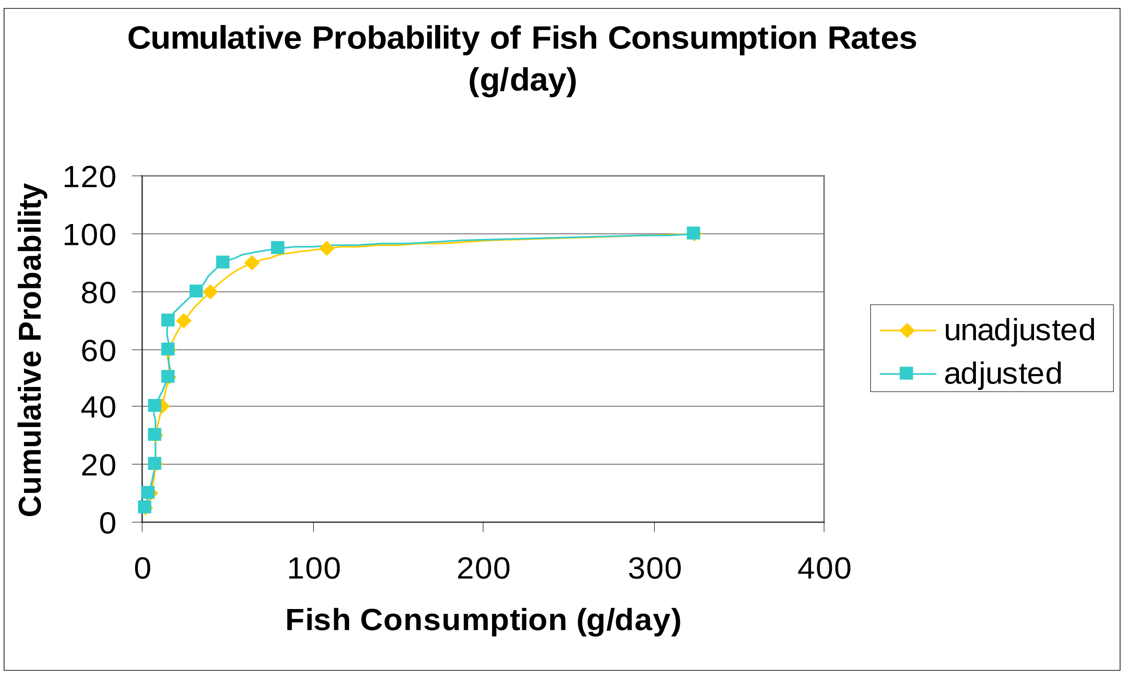
(Reprinted from SFEI, 2000)

The cumulative empirical distribution curves for the rate of fish consumption for all anglers who caught Bay fish in the SF Bay survey, both unadjusted and adjusted for avidity bias, are shown in Fig. 9-3. The fish consumption rate distribution is highly skewed to the right with a long upper tail, characteristic of a lognormal distribution. The skewness and kurtosis, shown in Table 9.6, are positive. A positive skewness indicates a distribution with a tail to the right. In other words, skewness is an indicator of the lack of symmetry of the distribution. The kurtosis indicates heaviness of the tails. Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution. That is, data sets with high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak.

The best fit for the empirical distribution of avidity adjusted fish consumption rates was checked using Crystal Ball (Decisioneering, 2008). The best fit was the lognormal distribution based on the Anderson-Darling, Chi-square, and Kolgomorov-Smirnov goodness of fit tests. The Anderson-Darling test was the most important for our purposes because it gave greater weight to the tails of the distribution. The right tail represents the most highly exposed in the population so it is important to properly characterize this region of the distribution. Because the lognormal distribution was found to be the best fit, Crystal Ball was also used to fit a lognormal parametric model to the avidity-adjusted data.

Moments and percentiles of the empirical distributions (unadjusted and adjusted for avidity) and of the lognormal fitted avidity adjusted fish consumption rates are presented in Table 9.6. Figure 9-4 depicts the cumulative probability distribution of the lognormal fitted data. The lognormally fit distribution is slightly more skewed to the right than the original empirical distribution. Nonetheless, the empirical avidity adjusted distribution was non-continuous, as evidenced by the somewhat staircase appearance of its graphs (Figs 9-2 and 9-3). The 20th, 30th, and 40th cumulative percentiles all had the same consumption rate value (i.e., 8 g/day) (Table 9.6). Likewise, the 50th, 60th, and 70th percentiles had a 16 g/day value. Fitting a lognormal distribution to the empirical data smoothes the choppy empirical distribution. Though the empirical distribution was appropriate for the sample, the lognormally fit distribution is likely more realistic for the population. For the empirical data, the unadjusted values are higher than the adjusted values because the correction for avidity bias is crucial to compensate for the increase of fish consumption rates with increased frequency (i.e., avidity) of fishing.

Figure 9-3



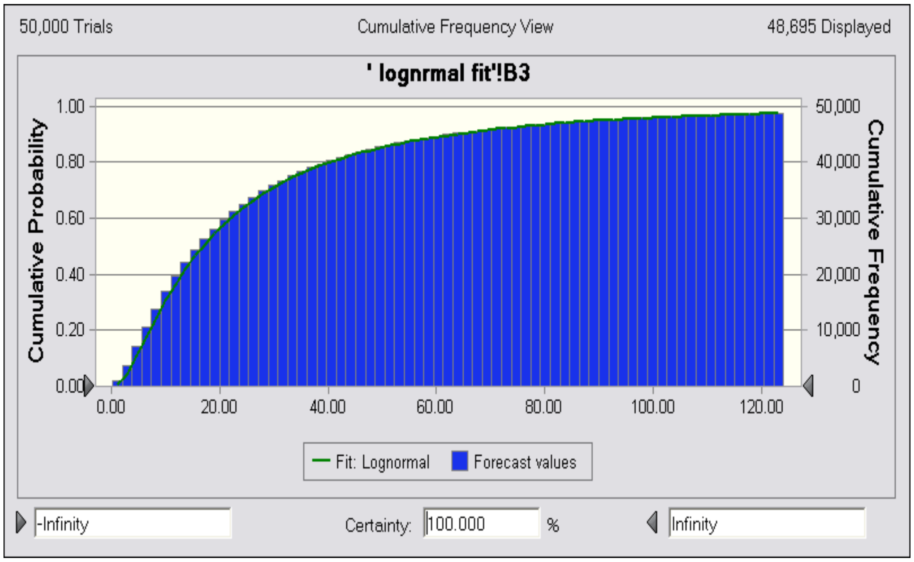
Data source: SFEI (2000)

Table 9.6 Comparison of Empirical Distributions and the Recommended Lognormal Model of Fish Consumption Rates for Stochastic Analysis

	Moments and Percentiles (g/day)		
	Empirical Distribution Unadjusted[a]	**Empirical Distribution Avidity-Bias Adjusted**[a]	**Lognormal Parametric Model Fit to Avidity-Bias Adjusted Data**
Geometric Mean	16.55	13.97	[b]
Arithmetic Mean	28.08	23.02	28.8
Standard Deviation	39.63	32.05	39.6
Skewness	3.9	[b]	6.7
Kurtosis	19.9	[b]	140.3
PERCENTILES			
Sample Minimum	2.00	2.00	0.0
10	5.33	4.00	4.5
20	8.00	8.00	7.1
30	8.00	8.00	9.9
40	12.00	8.00	13.0
50	16.00	16.00	16.9
60	16.00	16.00	22.0
70	24.00	16.00	29.0
80	36.00	32.00	40.3
90	56.00	48.00	63.4
95	108.00	80.00	92.4
99	[b]	[b]	177.0
Sample Maximum	324.00	324.00	[c]

[a] Data from SFEI (2000), Appendix K, Table K29
[b] Not Reported
[c] Not Applicable

Figure 9-4 Cumulative Probability of Avidity Adjusted Fish Consumption Rates (g/day) fit to a Lognormal Distribution



9.9 References

Allen MJ, Velez PV, Diehl DW, McFadden SE and Kelsh M (1996). Demographic variability in seafood consumption rates among recreational anglers of Santa Monica Bay, California, in 1991-1992. Fishery Bulletin 94(4): 597-610.

Anderson HA, Hanrahan LP, Smith A, Draheim L, Kanarek M and Olsen J (2004). The role of sport-fish consumption advisories in mercury risk communication: a 1998-1999 12-state survey of women age 18-45. Environ Res 95(3): 315-24.

Burger J (2000). Gender differences in meal patterns: role of self-caught fish and wild game in meat and fish diets. Environ Res 83(2): 140-9.

Decisioneering (2008). Crystal Ball, Version 11, Fusion Edition, Oracle Corporation, Redwood Shores, CA.

Harnly M, Seidel S, Rojas P, Fornes R, Flessel P, Smith D, Kreutzer R and Goldman L (1997). Biological monitoring for mercury within a community with soil and fish contamination. Environ Health Perspect 105(4): 424-9.

Imm P, Knobeloch L and Anderson HA (2007). Maternal recall of children's consumption of commercial and sport-caught fish: findings from a multi-state study. Environ Res 103(2): 198-204.

Mayfield DB, Robinson S and Simmonds J (2007). Survey of fish consumption patterns of King County (Washington) recreational anglers. J Expo Sci Environ Epidemiol 17(7): 604-12.

Meredith EK and Malvestuto SP (1996). Evaluation of two on-site survey methods for determining daily per capita freshwater fish consumption by anglers. Am Fisheries Soc Symp 16: 271-6.

Murray DM and Burmaster DE (1994). Estimated distribution for average daily consumption of total and self-caught fish for adults in Michigan angler households. Risk Analysis 14(4): 513-9.

Nadon S, Kosatsky T and Przybysz R (2002). Contaminant exposure among women of childbearing age who eat St. Lawrence River sport fish. Arch Environ Health 57(5): 473-81.

OEHHA (2000). Air Toxics Hot Spots Program Risk Assessment Guidelines. Part IV. Exposure Assessment and Stochastic Technical Support Document. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Sacramento, CA. Available online at: http://www.oehha.ca.gov.

OEHHA (2001). Chemicals in Fish: Consumption of Fish and Shellfish in California and the United States. Final Report. Pesticide and Environmental Toxicology Section, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency. Available online at: www.oehha.ca.gov/fish/pdf/Fishconsumptionrpt.pdf.

OEHHA (2009). Technical Support Document for Cancer Potency Factors:Methodologies for derivation, listing of available values, and adjustments to allow for early life stage exposures. California Environmental Protection Agency, Office of Environrmental Health Hazard Assessment. Online at:http://www.oehha.ca.gov/air/hot_spots/2009/TSDCancerPotency.pdf.

Price PS, Su HS and Gray MN (1994). The effect of sampling bias on estimates of angler consumption rates in creel surveys. J Expo Anal Environ Epidemiol 4(3): 355-71.

Puffer HW, Azen SP, Duda MJ and Young DR (1982b). Consumption Rates of Potentially Hazardous Marine Fish Caught in the Metropolitan Los Angeles Area. Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Corvallis, Oregon. Report No. EPA-600/3-82-070.

Puffer HW, Azen SP and Young DR (1982a). Potential health hazards from consumption of fish caught in polluted coastal waters of Los Angeles County. N Am J Fish Management 2: 74-9.

SCCWRP and MBC. (1994). *Santa Monica Bay Seafood Consumption Study. Final Report*. Santa Monica Restoration Project, Monterey Park, CA. Prepared by Southern California Coastal Water Research Project and MBC Applied Environmental Sciences.

SDCDHS. (1990). *San Diego Bay Health Risk Study*. June 12, 1990. San Diego County Department of Health Services. Prepared for Port of San Diego, San Diego, CA. Doc No 25467.

SFEI. (2000). *San Francisco Bay Seafood Consumption Report*. San Francisco Estuary Institute, Richmond CA. Available online at: http://www.sfei.org/node/2022.

Shilling F, White A, Lippert L and Lubell M (2010). Contaminated fish consumption in California's Central Valley Delta. Environ Res 110(4): 334-44.

Silver E, Kaslow J, Lee D, Lee S, Lynn Tan M, Weis E and Ujihara A (2007). Fish consumption and advisory awareness among low-income women in California's Sacramento-San Joaquin Delta. Environ Res 104(3): 410-9.

Toth JF and Brown RB (1997). Racial and gender meanings of why people participate in recreational fishing. Leisure Sci 19: 129-46.

U.S. EPA (1991). OSWER Directive 9285.6-03 Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors". PB91-921314.

U.S. EPA. (1997). *Exposure Factors Handbook*. Volume II - Food Ingestion Factors, Chapter 10 - Intake of Fish and Shellfish. United States Environmental Protection Agency, Washington DC, Doc No. EPA/600/P-95/002Fb. Available Online at: www.epa.gov/ncea/efh/pdfs/efh-chapter10.pdf.

U.S. EPA. (2000). *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories. Volume 2, Risk Assessment and Fish Consumption Limits, Third Edition*. United States Environmental Protection Agency, Washington DC. EPA823-B-00-008.

U.S. EPA. (2002). *Child-Specific Exposure Factors Handbook*. National Center for Environmental Assessment, United States Environmental Protection Agency, Washington DC, EPA/600/P-00/002B. Available online at: www.epa.gov/ncea.

West PC, Fly JM, Marnas R and Larkin F. (1989b). *Michigan Sport Anglers Fish Consumption Survey Supplement I, Non-Response Bias and Consumption Suppression Effect Adjustments: A Report to the Michigan Toxic Substance Control Commission*. September, 1989. University of Michigan, School of Natural Resources, Natural Resource Sociology Research Lab, Technical Report 2. Ann Arbor, MI.

West PC, Fly JM, Marnas R and Larkin F. (1989c). *Michigan Sport Anglers Fish Consumption Survey, Supplement II, Test for Stability of Consumption Rates Over Time: A Report to the Michigan Toxic Substance Control Commission.* . October, 1989. University of Michigan, School of Natural Resources, Natural Resource Sociology Research Laboratory Technical Report 3, Ann Arbor, MI

West PC, Fly JM, R. M and Larkin F. (1989a). *Michigan Sport Anglers Fish Consumption Survey: A Report to the Michigan Toxic Substance Control Commission.* May, 1989. University of Michigan, School of Natural Resources, Natural Resource Sociology Research Lab, Technical Report #1, Ann Arbor, MI

Wong K. (1997). Fishing for Food in San Francisco Bay: Part II. An Environmental Health and Safety Report from Save San Francisco Bay Association. Oakland, CA