DRAFT

HEALTH ADVISORY

SAFE EATING GUIDELINES FOR FISH FROM THE LOWER COSUMNES AND LOWER MOKELUMNE RIVERS (SACRAMENTO AND SAN JOAQUIN COUNTIES)

April 2006

Arnold Schwarzenegger
Governor
State of California

Dan Skopec
Acting Agency Secretary
California Environmental Protection Agency

Joan E. Denton, Ph.D.
Director
Office of Environmental Health Hazard Assessment

DRAFT

HEALTH ADVISORY

SAFE EATING GUIDELINES
FOR FISH FROM
THE LOWER COSUMNES AND
LOWER MOKELUMNE RIVERS
(SACRAMENTO AND
SAN JOAQUIN COUNTIES)

April 2006

Susan Klasing, Ph.D.
Margy Gassel, Ph.D.
Sue Roberts, M.S.
Robert Brodberg, Ph.D.

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

LIST OF CONTRIBUTORS

Reviewer
James Sanborn, Ph.D.

Final Reviewers
Anna Fan, Ph.D.
George Alexeeff, Ph.D.

ACKNOWLEDGEMENTS

We would like to acknowledge staff at the Central Valley Regional Water Quality Control Board, especially Michelle Wood and Janis Cooke, Ph.D., for coordinating and providing data. We acknowledge Shaun M. Ayers, Ph.D. and Darell G. Slotton, Ph.D., for providing data and technical information for studies conducted at the University of California at Davis. We appreciate the State Water Resources Control Board for providing useful data through the Toxic Substances Monitoring Program and the Surface Water Ambient Monitoring Program. Additionally, we thank Jay Davis, Ph.D., and Ben Greenfield, Ph.D., of the San Francisco Estuary Institute for providing data through the California Bay Delta Authority Mercury Project and California Bay Delta Authority Mercury in Fish Project.

FOREWORD

This health advisory provides safe eating guidelines for consumption of various fish species taken from the lower Cosumnes and Mokelumne rivers in Sacramento and San Joaquin counties, respectively. These guidelines were developed as a result of findings of high mercury levels in certain fish tested from this region and are provided to protect against possible adverse health effects from methylmercury as consumed from mercury-contaminated fish. Fish or shellfish with low mercury levels considered safe to eat frequently are also noted in the guidelines. This report provides background information and a description of the data and criteria used to develop the guidelines. Once completed, the guidelines contained herein will become the final state advisory.

For further information, contact:
Pesticide and Environmental Toxicology Branch
Office of Environmental Health Hazard Assessment
California Environmental Protection Agency
1515 Clay Street, 16th Floor
Oakland, California 94612
Telephone: (510) 622-3170

OR:

Pesticide and Environmental Toxicology Branch
Office of Environmental Health Hazard Assessment
California Environmental Protection Agency
1001 I Street, P.O. Box 4010
Sacramento, CA 95812-4010
Telephone: (916) 327-7319

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Mercury levels were evaluated in edible tissue of fish caught from the lower Cosumnes and Mokelumne rivers in Sacramento and San Joaquin counties, respectively, areas possibly affected by historic gold mining. Fish were collected and analyzed through the Toxic Substances Monitoring Program (TSMP), the CALFED Mercury Project, and the University of California at Davis (UCD). A number of chlorinated hydrocarbon contaminants, including DDTs and PCBs, were also measured in fish and obtained through the Delta-San Joaquin Study and the National Water Quality Assessment Program. Data were evaluated by the Office of Environmental Health Hazard Assessment (OEHHA) in an effort to determine whether there may be potential adverse health effects associated with the consumption of sport fish from these water bodies.

Almost all fish contain detectible levels of mercury, more than 95 percent of which occurs as methylmercury, a highly toxic form of the element. Consumption of fish is the major route of exposure to methylmercury in the United States. The critical target of methylmercury toxicity is the nervous system, particularly in developing organisms such as the fetus and young children. Significant methylmercury toxicity can occur to the fetus during pregnancy even in the absence of symptoms in the mother. In 1985, the United States Environmental Protection Agency (U.S. EPA) set a reference dose (RfD, that is the daily exposure likely to be without significant risk of deleterious effects during a lifetime) for methylmercury of $3x10^{-4}$ mg/kg-day, based on central nervous system effects (ataxia and paresthesias) in adults. In 1995, and confirmed in 2001, this RfD was lowered to $1x10^{-4}$mg/kg-day, based on developmental neurologic abnormalities in infants exposed *in utero*, using the Iraqi and Faroe Island data, respectively. OEHHA finds convincing evidence that the fetus is more sensitive than adults to the neurotoxic effects of mercury, but also recognizes that fish can play an important role in a healthy diet, particularly when it replaces other higher fat sources of protein. Numerous human and animal studies have shown that fish oils have beneficial cardiovascular and neurological effects. Because it is important to protect the most sensitive population without unduly restricting fish consumption in others, OEHHA chooses to use both the current and previous U.S. EPA reference doses for two distinct population groups. In these guidelines, the current RfD based on effects in infants will be used for women of childbearing age and children aged 17 and younger. The previous RfD, based on effects in adults, will be used for women beyond their childbearing years and men.

In order to provide safe eating guidelines for various fish species, contaminant concentrations in fish from a water body are compared to OEHHA guidance tissue levels (GTLs) for those chemicals. GTLs are used to provide meal consumption advice to prevent consumers from being exposed to more than the average daily reference dose for non-carcinogens or to a risk level greater than $1x10^{-4}$ for carcinogens. One or more data evaluation approaches are then used to develop site-specific (water body) consumption advice. Safe eating guidelines identify those fish species with higher contaminant levels whose consumption should be restricted (see the “Eat in Moderation” table) or avoided altogether (see the “Avoid” table), as well as those low-contaminant fish that may be consumed frequently as part of a healthy diet (see the “Enjoy” table). A statistically representative sample size was available to provide safe eating guidelines for the Cosumnes River for largemouth bass, red swamp crayfish, and Asiatic clams. For the Mokelumne River, sample size was sufficient to develop safe eating guidelines for largemouth bass, bluegill, white catfish, signal crayfish, and Asiatic clams. Supporting data, such as mercury concentration for another species at a similar trophic level or for the same species in a nearby tributary, were used to develop additional consumption guidelines for other sport fish or shellfish, as appropriate.

All individuals, especially women of childbearing age and children aged 17 and younger, are advised to follow the safe eating guidelines to ensure that methylmercury ingestion does not exceed the reference dose. To help sport fish consumers achieve this goal, OEHHA has developed guidelines for all fish and shellfish species caught in the lower Cosumnes and lower Mokelumne rivers. Meal sizes should be adjusted to body weight as described in the safe eating guidelines table.

For general advice on how to limit your exposure to chemical contaminants in sport fish (e.g., eating smaller fish of legal size), as well as a fact sheet on methylmercury in sport fish, see the California Sport Fish Consumption Advisories (http://www.oehha.ca.gov/fish.html) and Appendices 1 and 2. Advice for other California water bodies can be found online at: http://www.oehha.ca.gov/fish/so_cal/index.html. It should be noted that, unlike the case for many chlorinated hydrocarbon contaminants, various cooking and cleaning techniques will not reduce the methylmercury content of fish.

SAFE EATING GUIDELINES

FISH AND SHELLFISH CONSUMPTION FROM THE LOWER COSUMNES RIVER AND NEARBY CREEKS AND SLOUGHS

Fish and shellfish are nutritious and should be part of a healthy, balanced diet. It is important, however, to choose your fish wisely. The American Heart Association recommends healthy adults eat at least two meals of fish a week. OEHHA recommends that you choose fish to eat that are low in mercury such as those in the "Enjoy" category. Because many types of fish from the lower Cosumnes River contain higher levels of mercury, OEHHA provides the recommendations below that you can follow to reduce the risks from exposure to methylmercury in fish.

Women of childbearing age, pregnant or breastfeeding women, and children 17 years and under

AVOID DO NOT EAT MORE THAN THE AMOUNT LISTED BELOW:	
DO NOT EAT	Largemouth, smallmouth or spotted bass; or Sacramento pikeminnow
NO MORE THAN 1 MEAL A MONTH	All other fish or crayfish species*

***Asiatic clams may be eaten up to 3 times a week

Women beyond childbearing age and men

ENJOY UP TO 2 MEALS A WEEK
Bluegill or redear sunfish or Asiatic clams
EAT IN MODERATION **NO MORE THAN 1 MEAL A WEEK**
Crayfish or Sacramento sucker or white catfish
AVOID **NO MORE THAN 1 MEAL A MONTH**
Largemouth, smallmouth or spotted bass; or Sacramento pikeminnow

- **EVERYONE FOLLOW THE STRIPED BASS ADVISORY FOR DELTA WATER BODIES.** WOMEN OF CHILDBEARING AGE AND CHILDREN 17 YEARS AND YOUNGER: no more than one meal per month and none over 27 inches. WOMEN BEYOND CHILDBEARING AGE AND MEN: no more than two meals per month and none over 35 inches.
- **CONTACT WITH THE WATER IS SAFE.**
- **EAT SMALLER FISH OF LEGAL SIZE**. Fish build up mercury in their bodies as they grow.
- **MEAL SIZE DEPENDS ON BODY WEIGHT.** Meals are based on a 160 lb adult eating 8 ounces of fish (6 ounces after cooking)—about the size of two decks of cards. If you weigh less than 160 lbs, eat smaller portions of fish. Serve smaller meals to children.
- **DO NOT EAT MORE THAN ONE OF THE LISTED FISH SPECIES DURING THE SAME TIME PERIOD** unless you are only eating from the Enjoy (green) category. If you eat fish from one place, following the advisory, avoid eating fish from other sources during the same time period.
- **CONSIDER THE FISH YOU BUY FROM STORES AND RESTAURANTS.** Women of childbearing age and children can safely eat up to 2 meals a week of a variety of fish purchased from a store or restaurant, **OR** use this guide for eating fish caught from this water body. In a week when you eat 2 meals of fish purchased from stores or restaurants, avoid eating fish caught from a local water body. Commercial fish such as shrimp, king crab, scallops, farmed catfish, wild ocean salmon, oysters, tilapia, flounder, and sole generally contain some of the lowest levels of mercury. Women of childbearing age and children should not eat SHARK OR SWORDFISH.
- **FISH FROM OTHER WATER BODIES MAY ALSO CONTAIN MERCURY**. Not all water bodies in California have been tested. With the exception of ocean or river-run salmon and steelhead, which generally contain low levels of contaminants, fish caught from places without an advisory should be eaten in limited amounts.

SAFE EATING GUIDELINES

FISH AND SHELLFISH CONSUMPTION FROM THE LOWER MOKELUMNE RIVER AND NEARBY CREEKS AND SLOUGHS

Fish and shellfish are nutritious and should be part of a healthy, balanced diet. It is important, however, to choose your fish wisely. The American Heart Association recommends healthy adults eat at least two meals of fish a week. OEHHA recommends that you choose fish to eat that are low in mercury such as those in the "Enjoy" category. Because many types of fish from the lower Mokelumne River contain higher levels of mercury, OEHHA provides the recommendations below that you can follow to reduce the risks from exposure to methylmercury in fish.

Women of childbearing age, pregnant or breastfeeding women, and children 17 years and under

EAT IN MODERATION **NO MORE THAN 1 MEAL A WEEK**
Crayfish*
AVOID **DO NOT EAT MORE THAN 1 MEAL A MONTH**
All fish species

*****Asiatic clams may be eaten up to 3 times a week

Women beyond childbearing age and men

ENJOY **UP TO 2 MEALS A WEEK**
Crayfish or bluegill or Sacramento sucker or white catfish or Asiatic clams*
AVOID **NO MORE THAN 1 MEAL A MONTH**
Largemouth, smallmouth or spotted bass; or Sacramento pikeminnow

*****Asiatic clams may be eaten up to 3 times a week

- **EVERYONE FOLLOW THE STRIPED BASS ADVISORY FOR DELTA WATER BODIES.** WOMEN OF CHILDBEARING AGE AND CHILDREN 17 YEARS AND YOUNGER: no more than one meal per month and none over 27 inches. WOMEN BEYOND CHILDBEARING AGE AND MEN: no more than two meals per month and none over 35 inches.
- **CONTACT WITH THE WATER IS SAFE.**
- **EAT SMALLER FISH OF LEGAL SIZE**. Fish build up mercury in their bodies as they grow.
- **MEAL SIZE DEPENDS ON BODY WEIGHT.** Meals are based on a 160 lb adult eating 8 ounces of fish (6 ounces after cooking)—about the size of two decks of cards. If you weigh less than 160 lbs, eat smaller portions of fish. Serve smaller meals to children.
- **DO NOT EAT MORE THAN ONE OF THE LISTED FISH SPECIES DURING THE SAME TIME PERIOD** unless you are eating from the Enjoy (green) category. If you eat fish from one place, following the advisory, avoid eating fish from other sources during the same time period.
- **CONSIDER THE FISH YOU BUY FROM STORES AND RESTAURANTS.** Women of childbearing age and children can safely eat up to 2 meals a week of a variety of fish purchased from a store or restaurant, **OR** use this guide for eating fish caught from this water body. In a week when you eat 2 meals of fish purchased from stores or restaurants, avoid eating fish caught from a local water body. Commercial fish such as shrimp, king crab, scallops, farmed catfish, wild ocean salmon, oysters, tilapia, flounder, and sole generally contain some of the lowest levels of mercury. Women of childbearing age and children should not eat SHARK OR SWORDFISH.
- **FISH FROM OTHER WATER BODIES MAY ALSO CONTAIN MERCURY**. Not all water bodies in California have been tested. With the exception of ocean or river-run salmon and steelhead, which generally contain low levels of contaminants, fish caught from places without an advisory should be eaten in limited amounts.

LOWER COSUMNES AND LOWER MOKELUMNE SPORT FISH

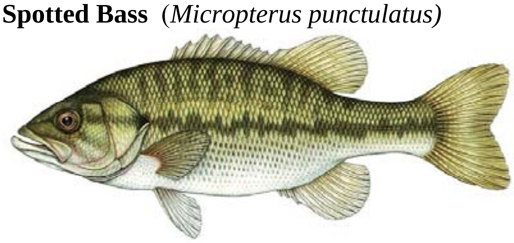
Largemouth Bass *(Micropterus salmoides)*

Duane Raver, USFWS

Smallmouth Bass (*Micropterus dolomieu*)

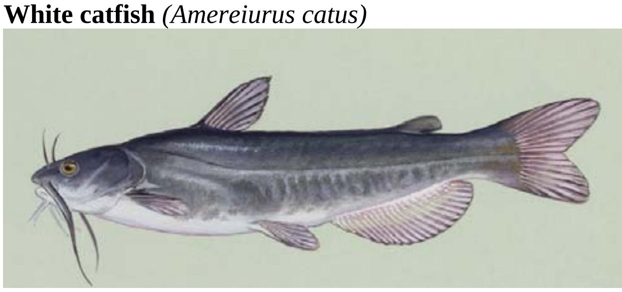
Duane Raver, USFWS

Spotted Bass (*Micropterus punctulatus)*



© 2005 ODNR, Division of Wildlife

White catfish *(Amereiurus catus)*



Duane Raver, USFWS

Sacramento Pikeminnow *(Ptychocheilus grandis)*

Rene' Reyes, USBR

Sacramento Sucker *(Catostomus occidentalis)*

Rene' Reyes, USBR

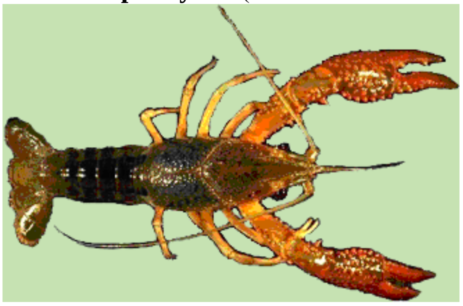
Bluegill *(Lepomis macrochirus)*

Duane Raver, USFWS

Redear Sunfish (*Lepomis microlophus)*

Duane Raver, USFWS

Red swamp crayfish (*Procambarus clarkii*)

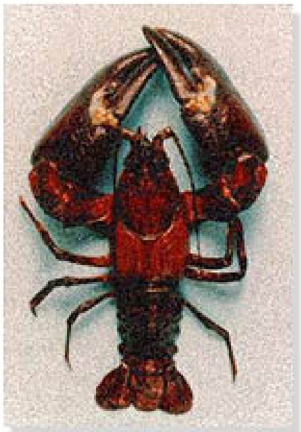


© Keith A. Crandall

Signal crayfish (*Pacifastacus leniusculs*)

© James W. Fetzner Jr.

Showing variation:



© 1995 David Holdich

Note: Pictures are not to scale

INTRODUCTION

Mercury contamination of fish is a national problem that has resulted in the issuance of fish consumption advisories in most states, including California (U.S. EPA, 2003). Mercury enters the environment from the breakdown of minerals in rocks and leaching from old mine sites. It is also emitted into air from mining deposits, the burning of fossil fuels, and other industrial sources, as well as from volcanic emissions. Mercury contamination thus occurs as a result of both natural and anthropogenic sources and processes. Once mercury is released into the environment, it cycles through land, air, and water. The deposition of mercury in aquatic ecosystems is a concern for public and environmental health because microorganisms (bacteria and fungi) in the sediments can convert inorganic mercury into organic methylmercury, a particularly toxic form of mercury. Once formed, methylmercury accumulates or "biomagnifies" in the aquatic food chain, reaching the highest levels in fish and other organisms at the top of the food web.

Elevated levels of mercury associated with historic gold and mercury mining have been found in fish in numerous reservoirs and stream sites in northern California (see, e.g., May et al., 2000; Alpers et al., 2004). As a result, fish consumption advisories based on mercury contamination have been issued by the Office of Environmental Health Hazard Assessment (OEHHA) for various water bodies in Nevada, Placer, Yuba, Glenn, Tehama, Lake, Yolo, Trinity, Colusa, Napa, Solano, Sacramento, and Santa Clara Counties. In an effort to assess mercury and select chlorinated hydrocarbon (e.g., pesticides and PCBs) levels in fish from other northern California water bodies that may have been impacted by mining or other human activities, samples collected from the Cosumnes and Mokelumne Rivers (see Figure 1) by the Toxic Substances Monitoring Program (TSMP; which is now included under the Surface Water Ambient Monitoring Program [SWAMP] of the State Water Resources Control Board), the CALFED Mercury Project, the Delta-San Joaquin Study, the National Water Quality Assessment Program, and researchers from UC Davis were evaluated. The safe eating guidelines included herein are based on the potential exposure to methylmercury through consumption of certain fish from these areas and seek to minimize the associated potential health risks of such exposure (see "Avoid" and "Eat in Moderation" tables). Although almost all sport and commercial fish contain measurable levels of mercury, exposure can reach unacceptable levels in some species, particularly in areas where local mercury contamination is a problem. Safe eating guidelines also include information about fish with low levels of mercury considered safe to eat frequently (see the "Enjoy" table for the Mokelumne River).

OEHHA is the agency responsible for evaluating potential public health risks from chemical contamination of sport fish. This includes issuing advisories, when appropriate, for the State of California. OEHHA's authorities to conduct these activities are based on mandates in the California Health and Safety Code, Section 59009, to protect public health, and Section 59011, to advise local health authorities, and the California Water Code Section 13177.5, to issue health advisories. Fish advisories developed by OEHHA are published in the California Sport Fishing Regulations and California Sport Fish Consumption Advisories. OEHHA now emphasizes "safe eating guidelines" as part of health advisories in an effort to inform consumers of healthy choices in fish consumption as well as those that should be avoided or restricted.

In evaluating the TSMP, CALFED Mercury Project, Delta-San Joaquin Study, National Water Quality Assessment Program, and UC Davis data, it was determined that some fish species in the Cosumnes and Mokelumne Rivers had sufficient levels of mercury that could be a concern for sport fish consumers. Recent levels of chlorinated hydrocarbon pesticides and PCBs found in a limited number of fish samples were not of concern. Because fish consumption advice was not currently in place in these rivers, development of safe eating guidelines was deemed appropriate.

BACKGROUND

The Cosumnes River is a tributary of the Mokelumne River, the lower reaches of which run through Sacramento and San Joaquin counties, respectively. For the purpose of this advisory, the lower Cosumnes River was defined as the entirety of the river within Sacramento County while the lower Mokelumne River was defined as both forks of the Mokelumne River downstream of Camanche Reservoir to the confluence of the San Joaquin River. These rivers were the site of the historic Camanche-Lancha Plana and Michigan Bar gold mining districts, where hydraulic and dredge mining operations took place from the gold rush until about 1940 (Clark, 1998). Mercury was often used in these processes to aid in the recovery of gold (Hunerlach and Alpers, 2003) and, as a result, may have contaminated the rivers as well as nearby streams and creeks.

The foothill and Delta regions through which these rivers run are important sport fishing areas in the state. The Cosumnes River Preserve is located on the lower Cosumnes River and is a habitat for a variety of sport fish species including black bass, crappie, sunfish, catfish, bluegill, and Chinook salmon (UCD, 1996). Fishing is only allowed from a boat within the perimeter of the preserve. The lower Mokelumne River and nearby sloughs, which lie within the Delta boundary, are known for striped bass, Chinook salmon, catfish, and black bass fishing (Fish Sniffer, 2000).

As noted above, mercury data used in this report originated from three different sources: TSMP[1], the CALFED Mercury Project[2] (Davis et al., 2003), and UC Davis (Slotton et al., 2002). Data were organized into a single electronic database in 2003 by the Central Valley Regional Water Quality Control Board (CVRWQCB); some corrections were made to originally published data at that time. Subsequently, OEHHA obtained the database from the CVRWQCB and made additional quality control revisions. The amended database was then used for preparation of these safe eating guidelines; data are referred to in the text and tables by their primary source (i.e., TSMP, CALFED or UC Davis). For legal and/or edible size fish (see criteria in footnotes of Tables 1 and 2), a total of seven sport fish species were collected by electrofishing equipment or gill nets from 1978 to 2000 at 15 sites along the Cosumnes and Mokelumne rivers and Sycamore Slough. Three species of shellfish were also collected. Species collected included largemouth bass, white catfish, Sacramento pikeminnow, Sacramento sucker, black bullhead, bluegill, redear sunfish, signal crayfish, red swamp crayfish, and Asiatic clams. Fish and shellfish were measured and/or weighed; boneless and skinless fillets, soft tissues (clams), or tail

---

[1] TSMP, a state water quality-monitoring program managed by the State Water Resources Control Board, was initiated in 1976 and continued until it was subsumed under SWAMP in 1997. The California Department of Fish and Game collects and analyzes the samples.
[2] The CALFED Mercury Project was funded by the CALFED Bay-Delta Program to investigate mercury cycling in the Bay-Delta System.

muscle tissues (crayfish) were submitted as individuals or composites to the California Department of Fish and Game (CDFG) Water Pollution Control Laboratory (TSMP samples), Moss Landing Marine Laboratories (TSMP and CALFED samples) or UC Davis. Mercury levels were determined by cold-vapor atomic absorption spectroscopy.

Several chlorinated hydrocarbon contaminants, including chlordane, DDTs, and PCBs, were also measured in samples of largemouth bass, brown bullhead, black bullhead, carp, white catfish, crayfish, and Asiatic clams collected from the Mokelumne River by the Delta-San Joaquin Study (Davis et al., 2000), TSMP or the United States Geological Survey National Water Quality Assessment Program (Brown, 1998). Homogenized tissue was analyzed by gas chromatography, using mass spectrometry (GC/MS) for chlorinated hydrocarbon determination. Mean values of these chemicals for each species (data not shown) were below OEHHA's screening values (Brodberg and Pollock, 1999) used to determine whether further evaluation or site-specific advice should be considered. As such, only mercury data were considered for these guidelines.

It is not possible to determine in advance how many samples of each fish species from each site will be necessary in order to statistically interpret contamination data for safe eating guidelines. However, U.S. EPA does recommend a minimum of three replicate composite samples of three fish per composite (nine total fish) in order to begin assessing the magnitude of contamination at a site. U.S. EPA also recommends that at least two fish species be sampled per site. Although composite analysis is generally the most cost-efficient method of estimating the average concentration of chemicals in a fish species, individual sampling provides a better measure of the range and variability of contaminant levels in a fish population (U.S. EPA, 2000a). Using these guidelines, OEHHA believes that a minimum of three replicates of three fish per composite or, preferably, nine individual fish samples of multiple species from each site should be analyzed for this type of pilot study. Fish samples should be collected from multiple (legal/edible-) size classes. Following this sampling protocol will allow estimation of the range and variation of contaminant concentrations at a particular site and derivation of a representative mean concentration for use in developing fish consumption advisories. More samples will provide a better estimate of the mean contaminant level in various fish species and are especially important for large water bodies.

Of the samples collected from the Cosumnes River, Asiatic clams ($n = 77$), largemouth bass ($n = 18$), redear sunfish ($n = 13$), and red swamp crayfish ($n = 21$) had sufficient sample size (≥ 9 fish per species) of legal/edible size fish (see Table 1) to be considered representative of mercury levels in those species, thereby allowing adequate estimation of the health risks associated with their consumption. For the Mokelumne River, Asiatic clams ($n = 105$), bluegill ($n = 25$), largemouth bass ($n = 37$), signal crayfish ($n = 83$), and white catfish ($n = 10$) were analyzed in adequate numbers to perform a health risk assessment (see Table 2). Interpretation of data for other fish species when there is a limited sample size can be found in the guidelines for fish consumption section of this report.

METHYLMERCURY TOXICOLOGY

Mercury is a metal found naturally in rocks, soil, air, and water that can be concentrated to high levels in the aquatic food chain by a combination of natural processes and human activities

(ATSDR, 1999). The toxicity of mercury to humans is greatly dependent on its chemical form (elemental, inorganic, or organic) and route of exposure (oral, dermal, or inhalation). Methylmercury (an organic form) is highly toxic and can pose a variety of human health risks (NAS/NRC, 2000). Of the total amount of mercury found in fish muscle tissue, methylmercury comprises more than 95 percent (ATSDR, 1999; Bloom, 1992). Because analysis of total mercury is less expensive than that for methylmercury, total mercury is usually analyzed for most fish studies. In this study, total mercury was measured and assumed to be 100 percent methylmercury for the purposes of risk assessment.

Fish consumption is the major route of exposure to methylmercury in the United States (ATSDR, 1999). As noted above, almost all fish contain detectable levels of methylmercury, which, when ingested, is almost completely absorbed from the gastrointestinal tract (Aberg et al., 1969; Myers et al., 2000). Once absorbed, methylmercury is distributed throughout the body, reaching the largest concentration in kidneys. Its ability to cross the placenta as well as the blood brain barrier allows methylmercury to accumulate in the brain and fetus, which are known to be especially sensitive to the toxic effects of this chemical (ATSDR, 1999). In the body, methylmercury is slowly converted to inorganic mercury and excreted predominantly by the fecal (biliary) pathway. Methylmercury is also excreted in breast milk (ATSDR, 1999). The biological half-life of methylmercury is approximately 44-74 days in humans (Aberg, 1969; Smith et al., 1994), meaning that it takes approximately 44-74 days for one-half of a single ingested dose of methylmercury to be eliminated from the body.

Human toxicity of methylmercury has been well studied following several epidemics of human poisoning resulting from consumption of highly contaminated fish (Japan) or seed grain (Iraq, Guatemala, and Pakistan) (Elhassani, 1982-83). The first recorded mass methylmercury poisoning occurred in the 1950s and 1960s in Minamata, Japan, following the consumption of fish contaminated by industrial pollution (Marsh, 1987). The resulting illness was manifested largely by neurological signs and symptoms such as loss of sensation in the hands and feet, loss of gait coordination, slurred speech, sensory deficits including blindness, and mental disturbances (Bakir et al., 1973; Marsh, 1987). This syndrome was subsequently named Minamata Disease. A second outbreak of methylmercury poisoning occurred in Niigata, Japan, in the mid-1960s. In that case, contaminated fish were also the source of illness (Marsh, 1987). In all, more than 2,000 cases of methylmercury poisoning were reported in Japan, including more than 900 deaths (Mishima, 1992).

The largest outbreak of methylmercury poisoning occurred in Iraq in 1971-1972 and resulted from consumption of bread made from seed grain treated with a methylmercury fungicide (Bakir et al., 1973). This epidemic occurred over a relatively short term (several months) compared to the Japanese outbreak. The mean methylmercury concentration of wheat flour samples was found to be 9.1 micrograms per gram (μg/g). Over 6,500 people were hospitalized, with 459 fatalities. Signs and symptoms of methylmercury toxicity were similar to those reported in the Japanese epidemic.

Review of data collected during and subsequent to the Japan and Iraq outbreaks identified the critical target of methylmercury as the nervous system and the most sensitive subpopulation as the developing organism (U.S. EPA, 1997). During critical periods of prenatal and postnatal structural and functional development, the fetus and children are especially susceptible to the toxic effects of methylmercury (ATSDR, 1999; IRIS, 1995). When maternal methylmercury consumption is very high, as happened in Japan and Iraq, significant methylmercury toxicity can occur to the fetus during pregnancy, with only very mild or even in the absence of symptoms in the mother. In those cases, symptoms in children are often not recognized until development of cerebral palsy and/or mental retardation many months after birth (Harada, 1978; Marsh et al., 1980; Marsh et al., 1987; Matsumoto et al., 1964; Snyder, 1971).

The International Agency for Research on Cancer (IARC) has listed methylmercury compounds as possible human carcinogens, based on inadequate data in humans and limited evidence in experimental animals (increased incidence of tumors in mice exposed to methylmercury chloride) (IARC, 1993). Based on IARC's evaluation, OEHHA has administratively listed methylmercury compounds on the Proposition 65 list of chemicals known to the State of California to cause cancer. No estimate of the increased cancer risk from lifetime exposure has been developed for methylmercury.

DERIVATION OF REFERENCE DOSES FOR METHYLMERCURY

A reference dose (RfD) is an estimate of daily human exposure to a chemical that is likely to be without significant risk of adverse effects during a lifetime (including to sensitive population subgroups), expressed in units of mg/kg-day (IRIS, 1995). This estimate includes a safety factor to account for data uncertainty. The underlying assumption of a reference dose is that, unlike carcinogenic effects, there is a threshold dose below which certain toxic effects will not occur. The reference dose for a particular chemical is derived from review of relevant toxicological and epidemiological studies in animals and/or humans. These studies are used to determine a No-Observed-Adverse-Effect-Level (NOAEL; the highest dose at which no adverse effect is seen), a Lowest-Observed-Adverse-Effect-Level (LOAEL; the lowest dose at which any adverse effect is seen), or a benchmark dose level (BMDL; a statistical lower confidence limit of a dose that produces a certain percent change in the risk of an adverse effect) (IRIS, 1995). Based on these values and the application of uncertainty factors to account for incomplete data and sensitive subgroups of the population, a reference dose is then generated. Exposure to a level above the RfD does not mean that adverse effects will occur, only that the possibility of adverse effects occurring has increased (IRIS, 1993).

The first U.S. EPA RfD for methylmercury was developed in 1985 and set at 3×10^{-4} mg/kg-day (U.S. EPA, 1997). This RfD was based, in part, on a World Health Organization (WHO) report summarizing data obtained from several early epidemiological studies on the Iraqi and Japanese methylmercury poisoning outbreaks (WHO, 1976). WHO found that the earliest symptoms of methylmercury intoxication (paresthesias) were reported at blood and hair concentrations ranging from 200-500 µg/L and 50-125 µg/g, respectively, in adults. In cases where ingested mercury dose could be estimated (based, for example, mercury concentration in contaminated bread and number of loaves consumed daily), an empirical correlation between blood and/or hair mercury concentrations and onset of symptoms was obtained. From these studies, WHO determined that methylmercury exposure equivalent to long-term daily intake of 3-7 µg/kg body weight in adults was associated with an approximately 5 percent prevalence of paresthesias (WHO, 1976). U.S. EPA further cited a study by Clarkson et al. (1976) to support the range of blood mercury concentrations at which paresthesias were first observed in sensitive members of the adult population. This study found that a small percentage of Iraqi adults exposed to methylmercury-treated seed grain developed paresthesias at blood levels ranging from 240 to 480 µg/L. The low end of this range was considered to be a LOAEL and was estimated to be equivalent to a dosage of 3 µg/kg-day. U.S. EPA applied a 10-fold uncertainty factor to the LOAEL to reach what was expected to be the NOAEL. Because the LOAEL was observed in sensitive individuals in the population after chronic exposure, additional uncertainty factors were not considered necessary for exposed adults (U.S. EPA, 1997).

Although this RfD was derived based on effects in adults, even at that time researchers were aware that the fetus might be more sensitive to methylmercury (WHO, 1976). It was not until 1995, however, that U.S. EPA had sufficient data from Marsh et al. (1987) and Seafood Safety (1991) to develop an oral RfD based on methylmercury exposures during the prenatal stage of development (IRIS, 1995). Marsh et al. (1987) collected and summarized data from 81 mother and child pairs where the child had been exposed to methylmercury *in utero* during the Iraqi epidemic. Maximum mercury concentrations in maternal hair during gestation were correlated with clinical signs in the offspring such as cerebral palsy, altered muscle tone and deep tendon reflexes, and delayed developmental milestones that were observed over a period of several years after the poisoning. Clinical effects incidence tables included in the critique of the risk assessment for methylmercury conducted by U.S. FDA (Seafood Safety, 1991) provided dose-response data for a benchmark dose approach to the RfD, rather than the previously used NOAEL/LOAEL method. The BMDL was based on a maternal hair mercury concentration of 11 parts per million (ppm). From that, an average blood mercury concentration of 44 µg/L was estimated based on a hair: blood concentration ratio of 250:1. Blood mercury concentration was, in turn, used to calculate a daily oral dose of 1.1 µg/kg-day, using an equation that assumed steady-state conditions and first-order kinetics for mercury. An uncertainty factor of 10 was applied to this dose to account for variability in the biological half-life of methylmercury, the lack of a two-generation reproductive study and insufficient data on the effects of exposure duration on developmental neurotoxicity and adult paresthesias. The oral RfD was then calculated to be $1x10^{-4}$ mg/kg-day, to protect against developmental neurological abnormalities in infants (IRIS, 1995). This fetal RfD was deemed protective of infants and sensitive adults.

The two previous RfDs for methylmercury were developed using data from high-dose poisoning events. Recently, the National Academy of Sciences was directed to provide scientific guidance to U.S. EPA on the development of a new RfD for methylmercury (NAS/NRC, 2000). Three large prospective epidemiological studies were evaluated in an attempt to provide more precise dose-response estimates for methylmercury at chronic low-dose exposures, such as might be expected to occur in the United States. The three studies were conducted in the Seychelles Islands (Davidson et al., 1995, 1998), the Faroe Islands (Grandjean et al., 1997, 1998, 1999), and New Zealand (Kjellstrom et al., 1986, 1989). The residents of these areas were selected for study because their diets rely heavily on consumption of fish and marine mammals, which provide a continual source of methylmercury exposure (NAS/NRC, 2000).

Although estimated prenatal methylmercury exposures were similar among the three studies, subtle neurobehavioral effects in children were found to be associated with maternal methylmercury dose in the Faroe Islands and New Zealand studies, but not in the Seychelle

Islands study. The reasons for this discrepancy were unclear; however, it may have resulted from differences in sources of exposure (marine mammals and/or fish), differences in exposure pattern, differences in neurobehavioral tests administered and age at testing, the effects of confounding variables, or issues of statistical analysis (NRC/NAS, 2000). The National Academy of Sciences report supported the current U.S. EPA RfD of $1x10^{-4}$ mg/kg-day for fetuses, but suggested that it should be based on the Faroe Islands study rather than Iraqi data.

U.S. EPA has published an updated RfD document that arrives at the same numerical RfD as the previous fetal RfD, using data from all three recent epidemiological studies while placing emphasis on the Faroe Island data (IRIS, 2001). In order to develop an RfD, U.S. EPA used several test scores from the Faroes data, rather than a single measure for the critical endpoint as is customary (IRIS, 2001). U.S. EPA developed BMDLs utilizing test scores for several different neuropsychological effects with cord blood as the preferred biomarker. The BMDLs for different neuropsychological effects in the Faroes study ranged from 46-79 µg mercury/liter blood. U.S. EPA then chose a one-compartment model for conversion of cord blood to ingested maternal dose, which resulted in estimated maternal mercury exposures of 0.857-1.472 µg/kg-day (IRIS, 2001). An uncertainty factor of ten was applied to the oral doses corresponding to the range of BMDLs to account for interindividual toxicokinetic variability in ingested dose estimation from cord-blood mercury levels and pharmacodynamic variability and uncertainty, leading to an RfD of $1x10^{-4}$ mg/kg-day (IRIS, 2001). In support of this RfD, U.S. EPA found that benchmark dose analysis of several neuropsychological endpoints from the Faroe Island and New Zealand studies, as well as an integrative analysis of all three epidemiological studies, converged on an RfD of $1x10^{-4}$ mg/kg-day (IRIS, 2001). U.S. EPA (IRIS, 2001) now considers this RfD to be protective for all populations. However, in their joint Federal Advisory for Mercury in Fish, U.S. EPA and U.S. FDA only apply this RfD to women who are pregnant or might become pregnant, nursing mothers, and young children (U.S. EPA, 2004) (see Guidelines for Fish Consumption section for further details).

OEHHA finds that there is convincing evidence that the fetus is more sensitive than adults to the neurotoxic and subtle neuropsychological effects of methylmercury. As noted previously, during the Japanese and Iraqi methylmercury poisoning outbreaks, significant neurological toxicity occurred to the fetus even in the absence of symptoms in the mother. In later epidemiological studies at lower exposure levels (e.g., in the Faroe Islands), these differences in maternal and fetal susceptibility to methylmercury toxicity were also observed. Recent evidence has shown that the nervous system continues to develop through adolescence (see, for example, Giedd et al., 1999; Paus et al., 1999; Rice and Barone, 2000). As such, it is likely that exposure to a neurotoxic agent during this time may damage neural structure and function (Adams et al., 2000), which may not become evident for many years (Rice and Barone, 2000). Thus, OEHHA considers the RfD based on subtle neuropsychological effects following fetal exposure to be the best estimate of a protective daily exposure level for pregnant or nursing women and children aged 17 years and younger.

OEHHA also recognizes that fish can play an important role in a healthy diet, particularly when it replaces other higher fat sources of protein. Numerous human and animal studies have shown that fish oils have beneficial cardiovascular and neurological effects (see, for example, Harris and Isley, 2001; Iso et al., 2001; Cheruka et al., 2002; Mori and Beilin et al., 2001; Daviglus et al., 1997; von Schacky et al., 1999; Valagussa et al., 1999; Moriguchi et al., 2000; Lim and Suzuki, 2000). Nonetheless, the hazards of methylmercury that may be present in fish, particularly to developing fetuses and children, cannot be overlooked. When contaminants are present in a specific food that can be differentially avoided, it is not necessary to treat all populations in the most conservative manner to protect the most sensitive population. Sport fish consumption advisories are such a case. Exposure advice can be tailored to specific risks and benefits for populations with different susceptibilities so that each population is protected without undue burden to the other. Fish consumption guidelines utilize the best scientific data available to provide the most relevant advice and protection for all potential consumers.

In an effort to address the risks of methylmercury contamination in different populations as well as the cardiovascular and neurological benefits of fish consumption, two separate RfDs will be used to assess risk for different population groups. OEHHA has formerly used separate methylmercury RfDs for adults and pregnant women to formulate advisories for methylmercury contamination of sport fish (Stratton et al., 1987). Additionally, the majority of states issue separate consumption advice for sensitive (e.g., children) and general population groups. OEHHA chooses to use both the current and previous U.S. EPA references doses for two distinct population groups. For these safe eating guidelines, the current RfD of $1x10^{-4}$ mg/kg-day, based on effects in infants, will be used for women of childbearing age and children aged 17 and younger. The previous RfD of $3x10^{-4}$ mg/kg-day, based on effects in adults, will be used for women beyond their childbearing years and men.

MERCURY LEVELS IN FISH FROM THE COSUMNES AND MOKELUMNE RIVERS

In general, mercury concentrations in fish and other biota are dependent on the mercury level of the environment in which they reside. However, there are many factors that affect the accumulation of mercury in fish tissue. Fish species and age (as inferred from length) are known to be important determinants of tissue mercury concentration (WHO, 1989; 1990). Fish at the highest trophic levels (i.e., top predatory fish) generally have the highest levels of mercury. Additionally, because the biological half-life of methylmercury in fish is much longer (approximately 2 years) than it is in mammals, tissue concentrations increase with increased duration of exposure (Krehl, 1972; Stopford and Goldwater, 1975; Tollefson and Cordle, 1986). Thus, within a given species, tissue methylmercury concentrations are expected to increase with increasing age and length. The accumulation of mercury in fish is also dependent on environmental pH, redox potential, temperature, alkalinity, buffering capacity, suspended sediment load, and geomorphology in individual water bodies (Andren and Nriagu, 1979; Berlin, 1986; WHO, 1989).

The mean mercury concentration, length, and sample size for each species collected and analyzed from the Cosumnes River and the Mokelumne River (including Sycamore Slough) are presented in Tables 1 and 2, respectively. Complete descriptive statistics for each fish species in this study can be found in Appendix 3 and 4 for the Cosumnes and Mokelumne rivers, respectively. Individual mercury concentrations and lengths of legal/edible size fish from which species means were generated can be found in Appendix 5. Individual mercury concentrations and lengths for fish below legal/edible size fish are presented in Appendix 6, although these fish were not used for development of the safe eating guidelines.

Examination of data from the two rivers showed that, depending on species, mercury concentrations ranged from 33% to over 100% higher in fish from the Cosumnes River compared to the Mokelumne River. Although this could be due, in part, to the somewhat larger fish caught in the Cosumnes River, it was considered prudent to develop separate safe eating guidelines for each river, when possible.

Mercury concentrations in legal/edible size fish and shellfish of all species from the Cosumnes River ranged from 0.01 ppm in an Asiatic clam to 2.09 ppm in a largemouth bass. For those species collected from the Cosumnes River with sufficient sample size to adequately represent mercury levels ($n \geq 9$ fish), the following mercury concentrations and fish lengths were reported for edible/legal-sized fish: mean mercury concentration for largemouth bass was 1.18 ppm, with a range of 0.65 to 2.09 ppm. Largemouth bass ranged in length from 305 to 485 mm, with a mean of 381 mm. Mercury concentrations in red swamp crayfish ranged from 0.25 to 1.83 ppm, with a mean of 0.42 ppm; lengths in this species ranged from 31-56 mm, with a mean of 44 mm. Asiatic clams had a mean mercury concentration of 0.04 ppm (range: 0.01 to 0.08 ppm) and a mean length of 27 mm.

Mercury concentrations in legal/edible size fish and shellfish of all species from the Mokelumne River (including Sycamore Slough) ranged from 0.02 ppm in an Asiatic clam composite to 1.58 ppm in a largemouth bass. For species with sufficient sample size to adequately represent mercury levels ($n \geq 9$ fish), largemouth bass had a mean mercury concentration of 0.81 ppm (range: 0.36 to 1.58 ppm) and a mean length of 368 mm (range: 312 to 532 mm). Bluegill had a mean mercury concentration of 0.25 ppm (range: 0.10 to 0.42 ppm) and a mean length of 176 mm (range: 137 to 212 mm). White catfish had a mean mercury level of 0.25 ppm (range: 0.12 to 0.29 ppm) and a mean length of 257 mm (range: 220 to 329 mm). Signal crayfish had mercury concentrations ranging from 0.06 to 0.34 ppm (mean: 0.18 ppm), while length ranged from 34 to 59 mm. The mercury concentration averaged 0.03 ppm in Asiatic clams; mean length in this species was 22 mm.

GUIDELINES FOR FISH CONSUMPTION

Guidance tissue levels have been developed that relate the number and size of recommended fish meals to methylmercury concentrations found in fish (Table 3). OEHHA has developed guidance levels for mercury (Brodberg and Klasing, 2003) similar to risk-based consumption limits recommended by U.S. EPA (U.S. EPA, 2000b). These guidance values were designed so that individuals consuming no more than a preset number of meals should not exceed the RfD for methylmercury. Meal sizes are based on a standard 8-ounce (227 g) portion of uncooked fish (approximately 6 ounces after cooking) for adults who weigh approximately 70 kg (approximately 160 lbs). This may be adjusted to higher or lower body weights by adding or subtracting one ounce to the meal size, respectively, for each 20-pound difference in body weight. OEHHA's advice allows fishers to consume up to three meals per week without exceeding the reference dose for a specific contaminant (e.g., mercury) (see Appendix 2 for additional general advice). Twelve meals per month is representative of an upper bound consumption rate for frequent sport fish consumers in California (Gassel, 2001). OEHHA begins issuing site-specific consumption advice if data indicate that consumption of twelve meals per month is potentially hazardous. This advice begins for sensitive populations when the methylmercury concentration exceeds 0.08 ppm. Guidance tissue levels for women beyond their childbearing years and men are approximately three times higher than for sensitive populations because of the 3-fold higher RfD level used for this population group.

Comparison of mean mercury concentrations in several fish species from the Cosumnes and Mokelumne rivers with the guidance tissue levels for mercury indicates that issuance of safe eating guidelines is appropriate for these water bodies. Consumers should be informed of the potential hazards from eating fish from this area, particularly those hazards relating to the developing fetus and children. All individuals, especially women of childbearing age and children aged 17 and younger, are advised to limit their fish consumption to reduce methylmercury ingestion to a level near the RfD.

For the Cosumnes River, sample size was sufficient to issue fish consumption guidelines for largemouth bass, red swamp crayfish, and Asiatic clams. For the Mokelumne River (including Sycamore Slough), sample size was sufficient to issue fish consumption guidelines for largemouth bass, white catfish, bluegill, signal crayfish, and Asiatic clams. When sample size for a particular species from a water body is too small to assure a statistically representative sample, other information may be useful to help develop consumption recommendations for that species. When there are less than nine individual or three composite samples at a site for a given species, advice for that species may be extrapolated from data for other, similar species at that site or from the same species at a similar site. This method is acceptable when evaluation of the entire data set shows clear trends that justify the issuance of prudent, protective health advice even in the absence of a statistically representative sample. For example, it may be reasonable to provide consumption advice for a particular species with few or no data (e.g., smallmouth bass) when adequate data are available for another, related fish species at that site (e.g., largemouth bass).

For the Cosumnes and Mokelumne rivers, supporting data were examined to determine whether, in an effort to be health protective, they could be used to assist in the development of fish consumption advice even in cases where the sample size for an individual species from each river was less than nine fish. Supporting data typically consist of contamination data for another closely related species at a similar trophic level or for the same species from a nearby water body. Because different species of black bass often contain similar levels of the same contaminant in the same water body, it is recommended that consumers follow the advice for largemouth bass for all other black bass species (smallmouth and spotted bass) caught in each of these rivers. There were no samples of Sacramento pikeminnow (formerly known as squawfish) collected from the Cosumnes River and an insufficient number collected from the Mokelumne River. Pikeminnow are large predator fish that consume various fish species and crayfish (Moyle, 2002) and frequently contain mercury concentrations similar to other high trophic level fish such as bass (see, for example, Klasing and Brodberg, 2004). Pikeminnow are thought to have been the top predator fish in the Central Valley prior to the introduction of species such as largemouth bass (Moyle, 2002). It is therefore recommended that fishers follow the black bass consumption advice for Sacramento pikeminnow caught in each of these rivers. Bluegill and signal crayfish were not collected in sufficient numbers from the Cosumnes River to provide a statistically valid sample. OEHHA recommends that fishers follow the redear sunfish advice for bluegill and the red swamp crayfish for signal crayfish when fishing from this river. Similarly, only five white catfish and seven Sacramento suckers were collected from the Cosumnes River while seven Sacramento suckers were also collected from the Mokelumne River. Because of the overall pattern of contamination in the two rivers, it seemed reasonable to provide consumption advice for these species using the individual means from each river.

Sufficient sample size was available to issue consumption advice for Asiatic clams; however, it is not known whether this species is commonly harvested or consumed from the area. Furthermore, although the concentration of mercury in Asiatic clams was very low in comparison to other species in these rivers, given the high concentration of mercury in most local species, it was not considered prudent to specifically recommend that any type of aquatic organism (fish or shellfish) be collected and consumed regularly from the Cosumnes River. One purpose of safe eating guidelines is to encourage consumers to eat more fish and shellfish from other water bodies that are less contaminated. As such, consumption advice for Asiatic clams is only provided as a footnote in the safe eating guidelines for both rivers.

Samples of striped bass were also collected from the Cosumnes and Mokelumne rivers; however, OEHHA recommends that consumers follow the existing striped bass advisory for the Delta when fishing from these rivers, which connect with the Delta. Women of childbearing age and children aged 17 and younger should eat no more than one meal per month of striped bass and not eat any striped bass over 27 inches in length. Women beyond childbearing age and men should eat no more than two meals per month of striped bass and not eat any striped bass over 35 inches in length.

Based on the evaluation of all data from the lower Cosumnes River (defined as the entirety of the river within Sacramento County), it is recommended that **women of childbearing age and children aged 17 and younger** do not consume any black bass species (largemouth, smallmouth, or spotted bass) or Sacramento pikeminnow from this water body. Additionally, because of the generally high levels of mercury found in all tested fish and crayfish in this water body, this population should limit consumption of any other fish or crayfish species from the lower Cosumnes River to no more one meal per month.

For the lower Mokelumne River (defined as both forks of the Mokelumne River downstream of Camanche Reservoir to the confluence of the San Joaquin River), because of the generally high levels of mercury found in all tested fish, it is recommended that **women of childbearing age and children aged 17 and younger** limit consumption of any fish species to no more than one meal per month. Alternatively, this population may eat up to one meal per week of crayfish.

OEHHA also recommends that **women of childbearing age and children aged 17 and younger** follow the Joint Federal Advisory for Mercury in Fish for commercial fish. This advisory recommends that these individuals do not eat shark, swordfish, king mackerel, or tilefish because of their high levels of mercury. It also recommends that these individuals can safely eat up to an average of 12 ounces (two average meals) per week of a variety of other cooked fish such as shrimp, canned light tuna, salmon, pollock, or (farm-raised) catfish. Albacore ("white") tuna is known to contain more mercury than canned light tuna; it is therefore recommended that no more than 6 ounces of albacore tuna be consumed per week. If 12 ounces of cooked fish from a store or restaurant are eaten in a given week, then OEHHA recommends that sport fish caught from the Cosumnes or Mokelumne rivers or other California water bodies should not be consumed in the same week.

For the lower Cosumnes River, OEHHA recommends that **women beyond their childbearing years and men** limit consumption of black bass species or Sacramento pikeminnow to one meal per month. Alternatively, this population may eat up to one meal per week of any other fish species or crayfish.

For the lower Mokelumne River, OEHHA recommends that **women beyond their childbearing years and men** limit consumption of black bass species or Sacramento pikeminnow to one meal per month. Alternatively, this population may eat to two meals per week of crayfish or bluegill or Sacramento sucker or white catfish.

Additionally, OEHHA recommends that women beyond their childbearing years and men take into account the commercial fish that they eat, especially high-mercury fish such as shark, swordfish, king mackerel, or tilefish. If they consume these species, they should reduce consumption of sport fish caught in the Cosumnes and Mokelumne rivers, or other California water bodies, accordingly.

It is very important to note that if an individual consumes multiple species or catches fish from more than one site, the recommended guidelines for different species and locations should not be combined. For example, if a person eats a meal of fish from the one meal per month category, he or she should not eat any other fish for at least one month. For fish in the meal per week category, an individual can eat one species of fish one week, and the same or a different species from the meal per week category the next week. Fish species in the three meals per week category can be combined in the same week.

For general advice on how to limit your exposure to chemical contaminants in sport fish (e.g., eating smaller fish of legal size), see Appendix 1. It should be noted that, unlike the case for many fat-soluble chlorinated hydrocarbon contaminants (e.g., DDTs and PCBs), various cooking and cleaning techniques will not reduce the methylmercury content of fish. Meal sizes should be adjusted to body weight as described in the advisory table.

SAFE EATING GUIDELINES

FISH AND SHELLFISH CONSUMPTION FROM THE LOWER COSUMNES RIVER AND NEARBY CREEKS AND SLOUGHS

Fish and shellfish are nutritious and should be part of a healthy, balanced diet. It is important, however, to choose your fish wisely. The American Heart Association recommends healthy adults eat at least two meals of fish a week. OEHHA recommends that you choose fish to eat that are low in mercury such as those in the “Enjoy” category. Because many types of fish from the lower Cosumnes River contain higher levels of mercury, OEHHA provides the recommendations below that you can follow to reduce the risks from exposure to methylmercury in fish.

.

Women of childbearing age, pregnant or breastfeeding women, and children 17 years and under

AVOID DO NOT EAT MORE THAN THE AMOUNT LISTED BELOW:	
DO NOT EAT	Largemouth, smallmouth or spotted bass; or Sacramento pikeminnow
NO MORE THAN 1 MEAL A MONTH	All other fish or crayfish species*

*****Asiatic clams may be eaten up to 3 times a week

Women beyond childbearing age and men

ENJOY UP TO 2 MEALS A WEEK
Bluegill or redear sunfish or Asiatic clams
EAT IN MODERATION NO MORE THAN 1 MEAL A WEEK
Crayfish or Sacramento sucker or white catfish
AVOID NO MORE THAN 1 MEAL A MONTH
Largemouth, smallmouth or spotted bass; or Sacramento pikeminnow

- **EVERYONE FOLLOW THE STRIPED BASS ADVISORY FOR DELTA WATER BODIES.** WOMEN OF CHILDBEARING AGE AND CHILDREN 17 YEARS AND YOUNGER: no more than one meal per month and none over 27 inches. WOMEN BEYOND CHILDBEARING AGE AND MEN: no more than two meals per month and none over 35 inches.
- **CONTACT WITH THE WATER IS SAFE.**
- **EAT SMALLER FISH OF LEGAL SIZE**. Fish build up mercury in their bodies as they grow.
- **MEAL SIZE DEPENDS ON BODY WEIGHT.** Meals are based on a 160 lb adult eating 8 ounces of fish (6 ounces after cooking)—about the size of two decks of cards. If you weigh less than 160 lbs, eat smaller portions of fish. Serve smaller meals to children.
- **DO NOT EAT MORE THAN ONE OF THE LISTED FISH SPECIES DURING THE SAME TIME PERIOD** unless you are only eating from the Enjoy (green) category. If you eat fish from one place, following the advisory, avoid eating fish from other sources during the same time period.
- **CONSIDER THE FISH YOU BUY FROM STORES AND RESTAURANTS.** Women of childbearing age and children can safely eat up to 2 meals a week of a variety of fish purchased from a store or restaurant, **OR** use this guide for eating fish caught from this water body. In a week when you eat 2 meals of fish purchased from stores or restaurants, avoid eating fish caught from a local water body. Commercial fish such as shrimp, king crab, scallops, farmed catfish, wild ocean salmon, oysters, tilapia, flounder, and sole generally contain some of the lowest levels of mercury. Women of childbearing age and children should not eat SHARK OR SWORDFISH.
- **FISH FROM OTHER WATER BODIES MAY ALSO CONTAIN MERCURY**. Not all water bodies in California have been tested. With the exception of ocean or river-run salmon and steelhead, which generally contain low levels of contaminants, fish caught from places without an advisory should be eaten in limited amounts.

SAFE EATING GUIDELINES
FISH AND SHELLFISH CONSUMPTION FROM THE LOWER MOKELUMNE RIVER AND NEARBY CREEKS AND SLOUGHS

Fish and shellfish are nutritious and should be part of a healthy, balanced diet. It is important, however, to choose your fish wisely. The American Heart Association recommends healthy adults eat at least two meals of fish a week. OEHHA recommends that you choose fish to eat that are low in mercury such as those in the “Enjoy” category. Because many types of fish from the lower Cosumnes River contain higher levels of mercury, OEHHA provides the recommendations below that you can follow to reduce the risks from exposure to methylmercury in fish.

Women of childbearing age, pregnant or breastfeeding women, and children 17 years and under

EAT IN MODERATION NO MORE THAN 1 MEAL A WEEK
Crayfish*
AVOID DO NOT EAT MORE THAN 1 MEAL A MONTH
All fish species

***Asiatic clams may be eaten up to 3 times a week

Women beyond childbearing age and men

ENJOY UP TO 2 MEALS A WEEK
Crayfish or bluegill or Sacramento sucker or white catfish or Asiatic clams*
AVOID NO MORE THAN 1 MEAL A MONTH
Largemouth, smallmouth or spotted bass; or Sacramento pikeminnow

***Asiatic clams may be eaten up to 3 times a week

- **EVERYONE FOLLOW THE STRIPED BASS ADVISORY FOR DELTA WATER BODIES.** WOMEN OF CHILDBEARING AGE AND CHILDREN 17 YEARS AND YOUNGER: no more than one meal per month and none over 27 inches. WOMEN BEYOND CHILDBEARING AGE AND MEN: no more than two meals per month and none over 35 inches.
- **CONTACT WITH THE WATER IS SAFE.**
- **EAT SMALLER FISH OF LEGAL SIZE**. Fish build up mercury in their bodies as they grow.
- **MEAL SIZE DEPENDS ON BODY WEIGHT.** Meals are based on a 160 lb adult eating 8 ounces of fish (6 ounces after cooking)—about the size of two decks of cards. If you weigh less than 160 lbs, eat smaller portions of fish. Serve smaller meals to children.
- **DO NOT EAT MORE THAN ONE OF THE LISTED FISH SPECIES DURING THE SAME TIME PERIOD** unless you are only eating from the Enjoy (green) category. If you eat fish from one place, following the advisory, avoid eating fish from other sources during the same time period.
- **CONSIDER THE FISH YOU BUY FROM STORES AND RESTAURANTS.** Women of childbearing age and children can safely eat up to 2 meals a week of a variety of fish purchased from a store or restaurant, **OR** use this guide for eating fish caught from this water body. In a week when you eat 2 meals of fish purchased from stores or restaurants, avoid eating fish caught from a local water body. Commercial fish such as shrimp, king crab, scallops, farmed catfish, wild ocean salmon, oysters, tilapia, flounder, and sole generally contain some of the lowest levels of mercury. Women of childbearing age and children should not eat SHARK OR SWORDFISH.
- **FISH FROM OTHER WATER BODIES MAY ALSO CONTAIN MERCURY**. Not all water bodies in California have been tested. With the exception of ocean or river-run salmon and steelhead, which generally contain low levels of contaminants, fish caught from places without an advisory should be eaten in limited amounts.

RECOMMENDATIONS FOR FURTHUR SAMPLING

To more clearly elucidate mercury contamination problems in the Cosumnes and Mokelumne rivers, it is recommended that further fish sampling be done. In particular, emphasis should be placed on collecting data for popular fish species that were not previously sampled or had low sample size. For example, various species of trout, which are popular sport fish and planted by DFG in the upper Cosumnes River, were not collected from either river. Similarly, data for crappie or channel catfish were also not available. Sampling at least nine fish of one or more of these or other local species would provide data necessary for development of fish consumption advice specific for these species. Collection of additional data will provide anglers with more information on their potential risks from consumption of high mercury fish as well as options for choosing lower mercury fish in these water bodies.

FIGURE 1. COSUMNES AND MOKELUMNE RIVER SAMPLING SITES

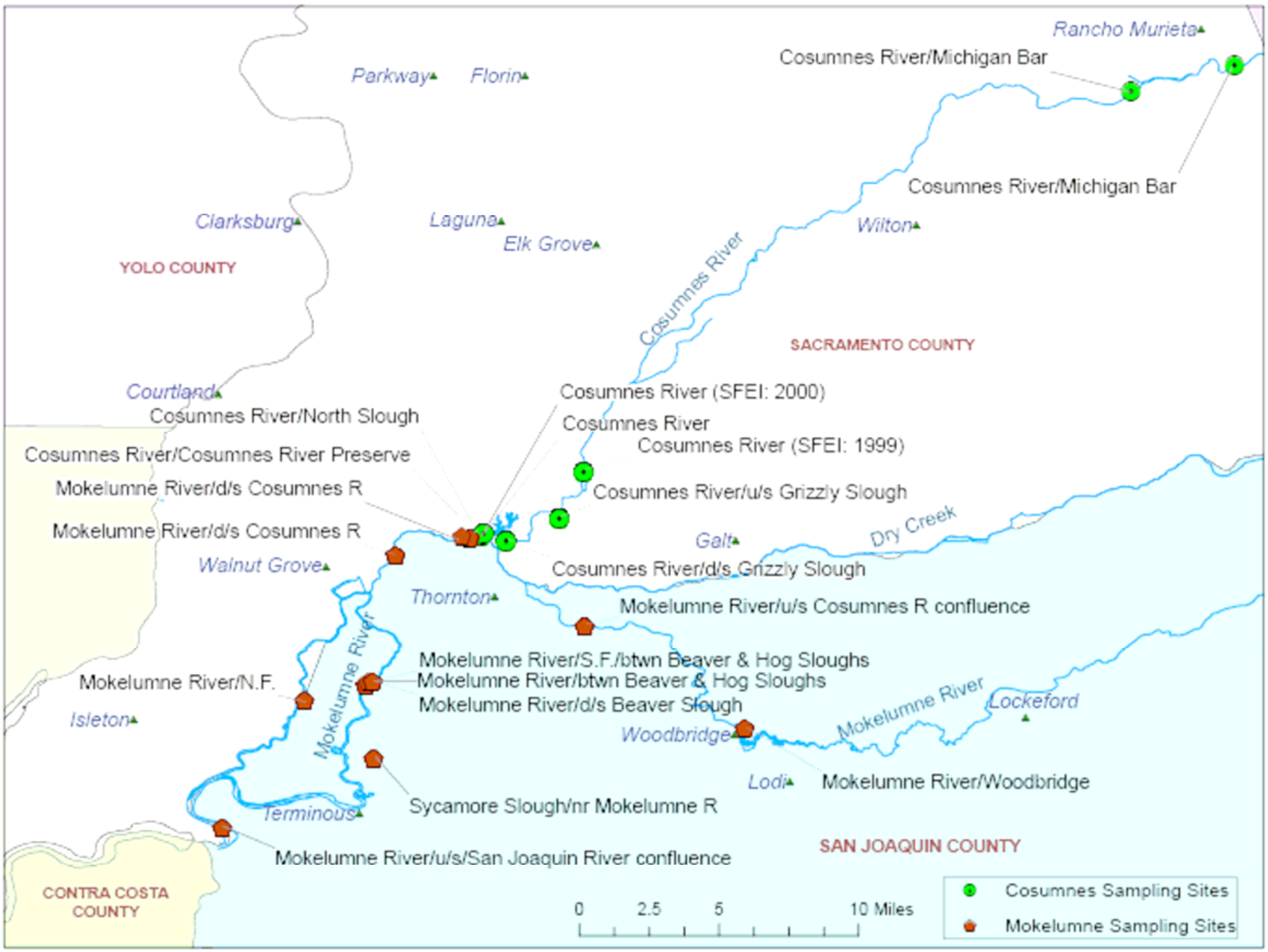


Table 1. Overall Mean Mercury Concentrations (ppm, wet weight) and Lengths (mm) of Fish from Cosumnes River Sites[1]			
	Mercury (ppm)	Length (mm)[2]	Number of Fish
Asiatic Clam	0.04	27	77
Bluegill	0.34	119	5
Largemouth Bass	1.18	381	18
Red Swamp Crayfish	0.42	44	21
Redear Sunfish	0.30	153	13
Sacramento Sucker	0.45	413	7
Signal Crayfish	0.29	41	7
White Catfish	0.54	294	5

[1] Excludes all striped bass and all fish below the following legal or edible size limits:

Bluegill: 100 mm
Largemouth Bass: 305 mm
Red Swamp and Signal Crayfish: 45 mm
Redear Sunfish: 130 mm
Sacramento Sucker: 200 mm
White Catfish: 200 mm

[2] Crayfish length was measured as median carapace. Clam length was measured as median length. For all other species, total length was measured—longest length from tip of tail fin to tip of nose/mouth. TSMP samples, a largemouth bass, fork length 371 mm, and a white catfish, fork length 247 mm, were converted to total lengths of 390 mm and 272 mm respectively, per OEHHA PETB conversion factors: fork length times 1.05 for largemouth bass and fork length times 1.1 for white catfish. Length values for composite samples are typically reported as average length.

Table 2. Overall Mean Mercury Concentrations (ppm, wet weight) and Lengths (mm) of Fish from Mokelumne River Sites[1]			
	Mercury (ppm)	Total Length (mm)[2]	Number of Fish
Asiatic Clams	0.03	22	105
Bluegill	0.25	176	25
Largemouth Bass	0.81	368	37
Sacramento Pikeminnow	0.57	293	3
Sacramento Sucker	0.30	327	7
Signal Crayfish	0.18	48	83
White Catfish	0.25	257	10

[1] Excludes all striped bass and all fish below the following legal or edible size limits:

Bluegill: 100 mm
Largemouth Bass: 305 mm
Sacramento Pikeminnow: 250 mm
Sacramento Sucker: 200 mm
Signal Crayfish: 45 mm
White Catfish: 200 mm

[2] Crayfish length was measured as median carapace. Clam length was measure as median length. For all other species, total length was measured—longest length from tip of tail fin to tip of nose/mouth. Three TSMP samples were converted from fork length to total length per OEHHA PETB conversion factor of fork length times 1.05 for largemouth bass and fork length times 1.1 for white catfish. Two largemouth bass, fork length 350 mm each, were converted to total lengths of 368 mm; and one white catfish, fork length 200, was converted to total length of 220 mm. Length values for composite samples are typically reported as average length.

Table 3. Guidance Tissue Levels (ppm total mercury or methylmercury wet weight) for Two Population Groups*					
Population Group (RfD)	3 Meals/ Week** (90 g/day)	2 Meals/ Week (30 g/day	1 Meal/ Week (30.0 g/day)	1 Meal/ Month (7.5 g/day)	No Consumption
Women of childbearing age and children aged 17 and younger ($1x10^{-4}$ mg/kg-day)	≤ 0.08	>0.08-0.12	>0.12-0.23	>0.23-0.93	>0.93
Women beyond their childbearing years and men ($3x10^{-4}$ mg/kg-day)	≤0.23	>0.23-0.35	>0.35-0.70	>0.70-2.80	>2.80

*The values in this table are based on the assumption that 100% of total mercury measured in fish is methylmercury. This may not be true for shellfish, so methylmercury needs to be measured directly in these species for use in this table.

** OEHHA's consumption advice protects fishers who eat up to three meals per week of sport fish. A Consumption rate of twelve meals per month is representative of an upper bound for frequent sport fish consumers in California (Gassel, 2001). OEHHA begins issuing site-specific consumption advice if data indicate that consumption of twelve meals per month is potentially hazardous.

The recommended level for consumption of fish contaminated with a non-carcinogenic chemical such as methylmercury is below or equivalent to the chemical's reference level. People could eat more fish with a lower tissue concentration (before they exceed the reference level) than fish with a higher concentration. The following general equation can be used to calculate the fish tissue concentration (in mg/kg) at which the consumption exposure from a chemical with a non-carcinogenic effect is equal to the reference level for that chemical at any consumption level:

$$\text{Tissue concentration} = \frac{(\text{RfD mg/kg - day})(\text{kg Body Weight})(\text{RSC})}{\text{CR kg/day}}$$

where,

RfD = Chemical specific reference dose or other reference level
BW = Body weight of consumer
RSC = Relative source contribution of fish to total exposure
CR = Consumption rate as the daily amount of fish consumed

For example: $\frac{(1 \times 10^{-4} \text{ mg/kg-day})(70 \text{ kg body weight})(1)}{.030 \text{ kg/day}} = 0.23$ mg/kg tissue

REFERENCES

Aberg, B.; Ekman, L.; Falk, R.; Greitz, U.; Persson, G.; Snihs, J-O. 1969. Metabolism of methyl mercury (^{203}Hg) compounds in man. Arch. Environ. Health. 19:478-485.

Adams, J.; Barone, S., Jr.; LaMantia, A.; Philen, R.; Rice, D.C.; Spear, L.; Susser, E. 2000. Workshop to identify critical windows of exposure for children's health: Neurobehavioral Work Group summary. Environ. Health Perspect. 108 (suppl. 3):535-544.

Alpers, C.N.; Marvin-DiPasquale, M.M.; Agee, J.; Slotton, D.G.; Ayers, S.; Saiki, M.K.; Martin, B.A.; May, T.W.; Hunerlach, M.P.; Humphreys, R.D. 2004. Mercury contamination, methylation, and bioaccumulation in an area affected by large-scale gold dredging: Lake Natoma drainage, American River watershed, California. Abstract presented to be at the 14th Annual Meeting, Northern California Regional Chapter, Society of Environmental Toxicology and Chemistry (NorCal SETAC), to be held May 11-12, 2004, Davis, California.

Andren, A.W.; Nriagu, J.O. 1979. The global cycle of mercury. In: Nriagu, J.O., ed. The biogeochemistry of mercury in the environment. Topics in environmental health, Vol. 3. Amsterdam: Elsevier/North-Holland Biomedical Press. p.1-21.

ATSDR 1999. Agency for Toxic Substances and Disease Registry. Toxicological profile for mercury (update). Prepared by Research Triangle Institute under contract no. 205-93-0606. Public Health Service, U.S. Department of Health and Human Services.

Bakir, F.; Damluji, S.F.; Amin-Zaki, L.; Murtadha, M.; Khalidi, A.; Al-Rawi, N.Y.; Tikriti, S.; Dhahir, H.I.; Clarkson, T.W.; Smith, J.C.; Doherty, R.A. 1973. Methylmercury poisoning in Iraq. Science 181:230-241.

Berlin, M. 1986. Mercury. In: Friberg, L.; Nordberg, G.F.; Vouk, V.B.; eds. Handbook on the toxicology of metals. 2nd ed. Vol. II. Specific metals. New York, Elsevier p. 387-445.

Bloom, N.S. 1992. On the chemical form of mercury in edible fish and marine invertebrate tissue. Can. J. Fish. Aquat. Sci. 49(5):1010-1017.

Brodberg, R.K.; Klasing, S.A. 2003. Evaluation of potential health effects of eating fish from Black Butte Reservoir (Glenn and Tehama Counties): Guidelines for sport fish consumption. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency.

Brodberg, R.K.; Pollock, G.A. 1999. Prevalence of Selected Target Chemical Contaminants in Sport Fish from Two California Lakes: Public Health Designed Screening Study. Final Project Report. EPA Assistance Agreement No. CX 825856-01-0. California Environmental Protection Agency. Office of Environmental Health Hazard Assessment. Sacramento, California. June 1999.

Brown, L. 1998. Concentrations of Chlorinated Organic Compounds in Biota and Bed Sediment in Streams of the Lower San Joaquin River Drainage, California. National Water Quality Assessment Program, US Geological Survey Open-File Report 98-171, USGS Sacramento, CA.

CDFG (California Department of Fish and Game). 2004. California Inland Water Angling Records. URL: http://www.dfg.ca.gov/fishing/html/AnglerRecognition/StateRecord/AnglingRecords.htm.

Cheruka, S.R.; Montgomery-Downs, H.E.; Farkas, S.L.; Thoman, E.B.; Lammi-Keefe, C.J. 2002. Higher maternal plasma docosahexaenoic acid during pregnancy is associated with more mature neonatal sleep-state patterning. American Journal of Clinical Nutrition 76:608-613.

Clark, W.B. 1998. Gold Districts of California. Bulletin 193. California Department of Conservation, Division of Mines and Geology.

Clarkson, T.W.; Amin-Zaki, L.; Al-Tikriti. 1976. An outbreak of methyl mercury poisoning due to consumption of contaminated grain. Fed. Proc. 35:2395-2399.

Davidson, P.W.; Myers, G.J.; Cox, C.; Axtell, C.; Shamlaye, C.; Sloane-Reeves, J.; Cernichiari, E.; Needham, L.; Choi, A.; Wang, Y.; Berlin, M.; Clarkson, T.W. 1998. Effects of prenatal and postnatal methylmercury exposure from fish consumption on neurodevelopment. JAMA 280:701-707.

Davidson, P.W.; Myers, G.J.; Cox, C.; Shamlaye, C.F.; Marsh, D.O.; Tanner, M.A.; Berlin, M.; Sloane-Reeves, J.; Cernichiari, E.; Choisy, O.; Choi, A.; Clarkson, T.W. 1995. Longitudinal neurodevelopmental study of Seychellois children following in utero exposure to methylmercury from maternal fish ingestion: outcomes at 19 and 29 months. Neurotoxicology 16(4):677-688.

Daviglus, M.L.; Stamler, J.; Orencia, A.J.; Dyer, A.R.; Liu, K.; Greenland, P.; Walsh, M.K.; Morris, D.; Shekelle, R.B. 1997. Fish consumption and the 30-year risk of fatal myocardial infarction. N. Engl. J. Med. 336:1046-53.

Davis, J.A.; Greenfield, B.K.; Ichikawa, G.; Stephenson, M. 2003. Mercury in sport fish from the Delta region (Task 2A). SFEI. Richmond, CA. 88 pp. URL : http://loer.tamug.tamu.edu/calfed/FinalReports.htm

Davis, J.A. ; May, M.D. ; Ichikawa, G. ; Crane, D. 2000. Contaminant concentrations in fish from the Sacramento-San Joaquin Delta and Lower San Joaquin River 1998. SFEI. Richmond, CA. 52 pp. URL : http:/www.sfei.org/cmr/deltafish/dfc.pdf

Elhassani, S.B. 1982-83. The many faces of methylmercury poisoning. J. Toxicol. Clin. Toxicol. 19(8):875-906.

Fish Sniffer. 2000. Lower Mokelumne River Recreation Area. URL: http://fishsniffer.com/maps/mokelumne.html.

Gassel, M. 2001. Chemicals in Fish: Consumption of Fish and Shellfish in California and the United States. Pesticide and Environmental Toxicology Section. Office of Environmental Health Hazard Assessment. California Environmental Protection Agency. Oakland, CA.

Gassel, M. 2004. Personal communication. October, 2004. Office of Environmental Health Hazard Assessment.

Giedd, J.N.; Blumenthal, J.; Jeffries, N.O.; Castellanos, F.X.; Liu, H.; Zijdenbos, A.; Paus, T.; Evans, A.C.; Rapoport, J.L. 1999. Brain development during childhood and adolescence: A longitudinal MRI study. Nature Neuroscience 2(10):861-863.

Grandjean, P.; Budtz-Jorgensen, E.; White, R.F.; Weihe, P.; Debes, F.; Keiding, N. 1999. Methylmercury exposure biomarkers as indicators of neurotoxicity in children aged 7 years. Am. J. Epidemiol. 150(3):310-305.

Grandjean, P.; Weihe, P.; White, R.; Debes, F.; Arai, S.; Yokoyama, K.; Murata, N.; Sorensen, N.; Dahl, R.; Jorgensen, P. 1997. Cognitive deficit in 7-year-old children with prenatal exposure to methylmercury. Neurotoxicol. Teratol. 19:417-428.

Grandjean, P.; Weihe, P.; White, R.F.; Keiding, N.; Budtz-Jorgensen, K.; Murato, K.; Needham, L. 1998. Prenatal exposure to methylmercury in the Faroe Islands and neurobehavioral performance at age seven years. Response to workgroup questions for presentation on 18-20 Nov. 1998. In Scientific Issues Relevant to Assessment of Health Effects from Exposure to Methylmercury. Appendix II-B. Faroe Islands Studies. National Institute for Environmental Health Sciences. Online at: http://ntp-server.niehs.nih.gov/Main_Pages/PUBS/MethMercWkshpRpt.html.

Hanson, L. 2004. Personal communication. December, 2004. California Department of Fish and Game.

Harada, M. 1978. Congenital Minamata Disease: Intrauterine methylmercury poisoning. Teratology. 18:285-288.

Harris, W.S.; Isley, W.L. 2001. Clinical trial evidence for the cardioprotective effects of omega-3 fatty acids. Curr. Atheroscler. Rep. 3(2):174-9.

Hunerlach, M.P.; Alpers, C.N. 2003. Mercury contamination from hydraulic gold mining in the Sierra Nevada, California. In: Gray, J.E., ed. Geologic studies of mercury by the U.S. Geological Survey. U.S.Geological Survey Circular 1248.

IARC. 1993. IARC Monographs on the evaluation of carcinogenic risks to humans: Beryllium, cadmium, mercury, and exposures in the glass manufacturing industry. Vol. 58. World Health Organization, International Agency for Research on Cancer.

IRIS. 1993. Integrated Risk Information System. Online at: http://www.epa.gov/iris/rfd.htm. Background Document 1A. Database maintained by the Office of Health and Environmental

Assessment. U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office, Cincinnati, Ohio.

IRIS. 1995. Integrated Risk Information System. Online at: http://www.epa.gov/iris/subst/0073.htm. Methylmercury (MeHg) (CASRN 22967-92-6). Database maintained by the Office of Health and Environmental Assessment. U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office, Cincinnati, Ohio.

IRIS. 2001. Integrated Risk Information System. Online at: http://www.epa.gov/iris/subst/0073.htm. Methylmercury (MeHg) (CASRN 22967-92-6). Database maintained by the Office of Health and Environmental Assessment. U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office, Cincinnati, Ohio.

Iso, H.; Rexrode, K.M.; Stampfer, M.J.; Manson, J.E.; Colditz, G.A.; Speizer, F.; Hennekens, C.H.; Willett, W.C. 2001. Intake of fish and omega-3 fatty acids and risk of stroke in women. J. Am. Med. Assoc. 285(3):304-12.

Kjellstrom, T.; Kennedy, P.; Wallis, S.; Mantell, C. 1986. Physical and mental development of children with prenatal exposure to mercury from fish. Stage I: Preliminary tests at age 4. National Swedish Environmental Protection Board Report 3080. Solna, Sweden.

Kjellstrom, T.; Kennedy, P.; Wallis, S.; Stewart, A.; Friberg, L.; Lind, B.; Wutherspoon, T.; Mantell, C. 1989. Physical and mental development of children with prenatal exposure to mercury from fish. Stage II: Interviews and psychological tests at age 6. National Swedish Environmental Protection Board Report 3642. Solna, Sweden.

Klasing, S; Brodberg, R. 2004. Fish Consumption Guidelines for Lake Natoma (Including Nearby Creeks and Ponds) and the Lower American River (Sacramento County). Office of Environmental Health Hazard Assessment, California Environmental Protection Agency.

Krehl, W.A. 1972. Mercury, the slippery metal. Nutr. Today November/December 90-102.

Lim, S.Y.; Suzuki, H. 2000. Intakes of dietary docosahexaenoic acid ethyl ester and egg phosphatidylcholine improve maze-learning ability in young and old mice. J. Nutr. 130(6):1629-32.

Linn, J. 2004. Personal Communication. October, 2004. California Department of Fish and Game.

Madgic, B. 1999. A Guide to California's Freshwater Fishes. Happy Camp, California: Naturegraph Publishers.

Marsh, D.O. 1987. Dose-response relationships in humans: Methyl mercury epidemics in Japan and Iraq. In: The Toxicity of Methyl Mercury. Eccles, C.U.; Annau, Z., eds. Baltimore, MD: John Hopkins University Press. p. 45-53.

Marsh, D.O.; Clarkson, T.W.; Cox, C.; Myers, G.J.; Amin-Zaki, L.; Al-Tikriti, S. 1987. Fetal methylmercury poisoning: Relationship between concentration in single strands of maternal hair and child effects. Arch. Neurol. 44:1017-1022.

Marsh, D.O.; Myers, G.J.; Clarkson, T.W.; Amin-Zaki, L.; Tikriti, S.; Majeed, M.A. 1980. Fetal methylmercury poisoning: Clinical and toxicological data on 29 cases. Ann. Neurol. 7:348-353.

Matsumoto, H.; Koya, G.; Takeuchi, T. 1964. Fetal Minamata Disease: A neuropathological study of two cases of intrauterine intoxication by a methyl mercury compound. J. Neuropathol. Exp. Neurol. 24:563-574.

May, J.T; Hothem, R.L.; Alpers, C.N.; Law, M.A. 2000. Mercury bioaccumulation in fish in a region affected by historic gold mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999. U.S. Geological Survey. Open-File Report 00-367. URL: http://ca.water.usgs.gov/archive/reports/ofr00367/

May, J.T.; Hothem, R.L.; Rytuba, J.J.; Duffy, W.G.; Alpers, C.N.; Ashley, R.P.; Hunerlach, M.P. 2004. Mercury concentrations in sediment, water, and aquatic biota from the Trinity River Watershed, 2000-2003. Abstract; Annual Meeting and Symposium, 2004, California-Nevada Chapter of the American Fisheries Society.

Mishima, A. 1992. Bitter Sea: The Human Cost of Minamata Disease. Tokyo: Kosei Publishing Co. 231 p.

Mori, T.A.; Beilin, L.J. 2001. Long-chain omega 3 fatty acids, blood lipids and cardiovascular risk reduction. Curr. Opin. Lipidol. 12(1):11-7.

Moriguchi, T.; Greiner, R.S.; Salem, N. 2000. Behavioral deficits associated with dietary induction of decreased brain docosahexaenoic acid concentration. J. Neurochem. 75(6):2563-73.

Moyle, P.B. 2002. Inland fishes of California. Revised and expanded. Berkeley: University of California Press. 502 p.

Myers, G.J.; Davidson, P.W.; Palumbo, D.; Shamlaye, C.; Cox, C.; Cernichiari, E.; Clarkson, T.W. 2000. Secondary analysis from the Seychelles Child Development Study: The child behavior checklist. Environ. Research. Section A 84:12-19.

NAS/NRC. 2000. Toxicological effects of methylmercury. Report of the National Research Council, Committee on the toxicological effects of methylmercury. Washington DC: National Academy Press.

Paus, T.; Zijdenbos, A.; Worsley, K.; Collins, D.L.; Blumenthal, J.; Giedd, J.N.; Rapoport, J.L.; Evans, A.C. 1999. Structural maturation of neural pathways in children and adolescents: In vivo study. Science 283:1908-1911.

Rasmussen, D. 1995. Toxic Substances Monitoring Program 1992-93 Data Report. 95-1WQ. State Water Resources Control Board (SWRCB), California Environmental Protection Agency.

Rice, D.; Barone, S., Jr. 2000. Critical periods of vulnerability for the developing nervous system: Evidence from humans and animal models. Environ. Health Perspect. 108 (suppl. 3):511-33.

Seafood Safety. 1991. Committee on Evaluation of the Safety of Fishery Products, Chapter on Methylmercury: FDA Risk Assessment and Current Regulations, National Academy Press, Washington, DC. p.196-221.

SFEI. 2001. San Francisco Estuary Institute. Unpublished electronic database sent to Margy Gassel at OEHHA from Ben Greenfield at SFEI on July 30, 2004.

Slotton, D.G.; Ayers, S.M.; Suchanek, T.H.; Weyand, R.D.; LIston, A.M.; MacDonald, C.; Nelson, D.C.; Johnson, B. 2002. The Effects of Wetland Restoration on the Production and Bioaccumulation of Methylmercury in the Sacramento-San Joaquin Delta, California. CALFED Mercury Program Draft Final Project Reports, September 2002. Report available at URL: http://loer.tamug.tamu.edu/calfed/DraftReports.htm

Smith, J.C.; Allen, P.V.; Turner, M.D.; Most, B.; Fisher, H.L.; Hall, L.L. 1994. The kinetics of intravenously administered methyl mercury in man. Toxicol. Appl. Pharmacol. 128(2):251-256.

Snyder, R.D. 1971. Congenital mercury poisoning. New Engl. J. Med. 218:1014-1016.

Stienstra, T. 2004. California Fishing. Santa Rosa, California: Foghorn Press.

Stopford, W.; Goldwater, L.J. 1975. Methylmercury in the environment: A review of current understanding. Environ. Health Perspectives 12:115-118.

Stratton, J.W.; Smith, D.F.; Fan, A.M.; Book, S.A. 1987. Methyl Mercury in Northern Coastal Mountain Lakes: Guidelines for Sport Fish Consumption for Clear Lake (Lake County), Lake Berryessa (Napa County), and Lake Herman (Solano County). Office of Environmental Health Hazard Assessment, California Environmental Protection Agency.

Tollefson, L.; Cordle, F. 1986. Methyl mercury in fish: A review of residue levels, fish consumption and regulatory action in the United States. Environ. Health Perspectives 68:203-208.

UCD. 1996. University of California – Davis. Cosumnes River Fish List. URL: http://watershed.ucdavis.edu/crg/reports/harrislist1996.pdf

U.S. EPA. 1997. Mercury Study Report to Congress. Volume VII: Characterization of Human Health and Wildlife Risks from Mercury Exposure in the United States. EPA-452/R-97-009. U.S. Environmental Protection Agency, Office of Air Quality Planning & Standards and Office of Research and Development, Washington, DC.

U.S. EPA. 2000a. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories. Vol. 1. Fish Sampling and Analysis. Third Edition. U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA. 2000b. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories. Vol. 2. Risk Assessment and Fish Consumption Limits. Third Edition. U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA. 2003. Fact Sheet. Update: National Listing of Fish and Wildlife Advisories. URL: http://www.epa.gov/waterscience/fish/advisories/factsheet.pdf.

U.S.EPA. 2004. Joint Federal Advisory for Mercury in Fish. What You Need to Know about Mercury in Fish and Shellfish. URL: http://www.epa.gov/waterscience/fishadvice/advice.html

Valagussa, F.; Fronzosi, M.G.; Geraci, E. et al. 1999. Dietary supplementation with n-3 fatty acids and vitamin E after myocardial infarction: results of the GISSI-Prevenzione trial. Lancet 354(9177):447-55.

von Schacky, C.; Angerer, P.; Kothny, W.; Theisen, K.; Mudra, H. 1999. The effect of dietary omega-3 fatty acids on coronary atherosclerosis. A randomized, double-blind, placebo-controlled trial. Ann. Intern. Med. 130(7):554-62.

WHO (World Health Organization). 1976. Environmental Health Criteria. Mercury. Geneva, Switzerland: World Health Organization.

WHO (World Health Organization). 1989. Mercury – Environmental Aspects. Environmental Health Criteria 86. Geneva: World Health Organization.

WHO (World Health Organization). 1990. Methylmercury. Environmental Health Criteria 101. Geneva: World Health Organization.

APPENDIX 1: METHYLMERCURY IN SPORT FISH: INFORMATION FOR FISH CONSUMERS

Methylmercury is a form of mercury that is found in most freshwater and saltwater fish. In some lakes, rivers, and coastal waters in California, methylmercury has been found in some types of fish at concentrations that may be harmful to human health. The Office of Environmental Health Hazard Assessment (OEHHA) has issued health advisories to fishers and their families giving recommendations on how much of the affected fish in these areas can be safely eaten. In these advisories, women of childbearing age and children are encouraged to be especially careful about following the advice because of the greater sensitivity of fetuses and children to methylmercury.

Fish are nutritious and should be a part of a healthy, balanced diet. As with many other kinds of food, however, it is prudent to consume fish in moderation. OEHHA provides advice to the public so that people can continue to eat fish without putting their health at risk.

WHERE DOES METHYLMERCURY IN FISH COME FROM?

Methylmercury in fish comes from mercury in the aquatic environment. Mercury, a metal, is widely found in nature in rock and soil, and is washed into surface waters during storms. Mercury evaporates from rock, soil, and water into the air, and then falls back to the earth in rain, often far from where it started. Human activities redistribute mercury and can increase its concentration in the aquatic environment. The coastal mountains in northern California are naturally rich in mercury in the form of cinnabar ore, which was processed to produce quicksilver, a liquid form of inorganic mercury. This mercury was taken to the Sierra Nevada, Klamath mountains, and other regions, where it was used in gold mining. Historic mining operations and the remaining tailings from abandoned mercury and gold mines have contributed to the release of large amounts of mercury into California's surface waters. Mercury can also be released into the environment from industrial sources, including the burning of fossil fuels and solid wastes, and disposal of mercury-containing products.

Once mercury gets into water, much of it settles to the bottom where bacteria in the mud or sand convert it to the organic form of methylmercury. Fish absorb methylmercury when they eat smaller aquatic organisms. Larger and older fish absorb more methylmercury as they eat other fish. In this way, the amount of methylmercury builds up as it passes through the food chain. Fish eliminate methylmercury slowly, and so it builds up in fish in much greater concentrations than in the surrounding water. Methylmercury generally reaches the highest levels in predatory fish at the top of the aquatic food chain.

HOW MIGHT I BE EXPOSED TO METHYLMERCURY?

Eating fish is the main way that people are exposed to methylmercury. Each person's exposure depends on the amount of methylmercury in the fish that they eat and how much and how often they eat fish.

Women can pass methylmercury to their babies during pregnancy, and this includes methylmercury that has built up in the mother's body even before pregnancy. For this reason, women of childbearing age are encouraged to be especially careful to follow consumption advice, even if they are not pregnant. In addition, nursing mothers can pass methylmercury to their child through breast milk.

You may be exposed to inorganic forms of mercury through dental amalgams (fillings) or accidental spills, such as from a broken thermometer. For most people, these sources of exposure to mercury are minor and of less concern than exposure to methylmercury in fish.

AT WHAT LOCATIONS IN CALIFORNIA HAVE ELEVATED LEVELS OF MERCURY BEEN FOUND IN FISH?

Methylmercury is found in most fish, but some fish and some locations have higher amounts than others. Methylmercury is one of the chemicals in fish that most often creates a health concern. Consumption advisories due to high levels of methylmercury in fish have been issued in about 40 states. In California, methylmercury advisories have been issued for San Francisco Bay and the Delta; Tomales Bay in Marin County; and at the following inland lakes: Lake Nacimiento in San Luis Obispo County; Lake Pillsbury and Clear Lake in Lake County; Lake Berryessa in Napa County; Guadalupe Reservoir and associated reservoirs in Santa Clara County; Lake Herman in Solano County; San Pablo Reservoir in Contra Costa County; Black Butte Reservoir in Glenn and Tehama Counties; Lake Natoma and the lower American River in Sacramento County; Trinity Lake in Trinity County; and certain lakes and river stretches in the Sierra Nevada foothills in Nevada, Placer, and Yuba counties. Other locations may be added in the future as more fish and additional water bodies are tested.

HOW DOES METHYLMERCURY AFFECT HEALTH?

Much of what we know about methylmercury toxicity in humans stems from several mass poisoning events that occurred in Japan during the 1950s and 1960s, and Iraq during the 1970s. In Japan, a chemical factory discharged vast quantities of mercury into several bays near fishing villages. Many people who consumed large amounts of fish from these bays became seriously ill or died over a period of several years. In Iraq, thousands of people were poisoned by eating contaminated bread that was mistakenly made from seed grain treated with methylmercury.

From studying these cases, researchers have determined that the main target of methylmercury toxicity is the central nervous system. At the highest exposure levels experienced in these poisonings, methylmercury toxicity symptoms included such nervous system effects as loss of coordination, blurred vision or blindness, and hearing and speech impairment. Scientists also discovered that the developing nervous systems of fetuses are particularly sensitive to the toxic effects of methylmercury. In the Japanese outbreak, for example, some fetuses developed methylmercury toxicity during pregnancy even when their mothers did not. Symptoms reported in the Japan and Iraq epidemics resulted from methylmercury levels that were much higher than what fish consumers in the U.S. would experience.

Individual cases of adverse health effects from heavy consumption of commercial fish containing moderate to high levels of methylmercury have been reported only rarely. Nervous system symptoms reported in these instances included headaches, fatigue, blurred vision, tremor, and/or some loss of concentration, coordination, or memory. However, because there was no clear link between the severity of symptoms and the amount of mercury to which the person was exposed, it is not possible to say with certainly that these effects were a consequence of methylmercury exposure and not the result of other health problems. The most subtle symptoms in adults known to be clearly associated with methylmercury toxicity are numbness or tingling in the hands and feet or around the mouth; however, these symptoms are also associated with other medical conditions not related to methylmercury exposure.

In recent studies of high fish-eating populations in different parts of the world, researchers have been able to detect more subtle effects of methylmercury toxicity in children whose mothers frequently ate seafood containing low to moderate mercury concentrations during their pregnancy. Several studies found slight decreases in learning ability, language skills, attention and/or memory in some of these children. These effects were not obvious without using very specialized and sensitive tests. Children may have increased susceptibility to the effects of methylmercury through adolescence, as the nervous system continues to develop during this time.

Methylmercury builds up in the body if exposure continues to occur over time. Exposure to relatively high doses of methylmercury for a long period of time may also cause problems in other organs such as the kidneys and heart.

CAN MERCURY POISONING OCCUR FROM EATING SPORT FISH IN CALIFORNIA?

No case of mercury poisoning has been reported from eating California sport fish. The levels of mercury in California fish are much lower than those that occurred during the Japanese outbreak. Therefore, overt poisoning resulting from sport fish consumption in California would not be expected. At the levels of mercury found in California fish, symptoms associated with methylmercury are unlikely unless someone eats much more than what is recommended or is particularly sensitive. The fish consumption guidelines are designed to protect against subtle effects that would be difficult to detect but could still occur following unrestricted consumption of California sport fish. This is especially true in the case of fetuses and children.

IS THERE A WAY TO REDUCE METHYLMERCURY IN FISH TO MAKE THEM SAFER TO EAT?

There is no specific method of cleaning or cooking fish that will significantly reduce the amount of methylmercury in the fish. However, fish should be cleaned and gutted before cooking because some mercury may be present in the liver and other organs of the fish. These organs should not be eaten.

In the case of methylmercury, fish size is important because large fish that prey upon smaller fish can accumulate more of the chemical in their bodies. It is better to eat the smaller fish within the same species, provided that they are legal size.

IS THERE A MEDICAL TEST TO DETERMINE EXPOSURE TO METHYLMERCURY?

Mercury in blood and hair can be measured to assess methylmercury exposure. However, this is not routinely done. Special techniques in sample collection, preparation, and analysis are required for these tests to be accurate. Although tests using hair are less invasive, they are also less accurate. It is important to consult with a physician before undertaking medical testing because these tests alone cannot determine the cause of personal symptoms.

HOW CAN I REDUCE THE AMOUNT OF METHYLMERCURY IN MY BODY?

Methylmercury is eliminated from the body over time provided that the amount of mercury taken in is reduced. Therefore, following the OEHHA consumption advice and eating less of the fish that have higher levels of mercury can reduce your exposure and help to decrease the levels of methylmercury already in your body if you have not followed these recommendations in the past.

WHAT IF I EAT FISH FROM OTHER SOURCES SUCH AS RESTAURANTS, STORES, OR OTHER WATER BODIES THAT MAY NOT HAVE AN ADVISORY?

Most commercial fish have relatively low amounts of methylmercury and can be eaten safely in moderate amounts. However, several types of fish such as large, predatory, long-lived fish have high levels of methylmercury, and could cause overly high exposure to methylmercury if eaten often. The U.S. Food and Drug Administration (FDA) is responsible for the safety of commercial seafood. In 2004, FDA and the U.S. Environmental Protection Agency (U.S. EPA) issued a Joint Federal Advisory for Mercury in Fish advising women who are pregnant or could become pregnant, nursing mothers, and young children not to eat shark, swordfish, king mackerel, or tilefish. The federal advisory also recommends that these individuals can safely eat up to an average of 12 ounces (two average meals) per week of a variety of other cooked fish purchased in stores or restaurants, such as shrimp, canned light tuna, salmon, pollock, or (farm-raised) catfish. Albacore ("white") tuna is known to contain more mercury than canned light tuna; it is therefore recommended that no more than six ounces of albacore tuna be consumed per week. In addition, the federal advisory recommends that women who are pregnant or may become pregnant, nursing mothers, and young children consume no more than one meal per week of locally caught fish, when no other advice is available, and eat no other fish that week. The federal advisory can be found at http://www.cfsan.fda.gov/~dms/admehg.html or http://www.epa.gov/ost/fishadvice/advice.html.

In addition, OEHHA offers the following general advice that can be followed to reduce exposure to methylmercury in fish. Chemical levels can vary from place to place. Therefore, your overall exposure to chemicals is likely to be lower if you fish at a variety of places, rather than at one location that might have high contamination levels. Furthermore, some fish species have higher chemical levels than others in the same location. If possible, eat smaller amounts of several different types of fish rather than a large amount of one type that may be high in contaminants. Smaller fish of a species will usually have lower chemical levels than larger fish in the same location because some of the chemicals may become more concentrated in larger, older fish. It is advisable to eat smaller fish (of legal size) more often than larger fish. Cleaning and cooking fish in a manner that removes fat and organs is an effective way to reduce other contaminants that may be present in fish.

WHERE CAN I GET MORE INFORMATION?

The health advisories for sport fish are printed in the California Sport Fishing Regulations booklet, which is available wherever fishing licenses are sold. OEHHA also offers a booklet containing the advisories, and additional materials such as this fact sheet on related topics. Additional information and documents related to fish advisories are available on the OEHHA Web Site at http://www.oehha.ca.gov/fish.html. County departments of environmental health may have more information on specific fishing areas.

APPENDIX 2. GENERAL ADVICE FOR SPORT FISH CONSUMERS

You can reduce your exposure to chemical contaminants in sport fish by following the recommendations below. Follow as many of them as you can to increase your health protection. This general advice is not meant to take the place of advisories for specific areas, but should be followed in addition to them. Sport fish in most water bodies in the state have not been evaluated for their safety for human consumption. This is why we strongly recommend following the general advice given below.

Fishing Practices

Chemical levels can vary from place to place. Your overall exposure to chemicals is likely to be lower if you eat fish from a variety of places rather than from one usual spot that might have high contamination levels.

Be aware that OEHHA may issue new advisories or revise existing ones. Consult the Department of Fish and Game regulations booklet or check with OEHHA on a regular basis to see if there are any changes that could affect you.

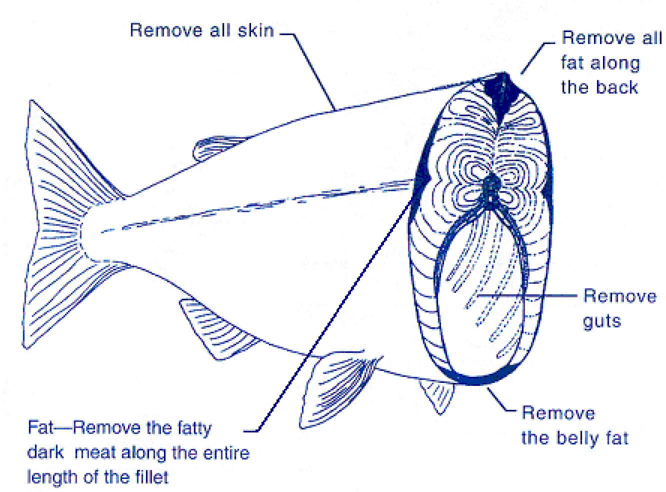
Consumption Guidelines

Fish Species: Some fish species have higher chemical levels than others in the same location. If possible, eat smaller amounts of several different types of fish rather than a large amount of one type that may be high in contaminants.

Fish Size: Smaller fish of a species will usually have lower chemical levels than larger fish in the same location because some of the chemicals may accumulate as the fish grows. It is advisable to eat smaller fish (of legal size).

Fish Preparation and Consumption

- Eat only the fillet portions. Do not eat the guts and liver because chemicals usually concentrate in those parts. Also, avoid frequent consumption of any reproductive parts such as eggs or roe.
- Many chemicals are stored in the fat. To reduce the levels of these chemicals, skin the fish when possible and trim any visible fat.
- Use a cooking method such as baking, broiling, grilling, or steaming that allows the juices to drain away from the fish. The juices will contain chemicals in the fat and should be thrown away. Preparing and cooking fish in this way can remove 30 to 50 percent of the chemicals stored in fat. If you make stews or chowders, use fillet parts.
- Raw fish may be infested by parasites. Cook fish thoroughly to destroy the parasites.



Advice for Pregnant Women, Women of Childbearing Age, and Children

Children and fetuses are more sensitive to the toxic effects of methylmercury, the form of mercury of health concern in fish. For this reason, OEHHA's advisories that are based on mercury provide special advice for women of childbearing age and children. Women should follow this advice throughout their childbearing years.

The U.S. Food and Drug Administration (FDA) is responsible for commercial seafood safety. FDA has issued the following advice about the risks of mercury in fish to pregnant women and women of childbearing age who may become pregnant. FDA advises these women not to eat shark, swordfish, king mackerel, or tilefish. FDA also advises that it is prudent for nursing mothers and young children not to eat these fish as well.

The U.S. Environmental Protection Agency has also issued national advice to protect women who are pregnant or may become pregnant, nursing mothers, and young children against consuming excessive mercury in fish. They recommend that these individuals eat no more than one meal per week of non-commercial freshwater fish caught by family and friends.

National advice for women and children on mercury in fish is available from the U.S. Environmental Protection Agency at *www.epa.gov/waterscience/fishadvice/advice.html* and the U.S. Food and Drug Administration at *www.cfsan.fda.gov/~dms/admehg.html*

APPENDIX 3. DESCRIPTIVE STATISTICS FOR MERCURY CONCENTRATION (PPM, WET WEIGHT) AND LENGTH (MM) FROM COSUMNES RIVER SITES

Descriptive Statistics[1] for Mercury Concentration (ppm, wet weight) and Length (mm) for Legal/Edible-Size Fish																	
	Mercury ppm						**Total Length mm Sample Size[2]**						**# Fish per Composite**				**Total # Fish**
Species	**Mean**	**Median**	**SD**	**Min**	**Max**	**CI[3]**	**Mean**	**Median**	**SD**	**Min**	**Max**	**CI[3]**	**n=1**	**n=2**	**n=3**	**n = 5**	**n=8**	
Asiatic Clam	.04	.04	.02	.01	.08	.03-.04	27	26	5	21	42	26-28	72	1	1	0	0	77
Bluegill	.34	.34	[4]	.34	.34	[4]	119	119	[4]	119	119	[4]	0	0	0	1	1	13
Largemouth Bass	1.18	1.26	.32	.65	2.09	1.02-1.34	381	387	45	305	485	358-403	13	0	0	1	0	18
Red Swamp Crayfish	.42	.38	.36	.07	1.83	.26-.59	44	46	7	31	56	41-47	21	0	0	0	0	21
Redear Sunfish	.30	.28	.02	.28	.33	.29-.31	153	142	14	142	170	144-161	0	0	0	1	0	5
Sacramento Sucker	.45	.49	.08	.27	.49	.37-.53	413	433	53	292	435	364-463	2	0	0	1	0	7
Signal Crayfish	.29	.27	.08	.20	.46	.22-.37	41	40	6	33	50	36-46	7	0	0	0	0	7
White Catfish	.54	.40	.19	.40	.76	.30-.77	294	272	46	272	376	238-351	2	0	1	0	0	5

[1] Data weighted by number of individuals per sample.

[2] Crayfish length was measured as median carapace. Clam length was measured as median length. For all other species, total length was measured—longest length from tip of tail fin to tip of nose/mouth. TSMP samples, a largemouth bass, fork length 371 mm, and a white catfish, fork length 247 mm, were converted to total lengths of 390 mm and 272 mm respectively per OEHHA PETB conversion factors: fork length times 1.05 for largemouth bass and fork length times 1.1 for white catfish. Length values for composite samples are typically reported as average length.

[3] 95 percent Confidence Interval.

[4] Confidence Interval and Standard Deviation are omitted because Mercury ppm and Length mm are constant.

APPENDIX 4. DESCRIPTIVE STATISTICS FOR MERCURY CONCENTRATION (PPM, WET WEIGHT) AND LENGTH (MM) FROM MOKELUMNE RIVER SITES

Descriptive Statistics[1] for Mercury Concentration (ppm, wet weight) and Length (mm) for Legal/Edible-Size Fish																								
	Mercury ppm						**Total Length mm Sample Size[2]**						**# Fish per Composite**											**Total # Fish**
Species	**Mean**	**Median**	**SD**	**Min**	**Max**	**CI[3]**	**Mean**	**Median**	**SD**	**Min**	**Max**	**CI[3]**	**n=1**	**n=2**	**n=3**	**n=4**	**n=5**	**n=6**	**n=9**	**n=14**	**n=21**	**n=26**	**n=31**	
Asiatic Clam	.03	.03	.01	.02	.04	.03-.03	22	22	2	20	25	22-23	0	C	C	1	C	C	1	1	1	1	1	105
Bluegill	.25	.24	.11	.10	.42	.20-.29	176	184	28	137	212	164-188	0	1	1	C	4	C	C	C	C	C	C	25
Largemouth Bass	.81	.75	.29	.36	1.58	.71-.90	368	368	41	312	532	355-382	27	C	C	C	2	C	C	C	C	C	C	37
Sacramento Pikeminnow	.57	.57	[4]	.57	.57	[4]	293	293	[4]	293	293	[4]	0	C	1	C	C	C	C	C	C	C	C	3
Sacramento Sucker	.30	.27	.05	.27	.37	.25-.34	327	322	13	321	357	315-339	2	C	C	C	1	C	C	C	C	C	C	7
Signal Crayfish	.18	.18	.07	.06	.34	.16-.19	48	50	5	34	59	47-49	83	C	C	C	C	C	C	C	C	C	C	83
White Catfish	.25	.28	.05	.12	.29	.21-.29	257	220	49	220	329	222-292	4	C	C	C	C	1	C	C	C	C	C	10

[1] Data weighted by number of individuals per sample.

[2] Crayfish length was measured as median carapace. Clam length was measured as median length. For all other species, total length was measured—longest length from tip of tail fin to tip of nose/mouth. Three TSMP samples were converted from fork length to total length per OEHHA PETB conversion factor of fork length times 1.05 for largemouth bass and fork length times 1.1 for white catfish. Two largemouth bass, fork length 350 mm each, were converted to total lengths of 368 mm; and one white catfish, fork length 200, was converted to total length of 220 mm. Length values for composite samples are typically reported as average length.

[3] 95 percent Confidence Interval.

[4] Confidence Interval and Standard Deviation are omitted because Mercury ppm and Length mm are constant.

APPENDIX 5. MERCURY VALUES OF INDIVIDUAL FISH TISSUE SAMPLES OF LEGAL/EDIBLE-SIZE

Common Name	Data Source	Year	Site	#	Total Length[1]	Weight (g)	Mercury Wet (ug/g)
Asiatic Clam	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	2	21.5	[2]	**.035**
Asiatic Clam	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	22.0	[2]	**.029**
Asiatic Clam	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	24.0	[2]	**.028**
Asiatic Clam	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	24.0	[2]	**.030**
Asiatic Clam	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	28.0	[2]	**.074**
Asiatic Clam	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	29.0	[2]	**.037**
Asiatic Clam	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	30.0	[2]	**.038**
Asiatic Clam	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	33.0	[2]	**.037**
Asiatic Clam	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	36.0	[2]	**.065**
Asiatic Clam	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	38.0	[2]	**.059**
Asiatic Clam	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	39.0	[2]	**.050**
Asiatic Clam	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	40.0	[2]	**.050**
Asiatic Clam	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	42.0	[2]	**.038**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	21.0	[2]	**.014**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	21.0	[2]	**.016**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	21.0	[2]	**.016**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	21.0	[2]	**.016**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	21.0	[2]	**.017**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	22.0	[2]	**.012**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	22.0	[2]	**.014**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	22.0	[2]	**.018**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	22.0	[2]	**.019**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	23.0	[2]	**.014**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	23.0	[2]	**.015**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	23.0	[2]	**.017**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	23.0	[2]	**.020**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	24.0	[2]	**.012**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	24.0	[2]	**.016**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	24.0	[2]	**.016**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	24.0	[2]	**.017**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	24.0	[2]	**.023**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	25.0	[2]	**.014**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	25.0	[2]	**.015**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	25.0	[2]	**.016**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	26.0	[2]	**.017**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	28.0	[2]	**.028**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	28.0	[2]	**.060**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	30.0	[2]	**.018**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	30.0	[2]	**.044**

Common Name	Data Source	Year	Site	#	Total Length[1]	Weight (g)	Mercury Wet (ug/g)
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	31.0	2	**.022**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	32.0	2	**.020**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	34.0	2	**.036**
Asiatic Clam	UCDavis3	1999	Cosumnes River/North Slough	1	39.0	2	**.026**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	23.0	2	**.051**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	24.0	2	**.042**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	24.0	2	**.054**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	25.0	2	**.041**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	25.0	2	**.050**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	26.0	2	**.043**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	26.0	2	**.045**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	26.0	2	**.051**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	26.0	2	**.052**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	27.0	2	**.046**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	27.0	2	**.047**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	27.0	2	**.048**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	27.0	2	**.048**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	27.0	2	**.054**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	27.0	2	**.055**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	27.0	2	**.057**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	28.0	2	**.052**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	28.0	2	**.067**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	28.0	2	**.083**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	29.0	2	**.039**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	29.0	2	**.044**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	29.0	2	**.051**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	29.0	2	**.055**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	29.0	2	**.058**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	29.0	2	**.060**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	29.0	2	**.065**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	29.0	2	**.065**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	30.0	2	**.047**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	34.0	2	**.058**
Asiatic Clam	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	35.0	2	**.072**
Asiatic Clam	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	14	19.5	2	**.045**
Asiatic Clam	UCDavis3	1999	Mokelumne River/N.F.	9	23.0	2	**.023**
Asiatic Clam	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	26	21.0	2	**.030**
Asiatic Clam	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	21	22.0	2	**.034**
Asiatic Clam	UCDavis3	1999	Mokelumne River/u/s Cosumnes River confluence	31	24.5	2	**.031**

Common Name	Data Source	Year	Site	#	Total Length[1]	Weight (g)	Mercury Wet (ug/g)
Asiatic Clam	UCDavis3	1999	Mokelumne River/u/s San Joaquin River confluence	4	25.0	[2]	**.025**
Bluegill	CALFED	1999	Cosumnes River	5	119.0	29.00	**.336**
Bluegill	CALFED	1999	Mokelumne River/btwn Beaver & Hog Sloughs	5	198.0	137.00	**.143**
Bluegill	CALFED	1999	Mokelumne River/btwn Beaver & Hog Sloughs	5	212.0	155.00	**.418**
Bluegill	CALFED	1999	Mokelumne River/d/s Cosumnes River	5	137.0	53.00	**.244**
Bluegill	CALFED	1999	Mokelumne River/d/s Cosumnes River	5	155.0	55.00	**.305**
Bluegill	CALFED	1999	Sycamore Slough/nr Mokelumne River	2	168.0	[2]	**.172**
Bluegill	CALFED	1999	Sycamore Slough/nr Mokelumne River	3	184.0	[2]	**.097**
Largemouth Bass	CALFED	1999	Cosumnes River	1	373.0	557.00	**1.300**
Largemouth Bass	CALFED	1999	Cosumnes River	1	338.0	638.00	**1.070**
Largemouth Bass	CALFED	1999	Cosumnes River	1	385.0	786.00	**1.360**
Largemouth Bass	CALFED	1999	Cosumnes River	1	364.0	831.00	**1.160**
Largemouth Bass	CALFED	1999	Cosumnes River	1	382.0	848.00	**.918**
Largemouth Bass	CALFED	1999	Cosumnes River	1	396.0	892.00	**1.390**
Largemouth Bass	CALFED	1999	Cosumnes River	1	467.0	1448.00	**1.350**
Largemouth Bass	CALFED	2000	Cosumnes River	1	305.0	[2]	**.771**
Largemouth Bass	CALFED	2000	Cosumnes River	1	325.0	[2]	**1.080**
Largemouth Bass	CALFED	2000	Cosumnes River	1	333.0	[2]	**.781**
Largemouth Bass	CALFED	2000	Cosumnes River	1	343.0	[2]	**1.000**
Largemouth Bass	CALFED	2000	Cosumnes River	1	412.0	[2]	**.650**
Largemouth Bass	CALFED	2000	Cosumnes River	1	485.0	[2]	**2.090**
Largemouth Bass	CALFED	1999	Mokelumne River/btwn Beaver & Hog Sloughs	1	363.0	614.00	**.736**
Largemouth Bass	CALFED	1999	Mokelumne River/btwn Beaver & Hog Sloughs	1	351.0	643.00	**.561**
Largemouth Bass	CALFED	1999	Mokelumne River/btwn Beaver & Hog Sloughs	1	372.0	716.00	**.779**
Largemouth Bass	CALFED	1999	Mokelumne River/btwn Beaver & Hog Sloughs	1	387.0	838.00	**.808**
Largemouth Bass	CALFED	1999	Mokelumne River/btwn Beaver & Hog Sloughs	1	394.0	910.00	**.658**
Largemouth Bass	CALFED	1999	Mokelumne River/btwn Beaver & Hog Sloughs	1	398.0	1031.00	**.910**
Largemouth Bass	CALFED	1999	Mokelumne River/btwn Beaver & Hog Sloughs	1	421.0	1120.00	**.745**
Largemouth Bass	CALFED	2000	Mokelumne River/d/s Cosumnes River	1	312.0	[2]	**.670**
Largemouth Bass	CALFED	2000	Mokelumne River/d/s Cosumnes River	1	313.0	[2]	**.588**

Common Name	Data Source	Year	Site	#	Total Length[1]	Weight (g)	Mercury Wet (ug/g)
Largemouth Bass	CALFED	2000	Mokelumne River/d/s Cosumnes River	1	313.0	[2]	**.856**
Largemouth Bass	CALFED	2000	Mokelumne River/d/s Cosumnes River	1	320.0	[2]	**1.020**
Largemouth Bass	CALFED	2000	Mokelumne River/d/s Cosumnes River	1	342.0	[2]	**1.240**
Largemouth Bass	CALFED	2000	Mokelumne River/d/s Cosumnes River	1	387.0	[2]	**1.360**
Largemouth Bass	CALFED	1999	Mokelumne River/d/s Cosumnes River	1	357.0	598.00	**1.010**
Largemouth Bass	CALFED	1999	Mokelumne River/d/s Cosumnes River	1	362.0	722.00	**.819**
Largemouth Bass	CALFED	1999	Mokelumne River/d/s Cosumnes River	1	341.0	750.00	**.752**
Largemouth Bass	CALFED	1999	Mokelumne River/d/s Cosumnes River	1	389.0	989.00	**.449**
Largemouth Bass	CALFED	1999	Mokelumne River/d/s Cosumnes River	1	399.0	1054.00	**1.350**
Largemouth Bass	CALFED	1999	Mokelumne River/d/s Cosumnes River	1	394.0	1113.00	**1.180**
Largemouth Bass	CALFED	1999	Mokelumne River/d/s Cosumnes River	1	425.0	1200.00	**1.580**
Largemouth Bass	CALFED	1999	Sycamore Slough/nr Mokelumne River	1	322.0	406.00	**.548**
Largemouth Bass	CALFED	1999	Sycamore Slough/nr Mokelumne River	1	317.0	411.00	**.364**
Largemouth Bass	CALFED	1999	Sycamore Slough/nr Mokelumne River	1	342.0	458.00	**.545**
Largemouth Bass	CALFED	1999	Sycamore Slough/nr Mokelumne River	1	326.0	542.00	**.672**
Largemouth Bass	CALFED	1999	Sycamore Slough/nr Mokelumne River	1	358.0	758.00	**.540**
Largemouth Bass	CALFED	1999	Sycamore Slough/nr Mokelumne River	1	410.0	995.00	**.537**
Largemouth Bass	CALFED	1999	Sycamore Slough/nr Mokelumne River	1	532.0	2697.00	**1.140**
Largemouth Bass	TSMP	1999	Cosumnes River/Cosumnes River Preserve	5	389.6	740.80	**1.260**
Largemouth Bass	TSMP	1999	Mokelumne River/d/s Beaver Slough	5	367.5	622.20	**.532**
Largemouth Bass	TSMP	1999	Mokelumne River/d/s Cosumnes River	5	367.5	900.70	**.948**
Red Swamp crayfish	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	32.0	7.33	**.403**
Red Swamp crayfish	UCDavis3	1998	Cosumnes River/d/s Grizzly Slough	1	41.0	19.00	**.501**
Red Swamp crayfish	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	47.0	20.96	**.353**
Red Swamp crayfish	UCDavis3	1998	Cosumnes River/d/s Grizzly Slough	1	46.0	21.10	**1.828**
Red Swamp crayfish	UCDavis3	1998	Cosumnes River/d/s Grizzly Slough	1	48.0	21.90	**.407**
Red Swamp crayfish	UCDavis3	1998	Cosumnes River/d/s Grizzly Slough	1	46.0	22.30	**.380**
Red Swamp crayfish	UCDavis3	1998	Cosumnes River/d/s Grizzly Slough	1	50.0	24.00	**.331**

Common Name	Data Source	Year	Site	#	Total Length[1]	Weight (g)	Mercury Wet (ug/g)
Red Swamp crayfish	UCDavis3	1998	Cosumnes River/d/s Grizzly Slough	1	46.0	25.20	**.583**
Red Swamp crayfish	UCDavis3	1998	Cosumnes River/d/s Grizzly Slough	1	46.0	26.00	**.767**
Red Swamp crayfish	UCDavis3	1998	Cosumnes River/d/s Grizzly Slough	1	46.0	29.40	**.449**
Red Swamp crayfish	UCDavis3	1998	Cosumnes River/d/s Grizzly Slough	1	54.0	49.00	**.416**
Red Swamp crayfish	UCDavis3	1998	Cosumnes River/d/s Grizzly Slough	1	56.0	56.60	**.402**
Red Swamp crayfish	UCDavis3	1999	Cosumnes River/North Slough	1	35.0	10.76	**.313**
Red Swamp crayfish	UCDavis3	1999	Cosumnes River/North Slough	1	44.0	26.20	**.070**
Red Swamp crayfish	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	31.0	5.53	**.118**
Red Swamp crayfish	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	31.0	6.81	**.149**
Red Swamp crayfish	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	43.0	12.07	**.150**
Red Swamp crayfish	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	43.0	18.50	**.194**
Red Swamp crayfish	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	45.0	23.20	**.245**
Red Swamp crayfish	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	47.0	24.96	**.435**
Red Swamp crayfish	UCDavis3	1999	Cosumnes River/u/s Grizzly Slough	1	51.0	35.47	**.352**
Redear Sunfish	CALFED	1999	Cosumnes River (SFEI: 1999)	5	170.0	93.00	**.329**
Sacramento Pike Minnow	CALFED	1999	Mokelumne River/d/s Cosumnes River	3	293.0	226.00	**.572**
Sacramento Sucker	CALFED	1999	Cosumnes River (SFEI: 1999)	5	433.0	831.00	**.492**
Sacramento Sucker	CALFED	2000	Cosumnes River (SFEI: 2000)	1	292.0	[2]	**.270**
Sacramento Sucker	CALFED	2000	Cosumnes River (SFEI: 2000)	1	435.0	[2]	**.428**
Sacramento Sucker	CALFED	2000	Mokelumne River/d/s Cosumnes River	1	321.0	[2]	**.357**
Sacramento Sucker	CALFED	2000	Mokelumne River/d/s Cosumnes River	1	357.0	[2]	**.374**
Sacramento Sucker	CALFED	1999	Mokelumne River/d/s Cosumnes River	5	322.0	388.00	**.267**
Signal crayfish	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	33.0	10.51	**.293**
Signal crayfish	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	40.0	19.07	**.272**
Signal crayfish	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	40.0	20.63	**.252**
Signal crayfish	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	43.0	23.91	**.273**
Signal crayfish	UCDavis3	1999	Cosumnes River/d/s Grizzly Slough	1	45.0	26.85	**.301**
Signal crayfish	UCDavis3	1999	Cosumnes River/North Slough	1	37.0	17.08	**.199**
Signal crayfish	UCDavis3	1999	Cosumnes River/North Slough	1	50.0	43.18	**.461**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	34.0	12.66	**.136**

Common Name	Data Source	Year	Site	#	Total Length[1]	Weight (g)	Mercury Wet (ug/g)
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	36.0	14.83	**.145**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	40.0	19.93	**.179**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	42.0	22.47	**.142**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	44.0	29.95	**.144**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	44.0	30.15	**.182**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	50.0	32.07	**.270**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	51.0	32.97	**.145**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	47.0	33.08	**.135**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	48.0	34.99	**.343**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	48.0	37.15	**.185**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	51.0	37.31	**.204**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	46.0	38.20	**.158**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	50.0	39.13	**.285**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	50.0	39.52	**.207**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	51.0	39.53	**.225**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	51.0	43.11	**.186**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	49.0	43.38	**.160**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	52.0	48.63	**.233**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	51.0	52.75	**.277**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	55.0	58.54	**.253**
Signal crayfish	UCDavis3	1999	Mokelumne River/d/s Cosumnes River	1	56.0	60.89	**.238**
Signal crayfish	UCDavis3	1999	Mokelumne River/N.F.	1	42.0	18.98	**.203**
Signal crayfish	UCDavis3	1999	Mokelumne River/N.F.	1	38.0	21.86	**.159**
Signal crayfish	UCDavis3	1999	Mokelumne River/N.F.	1	44.0	28.44	**.191**
Signal crayfish	UCDavis3	1999	Mokelumne River/N.F.	1	50.0	30.92	**.221**
Signal crayfish	UCDavis3	1999	Mokelumne River/N.F.	1	50.0	31.74	**.208**
Signal crayfish	UCDavis3	1999	Mokelumne River/N.F.	1	50.0	37.78	**.269**
Signal crayfish	UCDavis3	1999	Mokelumne River/N.F.	1	53.0	40.95	**.234**
Signal crayfish	UCDavis3	1999	Mokelumne River/N.F.	1	50.0	41.66	**.176**
Signal crayfish	UCDavis3	1999	Mokelumne River/N.F.	1	52.0	44.75	**.253**
Signal crayfish	UCDavis3	1999	Mokelumne River/N.F.	1	52.0	48.06	**.175**

Common Name	Data Source	Year	Site	#	Total Length[1]	Weight (g)	Mercury Wet (ug/g)
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	38.0	21.28	**.129**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	40.0	21.81	**.189**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	43.0	23.10	**.099**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	40.0	28.16	**.175**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	49.0	31.40	**.143**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	40.0	32.05	**.207**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	49.0	35.58	**.194**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	51.0	37.22	**.269**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	48.0	38.75	**.231**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	48.0	38.82	**.246**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	50.0	39.59	**.108**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	52.0	42.79	**.266**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	50.0	43.68	**.258**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	52.0	44.50	**.136**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	52.0	49.07	**.246**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	53.0	49.14	**.112**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	53.0	55.12	**.141**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	55.0	68.04	**.275**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	56.0	70.33	**.185**
Signal crayfish	UCDavis3	1999	Mokelumne River/S.F./btwn Beaver & Hog Sloughs	1	57.0	77.52	**.209**
Signal crayfish	UCDavis3	1998	Mokelumne River/u/s Cosumnes River confluence	1	37.0	16.70	**.076**
Signal crayfish	UCDavis3	1998	Mokelumne River/u/s Cosumnes River confluence	1	39.0	17.70	**.107**

Common Name	Data Source	Year	Site	#	Total Length[1]	Weight (g)	Mercury Wet (ug/g)
Signal crayfish	UCDavis3	1998	Mokelumne River/u/s Cosumnes River confluence	1	41.0	21.50	**.063**
Signal crayfish	UCDavis3	1998	Mokelumne River/u/s Cosumnes River confluence	1	46.0	27.50	**.056**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s Cosumnes River confluence	1	44.0	27.72	**.114**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s Cosumnes River confluence	1	44.0	27.87	**.102**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s Cosumnes River confluence	1	45.0	29.51	**.094**
Signal crayfish	UCDavis3	1998	Mokelumne River/u/s Cosumnes River confluence	1	46.0	30.50	**.081**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s Cosumnes River confluence	1	45.0	30.83	**.094**
Signal crayfish	UCDavis3	1998	Mokelumne River/u/s Cosumnes River confluence	1	47.0	34.20	**.080**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s Cosumnes River confluence	1	47.0	34.63	**.090**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s Cosumnes River confluence	1	49.0	39.96	**.161**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s Cosumnes River confluence	1	49.0	40.11	**.088**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s Cosumnes River confluence	1	50.0	45.19	**.061**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s Cosumnes River confluence	1	50.0	45.64	**.113**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s Cosumnes River confluence	1	52.0	47.00	**.241**
Signal crayfish	UCDavis3	1998	Mokelumne River/u/s Cosumnes River confluence	1	54.0	48.90	**.096**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s Cosumnes River confluence	1	51.0	50.94	**.105**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s Cosumnes River confluence	1	54.0	52.91	**.189**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s Cosumnes River confluence	1	56.0	67.04	**.133**
Signal crayfish	UCDavis3	1998	Mokelumne River/u/s Cosumnes River confluence	1	56.0	75.50	**.139**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s San Joaquin River confluence	1	41.0	22.06	**.249**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s San Joaquin River confluence	1	39.0	23.38	**.121**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s San Joaquin River confluence	1	47.0	34.25	**.144**

Common Name	Data Source	Year	Site	#	Total Length[1]	Weight (g)	Mercury Wet (ug/g)
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s San Joaquin River confluence	1	49.0	39.13	**.230**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s San Joaquin River confluence	1	49.0	43.35	**.237**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s San Joaquin River confluence	1	54.0	43.49	**.330**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s San Joaquin River confluence	1	53.0	45.65	**.295**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s San Joaquin River confluence	1	51.0	45.87	**.199**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s San Joaquin River confluence	1	53.0	46.83	**.200**
Signal crayfish	UCDavis3	1999	Mokelumne River/u/s San Joaquin River confluence	1	59.0	64.84	**.175**
Striped Bass	CALFED	1999	Cosumnes River	1	540.0	[2]	**.578**
Striped Bass	CALFED	1999	Cosumnes River	1	632.0	[2]	**1.000**
Striped Bass	CALFED	1999	Mokelumne River/btwn Beaver & Hog Sloughs	1	610.0	[2]	**.826**
Striped Bass	CALFED	1999	Mokelumne River/d/s Cosumnes River	1	823.0	[2]	**.691**
Striped Bass	CALFED	1999	Mokelumne River/d/s Cosumnes River	1	880.0	[2]	**.541**
Striped Bass	CALFED	1999	Mokelumne River/d/s Cosumnes River	1	615.0	1052.00	**.388**
Striped Bass	CALFED	1999	Mokelumne River/d/s Cosumnes River	1	732.0	1145.00	**.339**
Striped Bass	CALFED	1999	Mokelumne River/d/s Cosumnes River	1	747.0	1155.00	**.884**
Striped Bass	CALFED	1999	Mokelumne River/d/s Cosumnes River	1	643.0	1403.00	**1.200**
White Catfish	CALFED	2000	Cosumnes River	1	281.0	[2]	**.763**
White Catfish	CALFED	2000	Cosumnes River	1	376.0	[2]	**.723**
White Catfish	CALFED	1999	Mokelumne River/btwn Beaver & Hog Sloughs	1	289.0	344.00	**.205**
White Catfish	CALFED	1999	Mokelumne River/btwn Beaver & Hog Sloughs	1	329.0	513.00	**.123**
White Catfish	CALFED	1999	Mokelumne River/btwn Beaver & Hog Sloughs	1	323.0	524.00	**.285**
White Catfish	CALFED	1999	Sycamore Slough/nr Mokelumne River	1	310.0	463.00	**.201**
White Catfish	TSMP	1982	Cosumnes River/u/s Michigan Bar	3	271.7	201.50	**.400**
White Catfish	TSMP	1978	Mokelumne River/Woodbridge	6	220.0	219.20	**.280**

[1] Crayfish length was measured as median carapace. Clam length was measured as median length. For all other species, total length was measured—longest length from tip of tail fin to tip of nose/mouth. TSMP samples were converted from fork length to total length per OEHHA PETB conversion factors—fork length times 1.05 for largemouth bass and fork length times 1.1 for white catfish.

[2] Missing

APPENDIX 6. MERCURY VALUES OF INDIVIDUAL FISH TISSUE SAMPLES BELOW LEGAL/EDIBLE-SIZE

Common Name	Data Source	Year	Site	#	Total Length [1] (mm)	Weight (g)	Mercury Wet (ug/g)
LMB	CALFED	1999	Sycamore Slough/nr Mokelumne River	25	63.0	3.00	**.028**
LMB	CALFED	1999	Mokelumne River/btwn Beaver & Hog Sloughs	15	65.0	3.30	**.028**
LMB	CALFED	2000	Cosumnes River	1	201.0	[2]	**.418**
LMB	CALFED	2000	Mokelumne River/d/s Cosumnes River	1	210.0	[2]	**.308**
LMB	CALFED	2000	Mokelumne River/d/s Cosumnes River	1	222.0	[2]	**.360**
LMB	CALFED	2000	Cosumnes River	1	232.0	[2]	**.339**
LMB	CALFED	2000	Cosumnes River	1	252.0	[2]	**.420**
LMB	CALFED	2000	Cosumnes River	1	261.0	[2]	**.810**
LMB	CALFED	2000	Cosumnes River	1	262.0	[2]	**.946**
LMB	CALFED	2000	Mokelumne River/d/s Cosumnes River	1	273.0	[2]	**.561**
LMB	CALFED	2000	Mokelumne River/d/s Cosumnes River	1	275.0	[2]	**.766**
LMB	CALFED	2000	Cosumnes River	1	303.0	[2]	**.468**
LMB	TSMP	1981	Mokelumne River/Woodbridge	6	119.7	37.40	**.140**
LMB	TSMP	1980	Mokelumne River/Woodbridge	2	247.8	226.70	**.220**
LMB	TSMP	1979	Mokelumne River/Woodbridge	4	303.5	440.30	**.200**

[1] Length was measured as total length—longest length from tip of tail fin to tip of nose/mouth. TSMP samples were converted from fork length to total length per OEHHA PETB conversion factor for largemouth bass—fork length times 1.05.
[2] Missing