# HEALTH ADVISORY AND GUIDELINES FOR EATING FISH FROM CACHE CREEK

## (Lake, Yolo, and Colusa Counties)

**June 2014 Update**

**California Environmental Protection Agency**
**Office of Environmental Health Hazard Assessment**

# LIST OF CONTRIBUTORS

***Office of Environmental Health Hazard Assessment (OEHHA)***

***Authors***

Margy Gassel, Ph.D.
Robert Brodberg, Ph.D.

***Primary Reviewers***

Lori Lim, Ph.D.
Susan Klasing, Ph.D.

***Final Reviewers***

Anna Fan, Ph.D.
Lauren Zeise, Ph.D.
Allan Hirsch

***Director***

George V. Alexeeff, Ph.D.

# ACKNOWLEDGMENTS

Sampling and analysis of fish for contaminants are critical in the development of fish consumption advice. The Office of Environmental Health Hazard Assessment acknowledges the contribution of information from the following people and entities: D.G. Slotton, S.M. Ayers, T.H. Suchanek, R.D. Weyand, and A.M. Liston, researchers from the University of California at Davis; the Central Valley Regional Water Quality Control Board; the State Water Resources Control Board; and the California Department of Fish and Wildlife and its Moss Landing Marine Laboratories and Water Pollution Control Laboratory. Some data were downloaded from the California Environmental Data Exchange Network (CEDEN, http://www.ceden.us/AdvancedQueryTool).

***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

1001 I Street, P.O. Box 4010
Sacramento, CA 95812-4010
Telephone: (916) 327-7319

# LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ATL | Advisory Tissue Level |
| CDFW | California Department of Fish and Wildlife |
| CEDEN | California Environmental Data Exchange Network |
| mm | millimeter |
| OEHHA | Office of Environmental Health Hazard Assessment |
| ppb | parts per billion |
| RWB-5 | Central Valley Regional Water Quality Control Board |
| SBMM | Sulphur Bank Mercury Mine |
| TMDL | Total Daily Maximum Load |
| TSMP | Toxic Substances Monitoring Program |
| TL | total length |
| UCD | University of California at Davis |

# PREFACE

The Office of Environmental Health Hazard Assessment (OEHHA), a department in the California Environmental Protection Agency, is responsible for evaluating potential public health risks from chemical contamination of sport fish. This task includes issuing fish consumption advisories, when needed, 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
  - Section 59011, to advise local health authorities
- California Water Code
  - Section 13177.5, to issue health advisories

The health advisories are published in the California Department of Fish and Wildlife Sport Fishing Regulations.

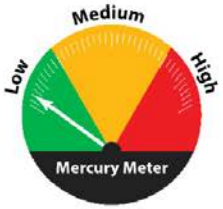
This report on the health advisory for eating fish from Cache Creek (Lake, Yolo, and Colusa Counties) is an update of the one originally issued in January 2005 and updated in March 2009. In both previous advisories, data for fish species from both Clear Lake and Cache Creek were combined. In May 2014, OEHHA updated the advisory for Clear Lake based on analysis of additional data for fish and shellfish from Clear Lake and made the advice specific to Clear Lake alone. Following the Clear Lake advisory update, OEHHA evaluated fish tissue data for Cache Creek alone and has updated that advisory as well. This report describes how the new guidelines were developed. The updated advice is shown in the illustrations following the Table of Contents.

# TABLE OF CONTENTS

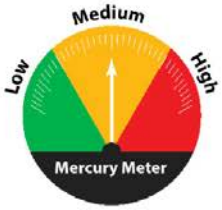
# FIGURES AND TABLES

# A Healthy Guide to Eating Fish from Cache Creek

## Women 18-45 years and children 1-17 years




Mosquitofish



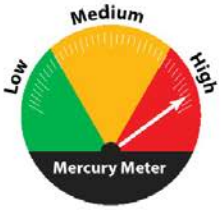

Bluegill or green sunfish

Carp

Catfish

Hardhead

Sucker




Crappie

Largemouth or smallmouth bass

Pikeminnow

| 2 servings a week | OR | 1 serving a week | Do not eat |
|---|---|---|---|

### What is a serving?

For Adults For Children

The recommended serving is the size and thickness of your hand. Give children smaller servings.

### Why eat fish?

Eating fish is good for your health.
Fish have Omega-3s that can reduce your risk for heart disease and improve how the brain develops in unborn babies and children.

### What is the concern?

Some fish have high levels of mercury.
Mercury can harm the brain, especially in unborn babies and children.

**California Office of Environmental Health Hazard Assessment** • www.oehha.ca.gov/fish.html • (916) 327-7319 or (510) 622-3170

# A Healthy Guide to Eating Fish from Cache Creek

## Women over 45 years and men

Mosquitofish

Bluegill or green sunfish

Carp

Catfish

Hardhead

Sucker

Crappie

Largemouth or smallmouth bass

Pikeminnow

**7 servings a week** OR **2 servings a week** OR **1 serving a week**

## What is a serving?

For Adults For Children

The recommended serving is the size and thickness of your hand. Give children smaller servings.

## Why eat fish?

Eating fish is good for your health.
Fish have Omega-3s that can reduce your risk for heart disease and improve how the brain develops in unborn babies and children.

## What is the concern?

Some fish have high levels of mercury.
Mercury can harm the brain, especially in unborn babies and children.

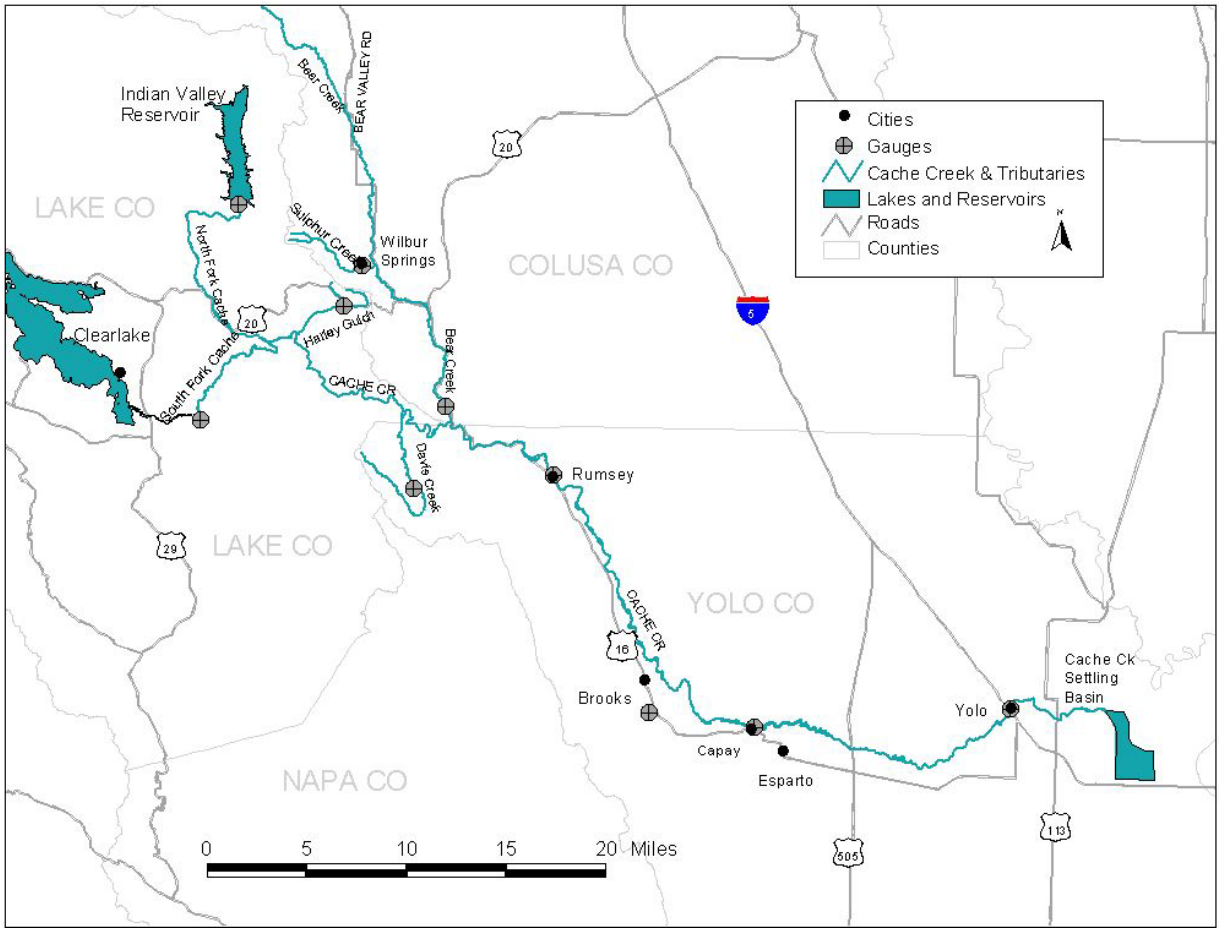
**California Office of Environmental Health Hazard Assessment** • www.oehha.ca.gov/fish.html • (916) 327-7319 or (510) 622-3170

# INTRODUCTION

Advice from the Office of Environmental Health Hazard Assessment (OEHHA) for eating fish from Cache Creek was previously combined with guidelines for fish and shellfish from Clear Lake. In this report, OEHHA is providing an advisory for Cache Creek alone, separate from advice for Clear Lake. This change makes each advisory more specific to the individual water body. While there is some overlap in species, the characteristics of Clear Lake and Cache Creek support somewhat different fish populations. Some new fish contaminant data from Cache Creek were included in the evaluation.

Clear Lake and Cache Creek are located in the California Coast Range in Lake, Yolo, and Colusa Counties, California. Clear Lake empties at its southern end into the South Fork of Cache Creek, forming the headwaters of the mainstem of Cache Creek. Cache Creek is approximately 80 miles long, flows southeastward, and eventually drains into the Yolo Bypass of the Sacramento River (Figure 1). Cache Creek consists of three sub-basins: the North Fork of Cache Creek, beginning above Indian Valley Reservoir; the South Fork of Cache Creek, beginning at the Clear Lake dam; and Bear Creek, located north of Lower Cache Creek.

FIGURE 1. MAP OF CACHE CREEK WITH CLEAR LAKE AND BEAR CREEK




Bear Creek (Colusa County) was also included in the past advisories for Clear Lake and Cache Creek. Because of extraordinarily high mercury levels in fish from Bear Creek, and the

absence of newer data, the advice of no consumption of any fish or shellfish remains the same.

# BACKGROUND INFORMATION ON CACHE CREEK

As a result of historic volcanic activity, rich mineral deposits are present in the region[1]. There are three inactive mercury-mining districts in the area. Mercury mining became a significant industry in the Clear Lake Mining District in 1873, when the Sulphur Bank Mercury Mine (SBMM) was developed on the southeast shore of Clear Lake. Open pit mining, in particular, resulted in significant mercury contamination to Clear Lake beginning in 1927 and continuing intermittently until 1957 (Suchanek et al., 2008). The SBMM also contributes mercury to the South Fork Cache Creek. In the other two mining districts, another 11 inactive mines discharge into Bear Creek and Cache Creek (Cooke et al., 2004).

A shallow magma chamber beneath the Geysers-Clear Lake area is the source of geothermal activity throughout the region. Geothermal waters are also frequently associated with the formation of ores (Slotton et al., 2004). A large number of these springs vent directly into Clear Lake or flow directly into drainages in the Cache Creek watershed (Cooke et al., 2004).

The Central Valley Regional Water Quality Control Board (RWB-5) developed a Total Daily Maximum Load (TMDL) for Cache Creek and Bear Creek based on elevated mercury levels in fish tissue and water (Cooke et al., 2004). The goal of this TMDL is to lower mercury levels in the Cache Creek watershed and the Sacramento-San Joaquin Delta[2] to protect human and wildlife health. The TMDL is for Cache Creek between Clear Lake dam and the outflow of Cache Creek Settling Basin and Bear Creek from its headwaters to its confluence with Cache Creek.

Clear Lake and Indian Valley Reservoir (Figures 1 and 2) trap winter storm runoff that is released during the irrigation season for agricultural use in Yolo County (Cooke et al., 2004). Excess water flows downstream in summer, and as a result, South Fork Cache Creek experiences increased summer flows, except during years of drought (Cooke et al., 2004; Moyle, 2001).

Waters in the Cache Creek watershed are typically warm and alkaline, but the diverted water is more plentiful and colder than the original creek water. As a result, Cache Creek supports a fish fauna that is a mixture of native and introduced species (Moyle, 2001). Smallmouth bass, an introduced species, is abundant in Cache Creek and co-exists with native species such as Sacramento pikeminnow, hardhead, and sucker (Moyle, 2001).

Fish species collected and evaluated in this report are bluegill, brown bullhead, carp, channel catfish, green sunfish, hardhead, largemouth bass, mosquitofish, rainbow trout, smallmouth bass, Sacramento pikeminnow, Sacramento sucker, white catfish, and white crappie. The number of fish collected for some species was insufficient to develop advice, as discussed further below.

[1] Volcanoes in the area are now considered dormant.
[2] Cache Creek is a primary source of mercury to the Sacramento-San Joaquin Delta (Cooke et al., 2004).

# CHEMICAL OF POTENTIAL CONCERN

Methylmercury is the chemical of concern in Cache Creek. Fish samples from Cache Creek were analyzed for mercury, as a measure of methylmercury, the more toxic form that builds up in fish tissues. Nearly all total mercury in fish is in the organic form methylmercury (Bloom, 1992; Wiener et al., 2007). OEHHA therefore assumes all mercury detected in fish samples is methylmercury.

# DATA SOURCES

OEHHA used data for Cache Creek from the previous advisories. A review of other currently available datasets for Cache Creek yielded additional samples of bluegill. In addition, OEHHA checked the California Environmental Data Exchange Network (CEDEN[3]) for potential new data. The only additional fish tissue data for Cache Creek were those for mosquitofish. OEHHA issued advice for mosquitofish from Clear Lake based on the species being identified as important to tribal members of the Big Valley Rancheria of Pomo Indians. Therefore, OEHHA also included mosquitofish in this evaluation and advisory under the assumption that mosquitofish from Cache Creek might also be eaten.

The samples selected for evaluation met minimum legal size requirements per regulations in the California Department of Fish and Wildlife (CDFW, 2013-2014), when applicable. For Cache Creek, legal size requirements apply to largemouth bass and smallmouth bass. The minimum legal size is 12 inches (equivalent to 305 millimeters or mm). For fish species without legal requirements, samples were selected for evaluation based on OEHHA established guidelines for minimum sizes based on species size at maturity and professional judgment (Gassel and Brodberg, 2005).

Table 1 shows the samples collected, the project under which they were sampled, and the years of sampling. Only samples meeting minimum size criteria are included in the table. An exception was made for mosquitofish because tribal members reportedly eat them regardless of the size.

[3] http://www.ceden.us/AdvancedQueryTool

TABLE 1. FISH SAMPLED FROM CACHE CREEK BY SOURCE AND YEAR

| Fish Species | Number of Samples | Total Number of Fish | Data Source | Year |
|---|---|---|---|---|
| Bass, largemouth | 6 | 6 | UCD | 2000 |
| Bass, smallmouth | 8 | 8 | UCD | 2000 |
| Bullhead, brown | 4 | 4 | UCD | 1995 |
| Carp | 2 | 2 | UCD | 1995 |
| Catfish, channel | 4 | 4 | UCD | 1995 |
| | 2 | 2 | UCD | 2000 |
| Catfish, white | 3 | 3 | UCD | 2000 |
| Crappie, white | 3 | 3 | UCD | 1995 |
| Hardhead | 9 | 9 | UCD | 2000 |
| Mosquitofish | 7 | 142 | UCD | 2001 |
| Pikeminnow, Sacramento | 1 | 8 | TSMP | 1998 |
| | 21 | 21 | UCD | 2000 |
| Sucker, Sacramento | 1 | 6 | TSMP | 1981 |
| | 1 | 1 | UCD | 1995 |
| | 46 | 46 | UCD | 2000 |
| | 8 | 8 | RWB-5 | 2003 |
| Sunfish, bluegill | 2 | 2 | UCD | 1995 |
| | 7 | 7 | UCD | 2000 |
| | 10 | 10 | RWB-5 | 2003 |
| Sunfish, green | 1 | 10 | TSMP | 1980 |
| | 1 | 12 | TSMP | 1981 |
| | 4 | 4 | UCD | 2000 |
| Trout, rainbow | 6 | 6 | RWB-5 | 2003 |

UCD = University of California at Davis, TSMP = Toxic Substances Monitoring Program, RWB-5=Central Valley Regional Water Quality Control Board

An additional 64 smallmouth bass, 11 largemouth bass, and 10 pikeminnow were collected as part of these projects that were not included in Table 1. OEHHA did not include these samples in the evaluation because the bass were less than legal size, and the pikeminnow did not meet OEHHA's minimum length for this species (250 mm total length[4] [TL]).

The guidelines for eating fish from Cache Creek were based on chemical analysis of fish sampled under the three projects described below. These projects had adequate documentation of sample collection, fish preparation, chemical analyses, and quality assurance, and detection limits were below levels of health concern.

## UCD/CALFED MERCURY Project

Most of the fish samples in this evaluation were collected by researchers from the University of California at Davis (UCD) in 1995 and 2000-2001 under the CALFED Mercury Project[5]. The purpose of the project was to assess ecological and human health impacts of mercury in the San Francisco Bay-Delta watershed. It was implemented by scientists from multiple agencies and organizations[6].

[4] Total length is the maximum length of the fish, with the mouth closed and the tail fin pinched together.
[5] More information and reports can be found at http://loer.tamug.edu/calfed/FinalReports.htm.
[6] A list of participants is available at: http://loer.tamug.edu/calfed/Participants.htm.

### TOXIC SUBSTANCES MONITORING PROGRAM (TSMP)

A few samples collected under the historical Toxic Substances Monitoring Program (TSMP) were also included. Beginning in 1976, TSMP provided a statewide approach to detection and evaluation of toxic substances in fresh, estuarine, and marine waters through the analysis of fish and other aquatic life[7]. Fish samples were obtained from Cache Creek in 1978-79, 1981-82, and 1988-89.

OEHHA only used the results for mercury. The TSMP results for persistent organic compounds in the 1970s and 1980s are considered too old to represent current levels. Recent data are also more reliable because analytical methods have improved, and detection limits have decreased. Therefore, no usable data on PCBs and pesticides were available from TSMP. Mercury remains a ubiquitous environmental contaminant; local and global concentrations have not noticeably declined.

### CENTRAL VALLEY REGIONAL WATER QUALITY CONTROL BOARD (RWB-5)

The RWB-5 collected fish samples from Cache Creek in 2003 for the TMDL. Ten bluegill, eight sucker, and six rainbow trout were collected and analyzed for mercury by CDFW.

## MERCURY CONCENTRATIONS

Fish samples collected by UCD and RWB-5 were analyzed as skinless fillets of individual fish except for mosquitofish. Mosquitofish were analyzed as composite samples of whole fish. TSMP samples were analyzed as composite samples of skinless fillets. Composite samples are prepared from equal amounts of tissues from several individual fish of the same species. The results represent average concentrations for the group of fish in the sample. All results were reported in wet weight.

OEHHA used the arithmetic mean (average) of the mercury concentrations for each fish species to represent average human exposure. The averages were weighted by the number of fish in the samples when a species included composite samples. Table 2 shows the weighted mean mercury concentrations (in parts per billion, ppb) and total length for each fish species.

[7] In the early 2000s, TSMP was subsumed under a newer, mandated monitoring program, the Surface Water Ambient Monitoring Program, operated by the State Water Resources Control Board. More information is available at http://www.waterboards.ca.gov/water_issues/programs/swamp/about.shtml.

TABLE 2. MERCURY CONCENTRATIONS AND TOTAL LENGTH IN FISH FROM CACHE CREEK

| Fish Species | Number of Samples | Total Number of Fish | Mean Total Length[a] (mm) | Mean Mercury (ppb) | Mercury Range (ppb) |
|---|---|---|---|---|---|
| Bass, largemouth | 6 | 6 | 408 | 433 | 270-665 |
| Bass, smallmouth | 8 | 8 | 352 | 746 | 335-1515 |
| Bass, combined | 14 | 14 | 376 | 612 | 270-1515 |
| Catfish, brown bullhead | 4 | 4 | 304 | 270 | 220-310 |
| Catfish, channel | 6 | 6 | 406 | 348 | 225-570 |
| Catfish, white | 3 | 3 | 196 | 192 | 100-295 |
| Catfish, combined | 13 | 13 | 327 | 288 | 100-570 |
| Crappie, white | 3 | 3 | 246 | 547 | 480-650 |
| Minnows, carp | 2 | 2 | 225 | 275 | 270-280 |
| Minnows, hardhead | 9 | 9 | 301 | 404 | 275-705 |
| Minnows, combined | 11 | 11 | 287 | 381 | 270-705 |
| Mosquitofish | 7 | 142 | 34[b] | 91 | 30-140 |
| Trout, rainbow | 6 | 6 | 349 | 123 | 99-159 |
| Pikeminnow, Sacramento | 22 | 29 | 289 | 473 | 115-1390 |
| Sucker, Sacramento | 56 | 61 | 348 | 263 | 55-535 |
| Sunfish, bluegill | 19 | 19 | 148 | 295 | 55-641 |
| Sunfish, green | 6 | 26 | 129 | 293 | 210-395 |
| Sunfish, combined | 25 | 45 | 137 | 294 | 55-641 |

[a] When not provided, total length was estimated from fork length using length ratios obtained from the FishXing Version 3.0 Beta, 2006 FX3_Morph Table (http://www.fsl.orst.edu/geowater/FX3/help/SwimData/Fish_Length_Table.htm) or by calculating them from sample data with both fork length and total length.
[b] The data set did not indicate whether total length or another measure of length was used for this species.

# DEVELOPMENT OF GUIDELINES FOR EATING FISH FROM CACHE CREEK

## GENERAL INFORMATION

OEHHA compared the average mercury concentrations for each species to Advisory Tissue Levels (ATLs) as the basis for guidelines for eating fish from Cache Creek. OEHHA developed ATLs (Appendix I) that are acceptable exposure levels of specific contaminants in fish tissue based on toxicity of each chemical for a range of consumption rates. The development of the ATLs also included consideration of health benefits from eating fish (Klasing and Brodberg, 2008).

There are two sets of ATLs for exposure to methylmercury in fish because of age-related toxicity (Klasing and Brodberg, 2008). The fetus and children are more sensitive to the toxic effects of methylmercury. Thus, the ATLs for women who might become pregnant (typically 18 to 45 years of age) and children (the sensitive populations) are lower than for women over

45 years and men. The lower ATL values provide protection to allow for normal growth and development of the brain and nervous system of unborn babies and children.

There is much evidence and scientific consensus that eating fish is an important part of a healthy well-balanced diet and promotes significant health benefits. Reported potential health benefits include reduced rates of heart disease and stroke, decreased inflammation, and improved mental and visual functions (IOM, 2007). The potential beneficial effects are thought to stem largely from specific omega-3 fatty acids found in significant amounts in fish, namely

- docosahexaenoic acid or "DHA" and
- eicosapentaenoic acid or "EPA."

Studies have shown that children of mothers who ate low-mercury fish during pregnancy scored better on cognitive tests compared to children of mothers who did not eat fish or ate high-mercury fish (Oken et al., 2005, 2008). OEHHA's advisory process and development of ATLs considered the health benefits from fish consumption. Further discussion on the benefits and risks of fish consumption can be found in Klasing and Brodberg (2008).

For fish collected from Cache Creek, sample sizes were sufficient to develop advice for hardhead, mosquitofish, Sacramento pikeminnow, and Sacramento sucker. Related species were combined and averaged to give advice for species groups including bluegill and green sunfish; brown bullhead, channel catfish, and white catfish; carp and hardhead; and largemouth bass and smallmouth bass. Combining related species provided at least nine fish per species group, meeting OEHHA's criterion for sufficient samples to represent the population in the water body (Gassel and Brodberg, 2005). Furthermore, the mercury levels were similar in the species in each species group. In addition, OEHHA compared crappie to bass, as discussed below. Data were insufficient to develop advice for rainbow trout, and there were no related species in the dataset.

## Fish Eating Guidelines for Fish Species and Species Groups

OEHHA determined the following advice for each species or species group after comparing the mean mercury concentrations to the ATLs. A species group includes related species. Fish species within the same genus are most closely related, and Family is the next level of relationship.

### Bass

Largemouth bass (*Micropterus salmoides*) and smallmouth bass (*Micropterus dolomieu*) belong to the same genus. The advice for these two species based on the combined mean mercury concentration, 612 ppb, is "do not eat" for the sensitive population and one serving a week for women over 45 years and men.

### Catfish

Channel catfish (*Ictalurus punctatus*), white catfish (*Ameiurus catus*), and brown bullhead (*Ameiurus nebulosus*) are all in the same Family, Ictaluridae. Based on the combined mean mercury concentration for the three species, 288 ppb, the advice is one serving a week for the sensitive population and two servings a week for women over 45 years and men.

### Crappie

Only three individual white crappie (*Pomoxis annularis*) were analyzed. Crappie is in the same Family, Centrarchidae, as bass and smaller sunfish, such as bluegill. OEHHA generally does not combine crappie with small sunfish species or with bass for developing advice because past data have shown mercury levels in crappie to be intermediate between bass and small sunfish species. In this dataset, however, the mean mercury concentration, 547 ppb, and the range of mercury concentrations in crappie were similar to or higher than the concentrations in bass. Therefore, to be health protective, OEHHA is giving the same advice for bass to crappie. OEHHA recommends no consumption for the sensitive population and one serving a week for women over 45 years and men.

### Minnows (Carp and Hardhead)

Carp (*Cyprinus carpio*) and hardhead (*Mylopharodon conocephalus*) are members of the same Family, Cyprinidae. The combined mean concentration for these two species, 381 ppb mercury, corresponds to advice of one serving a week for the sensitive population and two servings a week for women over 45 years and men.

### Mosquitofish

The maximum reported length in mosquitofish is 35 mm TL in males and 65 mm TL in females (Moyle, 2002), making it hard to fillet the fish. Therefore, OEHHA assumes that whole fish are consumed. The mosquitofish samples in this evaluation were analyzed as whole fish, and the advice is based on whole fish. The mean mercury concentration of 91 ppb in mosquitofish (*Gambusia affinis*) corresponds to two servings a week for the sensitive population and seven servings a week for women over 45 years and men.

### Sacramento Pikeminnow

The advice for pikeminnow (*Ptychocheilus grandis*) based on the mean mercury concentration, 614 ppb, is “do not eat” for the sensitive population and one serving a week for women over 45 years and men.

### Sucker

The recommended number of servings for sucker (*Catostomus occidentalis*) based on the mean concentration of 256 ppb mercury is one serving a week for the sensitive population and two servings a week for women over 45 years and men.

### Sunfish

Bluegill (*Lepomis macrochirus*) and green sunfish (*Lepomis cyanellus)* are members of the same genus. Although they are in the same Family as bass and crappie, these smaller sunfish species are typically lower in mercury. OEHHA’s recommendation for eating bluegill or green sunfish is based on the combined mean mercury concentration, 294 ppb. The advice is one serving a week for the sensitive population and two servings a week for women over 45 years and men.

## MAXIMUM RECOMMENDED NUMBER OF SERVINGS PER WEEK

Table 3 summarizes the advice for each species or species group. For all species except mosquitofish, the advice is for eating skinless fillets (muscle) of the fish.

TABLE 3. MAXIMUM RECOMMENDED NUMBER OF SERVINGS PER WEEK

| Species Common Name | Women 18-45 Years and Children 1-17 Years | Women over 45 Years and Men |
|---|---|---|
| Bass | 0 | 1 |
| Crappie | 0 | 1 |
| Pikeminnow | 0 | 1 |
| Sunfish | 1 | 2 |
| Catfish | 1 | 2 |
| Hardhead | 1 | 2 |
| Carp | 1 | 2 |
| Sucker | 1 | 2 |
| Mosquitofish | 2 | 7 |

# REFERENCES

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

CDFW. 2013-2014. Freshwater Sport Fishing Regulations. Fish and Game Commission, Department of Fish and Wildlife, Natural Resources Agency, Sacramento, CA. Online at: http://www.dfg.ca.gov/regulations/FreshFish-Mar2013/

Cooke, J, Foe, C, Stanish, S, Morris, P. 2004. Cache Creek, Bear Creek, and Harley Gulch TMDL for Mercury. Staff Report. November 2004. California Environmental Protection Agency. Regional Water Quality Control Board Central Valley Region. Sacramento, California.

Gassel M, Brodberg RK. 2005. General Protocol for Sport Fish Sampling and Analysis. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Sacramento, California. Online at: http://www.oehha.ca.gov/fish/pdf/fishsampling121406.pdf

IOM. 2007. Seafood choices, balancing benefits and risks. Committee on Nutrient Relationships in Seafood: Selections to Balance Benefits and Risks. Institute of Medicine, Food and Nutrition Board. The National Academies Press, Washington, D.C.

Klasing S, Brodberg RK. 2008. Development of fish contaminant goals and Advisory Tissue Levels for common contaminants in California sport fish: Chlordane, DDTs, dieldrin, methylmercury, PCBs, selenium, and toxaphene. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Sacramento, California. Online at: http://www.oehha.ca.gov/fish/gtlsv/pdf/FCGsATLs27June2008.pdf

Moyle, PB. 2002. Inland Fishes of California. Revised and Expanded. University of California Press.

Moyle, PB. 2001. Putah and Cache. IN: A Thinking Mammal's Guide to the Watershed. AJ Boyer, J Goggins, D Leroy, D Robertson, R. Thayer, eds. Structure and design of the Putah and Cache website is copyright 2001 University of California. Available online at: http://bioregion.ucdavis.edu/book/13_Lower_Cache_Creek/13_02_moyle_irrigating.html

Oken E, Radesky JS, Wright RO, Bellinger D, Amarasiriwardena CJ, Kleinman KP, Hu H, Rich-Edwards JW, Gillman MW. 2008. Maternal fish intake during pregnancy, blood mercury levels, and infant cognition at age 3 years in a U.S. cohort. Am. J. Epidemiol. 167(10):1171-1181.

Oken E, Wright RO, Kleinman KP, Bellinger D, Amarasiriwardena CJ, Hu H, Rich-Edwards JW, Gillman MW. 2005. Maternal fish consumption, hair mercury, and infant cognition in a U.S. cohort. Environ. Health Perspect. 113(10):1376-1380.

Slotton, DG, Ayers SM, Suchanek TH, Weyand RD, and Liston AM. 2004. Mercury Bioaccumulation and Trophic Transfer in the Cache Creek Watershed, California, in Relation to Diverse Aqueous Mercury Exposure Conditions. CALFED Mercury Program Final Project Report. January 25, 2004.

Suchanek TH, Richerson PJ, Zierenberg RA, Eagles-Smith CA, Slotton DG, Harner EJ, Osleger DA, Anderson DW, Cech JJ, Jr., Schladow SG, Colwell AE, Mount JF, King PS, Adam DP, Mcelroy KJ. 2008. The legacy of mercury cycling from mining sources in an aquatic ecosystem: from ore to organism. Ecological Applications, 18(8) Supplement, 2008, pp. A12–A28.

Wiener, JG; Bodaly RA; Brown SS; Lucotte M; Newman MC; Porcella DB; Reash RJ; and Swain EB. 2007. Monitoring and evaluating trends in methylmercury accumulation in aquatic biota. Chapter 4 in Ecosystem Responses to Mercury Contamination: Indicators of Change (Harris RC, Krabbenhoft DP, Mason RP, Murray MW, Reash RJ, and Saltman T, editors). SETAC Press, Pensacola, Florida.

# APPENDIX I. ADVISORY TISSUE LEVELS

Advisory Tissue Levels (ATLs) guide the development of advice for people eating sport fish. ATLs show maximum numbers of recommended fish servings that correspond to the chemical levels found in fish. OEHHA uses ATLs to provide advice to prevent consumers from being exposed to:

- More than the average daily reference dose[8] for chemicals not known to cause cancer, such as methylmercury, or
- For cancer-causing chemicals, a risk level greater than one additional cancer case in a population of 10,000 people consuming fish at the given consumption rate over a lifetime. This cancer endpoint is the maximum acceptable risk level recommended by the USEPA (2000b) for fish advisories.

For each chemical, ATLs were determined for both cancer and non-cancer risk, if appropriate, for one to seven eight-ounce servings per week. The most health-protective ATL for each chemical, selected from either cancer or non-cancer based risk, is shown in the table below for each population group for zero to seven servings per week. When the guidelines for eating fish from Cache Creek are followed, exposure to chemicals in fish from this water body would be at or below the average daily reference dose or the cancer risk level of one in 10,000.

| Number of servings per week[a] | **Advisory Tissue Levels (ATLs, in ppb)** | |
|---|---|---|
| | Methylmercury | |
| | Women 18 to 45 years and children 1 to 17 years | Women over 45 years and men |
| 0 | >440 | >1,310 |
| 1 | >150-440 | >440-1,310 |
| 2 | >70-150 | >220-440 |
| 3 | >55-70 | >160-220 |
| 4 | >44-55 | >130-160 |
| 5 | >36-44 | >109-130 |
| 6 | >31-36 | >94-109 |
| 7 | ≤ 31 | ≤ 94 |

[a] Serving sizes (prior to cooking, wet weight) are based on an average 160 pound person. Individuals weighing less than 160 pounds should eat proportionately smaller amounts. When residue data are compared to this table they should also first be rounded to the second significant digit.

[8] The reference dose is an estimate of the maximum daily exposure to a chemical likely to be without significant risk of harmful health effects during a lifetime.