STATEWIDE HEALTH ADVISORY AND GUIDELINES FOR EATING FISH FROM CALIFORNIA'S LAKES AND RESERVOIRS WITHOUT SITE-SPECIFIC ADVICE

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LIST OF ABBREVIATIONS AND KEY TERMS

90th percentile value	The 90th percentile value represents an upper bound value for the distribution of the lake mean mercury concentrations from sampled lakes for a fish species. It means 90% of the lake mean fish mercury concentrations were at or below this value.
440 ppb threshold	Threshold for OEHHA recommendation of no consumption of a fish species by the sensitive population because the fish mercury concentration was greater than 440 ppb.
1310 ppb threshold	Threshold for OEHHA recommendation of no consumption of a fish species by women over 45 years old and men because the fish mercury concentration was greater than 1310 ppb.
ATL	Advisory Tissue Level
ATL range	Range of methylmercury concentrations associated with a particular recommended number of serving(s) per week.
CDFW	California Department of Fish and Wildlife (formerly California Department of Fish and Game)
DDTs	dichlorodiphenyltrichloroethane (DDT) and its metabolites dichlorodiphenyldichloroethane (DDD) and dichlorodiphenyldichloroethylene (DDE)
FMP	Fish Mercury Project
Lake mean concentration	Arithmetic mean concentration of a chemical from all samples for a fish species collected in a lake. The value is weighted by the number of fish in the sample.
No-advisory Lakes	Lakes and reservoirs that do not have consumption advice established by OEHHA
OEHHA	Office of Environmental Health Hazard Assessment
PCBs	polychlorinated biphenyls
Percent	%
ppb	parts per billion
regional water board	A term for one or more of the nine Regional Water Quality Control Boards in California

RfD	reference dose
RWB7	Region 7 of the State Water Resources Control Board
Sample mercury concentration	Measured mercury concentration in fish tissue sampled from a single fish or multiple fish (a composite)
Sensitive population	Women of child-bearing age (age 18 to 45 years) and children (ages 1 to 17 years)
SWAMP	Surface Water Ambient Monitoring Program
SWRCB	State Water Resources Control Board
TSMP	Toxic Substances Monitoring Program
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USEPA	U.S. Environmental Protection Agency

PREFACE

The Office of Environmental Health Hazard Assessment (OEHHA) is a department within the California Environmental Protection Agency. OEHHA is responsible for evaluating potential health risks from chemical contamination of sport fish and issuing health advisories and consumption guidelines. This authority is based on mandates in the:

- California Health and Safety Code
    - Section 59009, to protect public health; and
    - Section 59011, to advise local health authorities.
- California Water Code
    - Section 13177.5, to issue health advisories.

The consumption advice is published in the California Department of Fish and Wildlife Sport Fishing Regulations booklets under the section “Public Health Advisory on Fish Consumption.”

Health advisory and consumption guideline reports describe the evaluation of chemical contaminants in sport fish tested from water bodies in a certain location or region. The evaluation process also recognizes and integrates the health benefits from fish consumption. Fish consumers can use the information in the advisory to make choices about how frequently to eat the fish in their catch, and to select fish low in contaminants and high in beneficial omega-3 fatty acids.

This is the first statewide advisory and report, and the focus is on sport fish caught from lakes and reservoirs where there is currently no site-specific advice issued by OEHHA.

TABLE OF CONTENTS

EXECUTIVE SUMMARY 1
A Healthy Guide to Eating Fish from Lakes and Reservoirs without Site-Specific Advice 3
INTRODUCTION 5
CHEMICALS OF CONCERN 7
STATEWIDE ADVISORY PROCEDURE 8
DATASET SELECTION 8
Data Sources 8
Fish Species 11
Criteria for Data Adequacy 13
LABORATORY ANALYSIS OF MERCURY IN FISH SAMPLES 24
ADVISORY TISSUE LEVELS 24
ANALYSIS OF MERCURY CONCENTRATION DATA 25
Sample Basis 25
Lake Basis 26
DEVELOPMENT OF STATEWIDE CONSUMPTION ADVICE 26
Geographic Consideration 27
Statewide Procedure 28
MERCURY CONCENTRATIONS AND BASIS FOR STATEWIDE ADVICE 28
INDIVIDUAL FISH SPECIES 28
Bass 28
Bullhead and Catfish 30
Carp 32
Sunfish 34
Brown Trout 35
Rainbow Trout 38
ALL SPECIES SUMMARY 39
FUTURE WORK 42
REFERENCES 43
APPENDIX I. List of Lakes in the Statewide Dataset 47

LISTS OF FIGURES AND TABLES

Figure 1. Location of mines and water bodies with fish consumption advisories..... 6
Figure 2. Statewide consumption advice scheme 9
Figure 3. Fishing lakes and lakes with mercury data in the statewide advisory dataset 15
Figure 4. Location of SWRCB water board regions..... 16
Figure 5. Lakes with bass mercury data in the statewide dataset 18
Figure 6. Lakes with bullhead and catfish mercury data in the statewide dataset..... 19
Figure 7. Lakes with carp mercury data in the statewide dataset..... 20
Figure 8. Lakes with sunfish mercury data in the statewide dataset 21
Figure 9. Lakes with rainbow trout mercury data in the statewide dataset 22
Figure 10. Lakes with brown trout mercury data in the statewide dataset..... 23
Figure 11. Distribution of lakes with bass mercury levels among SWRCB water board regions..... 27
Figure 12. Fish length and mercury concentrations of bass 29
Figure 13. Distribution of lake mean mercury concentrations for bass 30
Figure 14. Fish length and mercury concentrations of bullhead and catfish..... 31
Figure 15. Distribution of lake mean mercury concentrations for bullhead and catfish.. 31
Figure 16. Fish length and mercury concentrations of carp..... 33
Figure 17. Distribution of lake mean mercury concentrations for carp..... 33
Figure 18. Fish length and mercury concentrations of sunfish 34
Figure 19. Distribution of lake mean mercury concentrations for sunfish 35
Figure 20. Fish length and mercury concentrations of brown trout..... 36
Figure 21. Brown trout fish length and mercury concentration correlation..... 37
Figure 22. Distribution of lake mean mercury concentrations for brown trout..... 37
Figure 23. Fish length and mercury concentrations of rainbow trout..... 38
Figure 24. Distribution of lake mean mercury concentrations for rainbow trout..... 39
Figure 25. Consumption recommendations for two population groups at statewide mercury concentrations 41

Table 1. Fish species in the statewide advisory dataset..... 12
Table 2. Sample size and project contribution to the statewide advisory dataset..... 13
Table 3. Distribution of California lakes by SWRCB water board regions 16
Table 4. Distribution of lakes with fish mercury data by SWRCB water board regions.. 17
Table 5. Advisory Tissue Levels for methylmercury 25
Table 6. Lake mean mercury concentrations in fish of the statewide advisory dataset. 26
Table 7. Statewide consumption advice for lakes without site-specific advice 42
Table 8. Mercury tissue data completeness for lakes in the statewide dataset..... 42

EXECUTIVE SUMMARY

In this report, the Office of Environmental Health Hazard Assessment (OEHHA) develops a statewide advisory for sport fish taken from California lakes and reservoirs that do not currently have fish consumption advisories. These water bodies are referred to as no-advisory lakes. Fish consumers can use this statewide advice to make decisions about which fish species to eat from these lakes and how often. For fish from lakes with advisories, consumers should follow OEHHA's established site-specific advice[1].

The statewide advisory focuses on exposure of fish consumers to mercury. Mercury is a trace metal that occurs naturally in the environment. It is redistributed as a result of human activities such as mining and burning of fossil fuels. In water bodies, the chemical form changes to the more toxic organic form, methylmercury, which builds up in fish and other organisms. Methylmercury can cause harm to the nervous system. Unborn babies and children are particularly susceptible to this effect because their nervous systems are still developing. This is the reason OEHHA identifies women ages 18-45 years, the child-bearing period, and children (ages 1 to 17) as the sensitive population. OEHHA provides different advice for them than for women over 45 years and men.

The mercury levels in fish tissue determine the advice for eating most fish in existing California fish consumption advisories. Total mercury is commonly analyzed and assumed to be methylmercury because almost all mercury present in fish is in this form. To develop advisories for an individual water body, OEHHA needs good data on chemical levels in multiple species. Getting these data takes extensive resources. For these reasons, OEHHA has only developed fish advisories for a fraction of the water bodies in the state. However, various regional and state programs have collected fish samples from a number of no-advisory lakes and analyzed them for mercury. For this statewide advisory, OEHHA evaluated the fish tissue mercury levels of common sport fish from no-advisory lakes throughout the state. Adequate samples from a broad distribution of locations were available to develop statewide advice for bass[2], bullhead, catfish, carp, sunfish[3], brown trout, and rainbow trout. Sampling of other fish species was inadequate for developing statewide advice.

For each species included in the statewide advice, OEHHA:

- Selected mercury data and fish species from no-advisory lakes
- Calculated the 90th percentile value of these lake mean mercury concentrations for each species
- Compared each 90th percentile value with Advisory Tissue Levels (ATLs) for methylmercury

[1] OEHHA's fish advisories can be found at http://www.oehha.ca.gov/fish/so_cal/index.html
[2] Bass includes largemouth bass, smallmouth bass, and spotted bass.
[3] Sunfish includes bluegill, redear sunfish, green sunfish, and pumpkinseed.

Mean mercury levels in fish vary a lot because lake conditions also vary. Using the grand mean concentration for all lakes combined would not protect people eating fish from more contaminated lakes. Instead, OEHHA selected the 90th percentile value of all lake mean mercury concentrations from sampled lakes for a species as the health-protective basis for consumption advice for the statewide advisory. The 90th percentile value is a higher value than the mean concentration used for site-specific advisories. Therefore, fewer servings of fish are recommended. OEHHA used the higher value because the advice is to be applied statewide including some lakes with high fish tissue mercury and unsampled lakes with no mercury data for the fish. OEHHA determined the statewide advice for each species by comparing the 90th percentile value of the distribution of lake mean mercury concentrations to the OEHHA Advisory Tissue Levels (ATL)[4] for methylmercury.

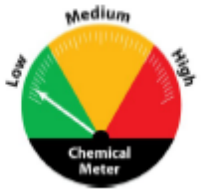
For each fish species, OEHHA developed advice for the two population groups because of the age-related toxicity of methylmercury. The statewide advice is shown in the graphic illustrations following this summary. The advisory shows the maximum number of servings to eat each week for the selected species. The guidelines also identify species high in omega-3 fatty acids. OEHHA encourages people to eat fish such as rainbow trout and brown trout at or under 16 inches that have low mercury levels and high levels of omega-3 fatty acids. Some fish have higher mercury levels, such as bass, carp, and large (over 16 inches) brown trout. OEHHA recommends that women ages 18 to 45 and children ages 1 to 17 not eat these fish. Women over 45 years and men can eat one serving a week of these fish. These guidelines, when followed, will help consumers lower the risk and increase the benefits from eating sport fish caught in California lakes.

More data are needed for many of the lakes evaluated for this report. Only eight lakes met OEHHA's criteria of at least nine fish per fish species and three or more representative species. OEHHA will coordinate with the state's Regional Water Quality Control Board(s) and other entities to plan further sampling and analysis of mercury and other common chemicals in fish. OEHHA will develop advice for eating fish from specific lakes and reservoirs as data become available. Efforts will be directed toward lakes found to contain high-mercury fish as well as those with low-mercury fish. Advice for the latter would be helpful for people who want to fish at lakes where more species have low mercury levels.

[4] The ATLs are acceptable levels in fish tissue based on chemical toxicity with consideration of the health benefits from eating fish (Klasing and Brodberg, 2008).

A Healthy Guide to Eating Fish from Lakes and Reservoirs without Site-Specific Advice

Women 18-45 years and children 1-17 years



Rainbow trout

= High in Omega-3s

Bullhead

Catfish

Bluegill or other sunfish

Brown trout
16 inches or less

Bass

Carp

Brown trout
over 16 inches

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. Women over 45 years and men have lower risk and can eat more fish.

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A Healthy Guide to Eating Fish from Lakes and Reservoirs without Site-Specific Advice

Women over 45 years and men can safely eat more fish

Rainbow trout

Bullhead

Catfish

Bluegill or other sunfish

Brown trout

Bass

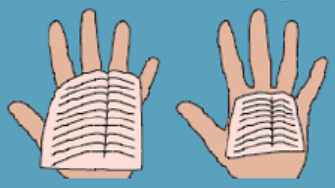
Carp

Brown trout over 16 inches

= High in Omega-3s

6 servings a week	OR	2 servings a week from this group	OR	1 serving a week from this group

What is a serving?



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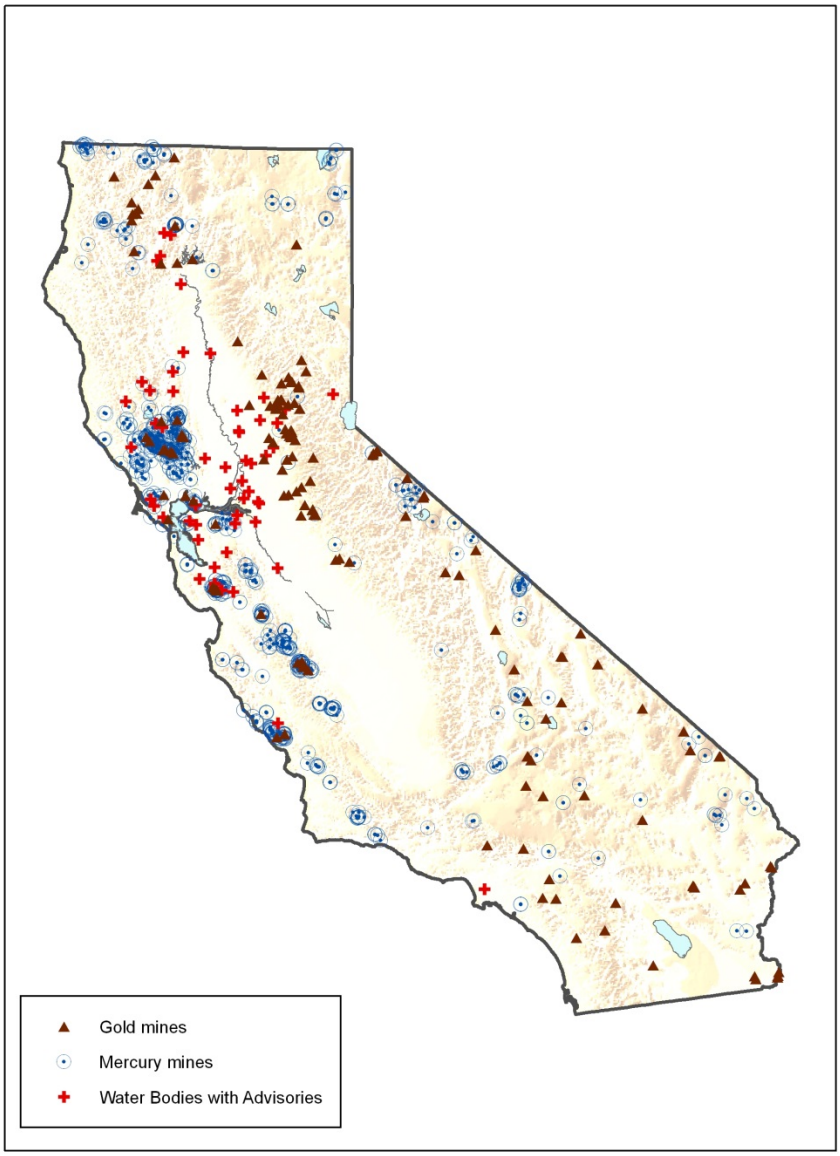
INTRODUCTION

California has thousands of inland lakes and reservoirs, as well as many miles of creeks, streams, rivers, and coast. Fishing activities are known to occur at many of these water bodies, as reported by the California Department of Fish and Wildlife (CDFW[1]), the State Water Resources Control Board (SWRCB), and fishing experts. Sport fish from some of these water bodies have been shown to contain chemical contaminants at levels that may be of human health concern (Davis et al., 2007, 2010, and 2012). The Office of Environmental Health Hazard Assessment (OEHHA) has developed consumption advisories for sport fish for a number of California water bodies.[2] Water bodies with advisories developed by OEHHA are localized mainly in areas of historical mercury or gold mining operations in Northern California (Figure 1) where contaminant levels are expected to be higher and contaminant data are more readily available (Alpers et al., 2005). These advisories provide fish consumers with information to make choices about how frequently to eat the fish in their catch, and to select fish low in contaminants and high in beneficial omega-3 fatty acids. However, there are many water bodies that have not been evaluated because developing an advisory for an individual water body requires adequate chemical contaminant data for multiple species and is resource intensive. Thus, OEHHA conducted an evaluation to develop a statewide advisory for sport fish taken from California lakes and reservoirs that do not currently have fish consumption advisories as described in this report. As more fish are analyzed and data become available for specific lakes, OEHHA plans to provide site-specific advice for these lakes.

In this first evaluation of fish contaminant data on a statewide basis, OEHHA examined the mercury data in fish sampled from lakes where OEHHA has not issued consumption advice, referred to collectively as “no-advisory lakes” in this report. These data came from several regional studies. The overall evaluation was greatly facilitated by the results of a statewide survey of chemical contamination in lakes and reservoirs (Davis et al., 2010; the study design will be described in a later section). OEHHA determined that sample sizes from individual no-advisory lakes were inadequate to develop water body-specific advisories for the vast majority of lakes. However, a sufficient number of samples were available to develop statewide fish consumption advice for no-advisory lakes as a group. The resulting statewide advisory will better reflect environmental conditions and contamination in California compared to the 2004 U.S. Environmental Protection Agency/Food and Drug Administration (USEPA/FDA) joint federal advisory for mercury in fish (USEPA, 2004a and 2004b). Currently, almost 40 states have developed statewide fish consumption advisories, based primarily on concern regarding the risk of mercury exposure to pregnant women and children (USEPA, 2011).

[1] Formerly Department of Fish and Game. Name change effective January 1, 2013.
[2] OEHHA fish advisories can be found at: http://www.oehha.ca.gov/fish.html

FIGURE 1. LOCATION OF MINES AND WATER BODIES WITH FISH CONSUMPTION ADVISORIES



Gold mines categorized by U.S. Geological Survey (USGS) as having had large and medium production are plotted (USGS, 2012). Small production gold mines are numerous, and including them would overlap and obscure mercury mines and advisory sites. Activities at mines could also contribute toward mercury contamination in fish of nearby water bodies. All mercury mines are included. Inland water bodies with existing advisories include lakes, reservoirs, rivers, and the Delta. For simplicity, each river or river segment with an advisory is indicated as a single point.

CHEMICALS OF CONCERN

Mercury is the main chemical of concern in fish from lakes and reservoirs in California. It is the only chemical consistently measured in fish from California's fish contaminant data sources, and its levels are the basis for the consumption advice for most fish. The main source of mercury in the aquatic environment in California is past gold and mercury mining activities, with additional sources of mercury from coal-fired combustion, waste incineration, and global cycling (Davis et al., 2010; Drevnick et al., 2009; Heyvaert et al., 2000a and 2000b; National Atmospheric Deposition Program, 2011). Geothermal springs also contribute mercury to the aquatic environment (Davis et al., 2010). Under suitable environmental conditions, mercury in the sediment is transformed by bacteria to the more toxic organic form, methylmercury. Methylmercury is then absorbed by fish when they eat smaller aquatic organisms. Methylmercury usually reaches the highest levels in predatory fish, such as bass. High levels of methylmercury can adversely affect the nervous system. Unborn babies and young children are particularly susceptible to this effect because their nervous systems are still developing. Detailed discussion of the toxicity of this chemical is presented in Klasing and Brodberg (2008).

In contrast to mercury, there are fewer monitoring studies conducted for persistent organics such as polychlorinated biphenyl congeners (PCBs) and persistent pesticides. PCBs bioaccumulate in high-lipid species or bottom feeders such as common carp, channel catfish, and brown bullhead. They are man-made chemicals previously used in electrical transformers, plastics, and lubricating oils. Their presence in lakes may be associated with prior leaks and spills. While PCBs were banned for use in the 1970s, they persist in the environment because they do not break down easily. Persistent pesticides such as chlordanes, dieldrin, and dichlorodiphenyltrichloroethane (DDT) in fish tissues can also be of concern for consumers in some places. A statewide survey of lakes showed only 1 percent (%) of the lakes sampled (3 of 272 lakes) had a species with high average PCB concentrations (Davis et al., 2010). Concern for pesticides in lakes is also low because the sampled lakes had very low levels of persistent pesticides.

STATEWIDE ADVISORY PROCEDURE

OEHHA followed the basic process used for developing water body-specific and regional (e.g., the Delta) consumption advice to develop the statewide consumption advice. The process involves these steps:

- Select chemical data and fish species to be evaluated
- Calculate chemical concentrations and other descriptive statistics as appropriate, for each fish species
- Compare chemical concentrations with Advisory Tissue Levels (ATLs) previously established by OEHHA for each chemical of concern.

The overall scheme for the development of the statewide advisory is presented in Figure 2. Details of the procedure are discussed in this section.

DATASET SELECTION

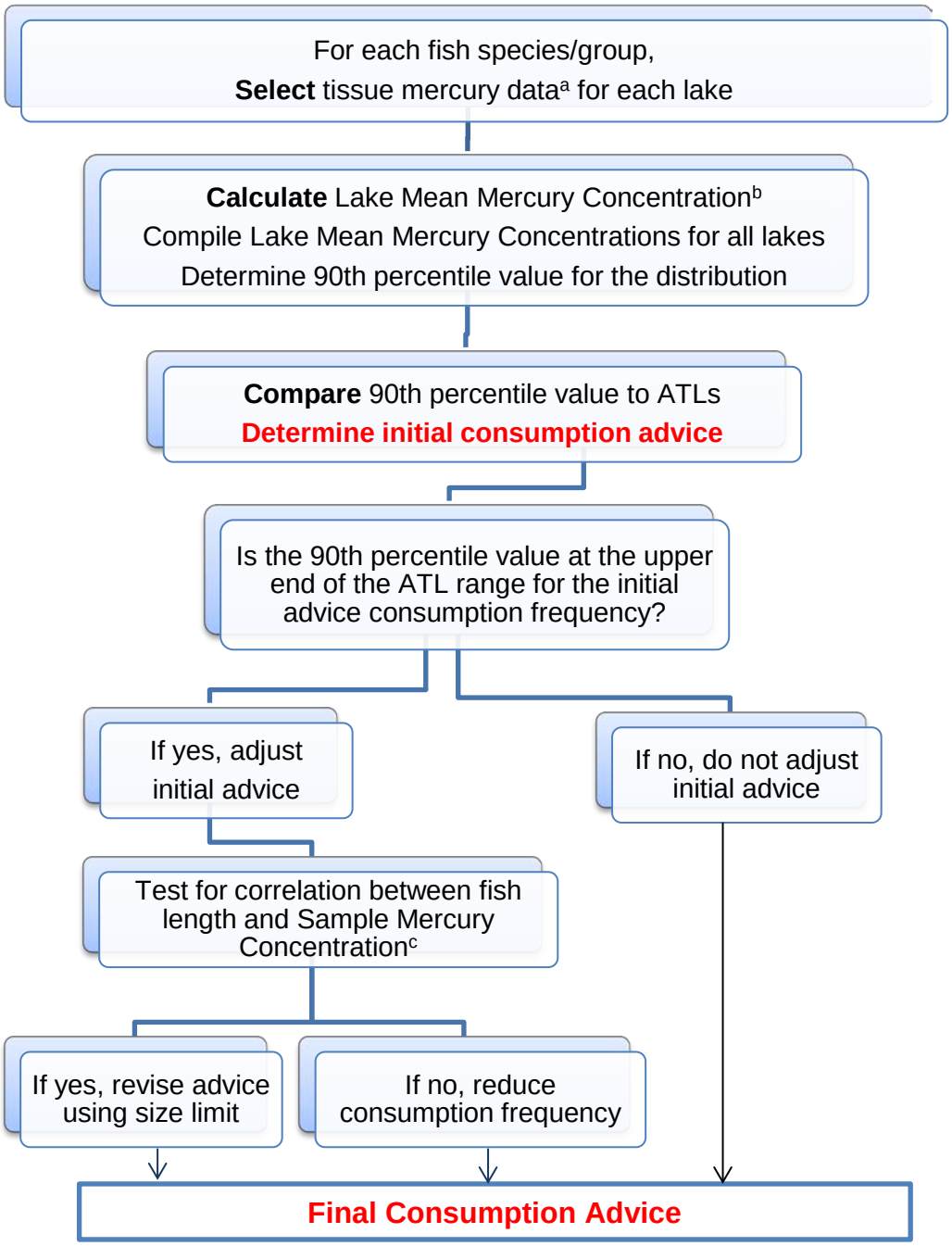
DATA SOURCES

The fish mercury data used in this report were compiled from lakes that do not have existing advisories.[3] The main sources of data used were: (1) the SWRCB State Water Ambient Monitoring Program (SWAMP) (referred to as the Lakes Study in this report; Davis et al., 2010); (2) the Toxic Substances Monitoring Program (TSMP); and (3) the Fish Mercury Project (FMP)[4]. These programs are explained in more detail below. Other minor sources that sampled more limited geographic areas were also used. The studies from these sources had good documentation of sample collection, fish preparation, chemical analyses, and quality assurance. Their detection limits for mercury were acceptable for use in this assessment. A sample is defined as the unit that was analyzed for contaminants in these studies. It is composed of either a single fish or multiple-fish composite. Composite samples are prepared from equal amount of tissues from several individual fish, all of the same species. The result of a composite sample represents an average concentration.

[3] OEHHA used data from validated files compiled as of November 2011. OEHHA continues to collect data from accessible sources and will add validated data to future prioritization and assessments of water bodies.

[4] SWAMP, TSMP, and FMP data can be downloaded at the California Environmental Data Exchange Network: http://ceden.org/ceden_data.shtml

FIGURE 2. STATEWIDE CONSUMPTION ADVICE SCHEME



a/ Included only those data that met criteria for adequate data: geographical distribution, number of samples, number of lakes sampled.
b/ Lake Mean Mercury Concentration: arithmetic mean concentration of a chemical from all samples for a fish species collected in a lake.
c/ Sample Mercury Concentration: measured mercury concentration in fish tissue sampled from a single fish or multiple fish (a composite).

Some data were obtained from original project sources and some were obtained from an electronic database organized in 2003 by the Central Valley Regional Water Quality Control Board. OEHHA reviewed the dataset and made corrections, when necessary, to create a dataset suitable for developing advisories. Brief descriptions of the data sources are presented below.

The Lakes Study

A statewide survey of inland water bodies was conducted by the SWAMP, which sampled 272 of California's lakes and reservoirs from 2007 to 2008 (Davis et al., 2010). Of the surveyed lakes, 222 were targeted for sampling as popular fishing lakes and an additional 50 were selected using a random sampling draw to provide a statistical statewide assessment. Twenty-three species of fish were collected overall; bass, carp, and rainbow trout were the most frequently collected species. Selected species were analyzed for mercury and one or more of the following chemicals: PCBs, dieldrin, DDT and its metabolites (DDTs), chlordanes, and selenium. The SWRCB used the data from this survey to characterize statewide water quality conditions.

TSMP: Toxic Substances Monitoring Program

The TSMP (1976-2003) was a state water quality-monitoring program managed by the SWRCB (SWRCB, 2013). The program objective was to provide statewide information on the occurrence of toxic substances by monitoring water bodies primarily targeted for known or suspected impaired water quality. CDFW staff collected fish and other aquatic life from multiple sites of fresh, estuarine, and marine waters throughout the state. No summary of the number of lakes sampled and fish collected at them during the course of the program is available. Some of this historic data has been entered in the California Environmental Data Exchange Network. The fish samples were analyzed for mercury and organochlorine compounds.

FMP: The Fish Mercury Project

The FMP was a three-year (2005 to 2007) sampling program funded by CALFED[5] (FMP, 2012). Monitoring of sport fish from Central Valley water bodies was planned and conducted by staff at CDFW, OEHHA, California Department of Public Health, University of California at Davis, and San Francisco Estuary Institute. More than 4,000 fish and 31 sport fish species were collected under the project objective to characterize spatial and temporal trends in mercury in fishery resources. Fish samples were collected from 146 popular sport fishing locations in the Delta watershed. The fillets were analyzed for total mercury.

[5] The CALFED Bay Delta Program was a state and federal partnership to improve water quality, increase water supply, as well as support ecosystem restoration and levee improvement in the San Francisco Bay-Delta.

Smaller Projects

Data from studies conducted by the Colorado River Regional Water Quality Control Board (Region 7; RWB7) and the United State Geological Survey (USGS) were also used for this advisory. The RWB7 Fish Study was conducted in 2004 to characterize fish tissue contamination. The RWB7 Study collected six fish species (total 98 samples) from 14 sites at lakes and rivers in the region for analysis of mercury, PCBs, and persistent pesticides.

The USGS conducted investigations to characterize the occurrence and distribution of mercury in water, sediment, and biota at 38 river and lake sites in the South Yuba River, Deer Creek, and Bear River watersheds in 1999 (May et al., 2000). Additionally, during 2000 to 2002, four sites within Trinity Lake and 19 sites along the Trinity River or in the watershed were sampled (May et al., 2005). Samples were analyzed for mercury.

Fish Species

Fish species selected for this report were those popular with anglers or targeted for monitoring as indicators of contamination (Table 1). Data for some species were combined as a single group based on their taxonomy (i.e., they are in the same family or genus) and past observed similarities in level of chemical contamination.

- The bass group consisted of taxonomically related largemouth, smallmouth, and spotted bass. OEHHA has previously developed unified consumption advice for these three bass species for individual water bodies.
- Bullhead and catfish were grouped because of the following:
    - They are in the same family
    - They may not be distinguishable by some fishermen
    - Their contaminant levels have generally resulted in similar consumption advice for a particular water body.
- The sunfish group included the small sunfish, also called panfish, and included bluegill, green sunfish, redear sunfish, and pumpkinseed. Crappie was not grouped into the sunfish group, even though they are of the same family, because they have been found to be more contaminated than the other small sunfish in some California water bodies (OEHHA, 2009).
- Rainbow trout and brown trout, which are both in the salmonid family, were also considered separately because they tended to have different mercury concentrations in some prior studies.

For the evaluation, OEHHA selected only those samples from each fish species with acceptable fish length. Fish size was measured as total length or fork length.[6] Fork lengths were converted to total lengths, as the standard measurement. OEHHA used limited available conversion factors for select species and estimated others by considering the degree of fork in the tail, which corresponds to the difference between

[6] Total length refers to the length from the tip of the snout to the tip of the longer lobe of the caudal fin. Fork length refers to the length from the tip of the snout to the end of the middle caudal fin rays.

these two length measurements. Fish lengths had to meet legal limits or edible size criteria (Gassel and Brodberg, 2005).

TABLE 1. FISH SPECIES IN THE STATEWIDE ADVISORY DATASET

Fish Species	**Common Names**	**Scientific Name** *Genus* (Family)
Bass	Largemouth bass, smallmouth bass, spotted bass	*Micropterus* (Centrarchidae)
Bullhead and Catfish	Brown bullhead, black bullhead, white catfish, channel catfish	*Ameiurus* (Ictaluridae) *Ictalurus* (Ictaluridae)
Carp	Common carp	*Cyprinus* (Cyprinidae)
Crappie	Black crappie, white crappie	*Pomoxis* (Centrarchidae)
Sacramento pikeminnow	Sacramento pikeminnow	*Ptychocheilus* (Cyprinidae)
Sacramento sucker	Sacramento sucker	*Catostomus* (Catostomidae)
Sunfish	Bluegill, redear sunfish, green sunfish, pumpkinseed	*Lepomis* (Centrarchidae)
Brown trout	Brown trout	*Salmo* (Salmonidae)
Rainbow trout	Rainbow trout, cutthroat trout, Eagle Lake trout	*Onchorhynchus* (Salmonidae)

There was a total of 272 lakes in the dataset (a list is provided in Appendix I). The total numbers of lakes and samples and fish for each species group in the dataset are shown in Table 2. Most species groups (56%) have 100 or more samples representing a total of more than 350 fish. Fewer samples of crappie, Sacramento pikeminnow, and Sacramento sucker were available. Table 2 also shows the proportion of samples in each species group derived from each project. Most of the data came from the Lakes Study (Davis et al., 2010) and FMP (FMP, 2012). Bass, carp, and rainbow trout were sampled at more lakes than other species because they were targeted for sampling in the Lakes Study.

TABLE 2. SAMPLE SIZE AND PROJECT CONTRIBUTION TO THE STATEWIDE ADVISORY DATASET

Fish Species	Total Lakes[a]	Total Samples	Total Fish	Percentage of Samples by Project[b]			
				Lakes Study	TSMP	FMP	RWB7, USGS
Bass[c]	142	1734	2045	83%	4%	12%	1%[d,e]
Bullhead and Catfish	50	145	456	25%	19%	53%	3%[d]
Carp	78	246	933	57%	13%	29%	1%[d]
Crappie	8	23	51	17%	4%	65%	13%[d]
Sacramento pikeminnow	4	28	28	64%	0%	36%	0%
Sacramento sucker	20	50	158	34%	14%	52%	0%
Sunfish[f]	34	189	382	3%	9%	86%	2%[d]
Brown trout	23	43	149	44%	26%	26%	5%[d]
Rainbow trout	86	228	856	63%	9%	29%	0%

Project Source abbreviations:

- FMP=Fish Mercury Project,
- TSMP=Toxic Substances Monitoring Program,
- RWB7=Regional Water Quality Control Board 7 (Colorado River Basin) Fish Study,
- USGS=U.S. Geological Survey study.

a/ There was a total of 272 lakes with different species combinations
b/ % of total samples for each fish species from the listed sources.
c/ Bass includes: largemouth bass, smallmouth bass, and spotted bass
d/ RWB7 data
e/ USGS data
f/ Sunfish includes: bluegill, green sunfish, redear sunfish, and pumpkinseed.

CRITERIA FOR DATA ADEQUACY

OEHHA established the following criteria to determine which species had adequate sample data to include in the statewide advisory dataset.

- Samples collected within the area where CDFW reported fishing sites of the species
- Samples collected within the biogeographic range[7] of the species
- For species with a statewide range:
    - Samples from the geographic jurisdictions of more than five regional water boards
    - Data from more than 100 samples or 50 lakes
- For species with a limited range:
    - Samples from regional water board jurisdictions in the species' range

[7] Biogeographic range is the geographical range where the species is distributed. Some fish species (for example bass) are widely distributed in California, while others (for example brown trout) are more limited to water bodies at higher elevations.

The locations of fishing lakes for this comparison were obtained from CDFW's Fishing Guide web site (CDFW, 2012[8]). CDFW created its map of fishing locations based on water bodies where the department stocked trout and on input from its staff. The CDFW Fishing Guide website also includes information on water bodies where selected species are likely to be found. The fishing lakes used in the comparisons do not include those where CDFW only listed hatchery trout. Hatchery trout generally have lower levels of mercury from hatchery feed, compared to food from the lake environment.

The distribution of lakes with mercury data and the CDFW fishing lakes showed a similar pattern (Figure 3). Most (80% of the popular fishing lakes selected by SWAMP in the Lakes Study are included in the CDFW list of fishing lakes. Note that these two categories of lakes are not evenly distributed across the state, but both are more concentrated in areas where there are more lakes (e.g., most lakes in California are in the Central Valley Region 5, see Table 3). The regional water board boundaries follow drainage basins and were established by the SWRCB to manage and protect water quality (Figure 4). They could reflect local environmental similarities affecting mercury levels within their boundaries.

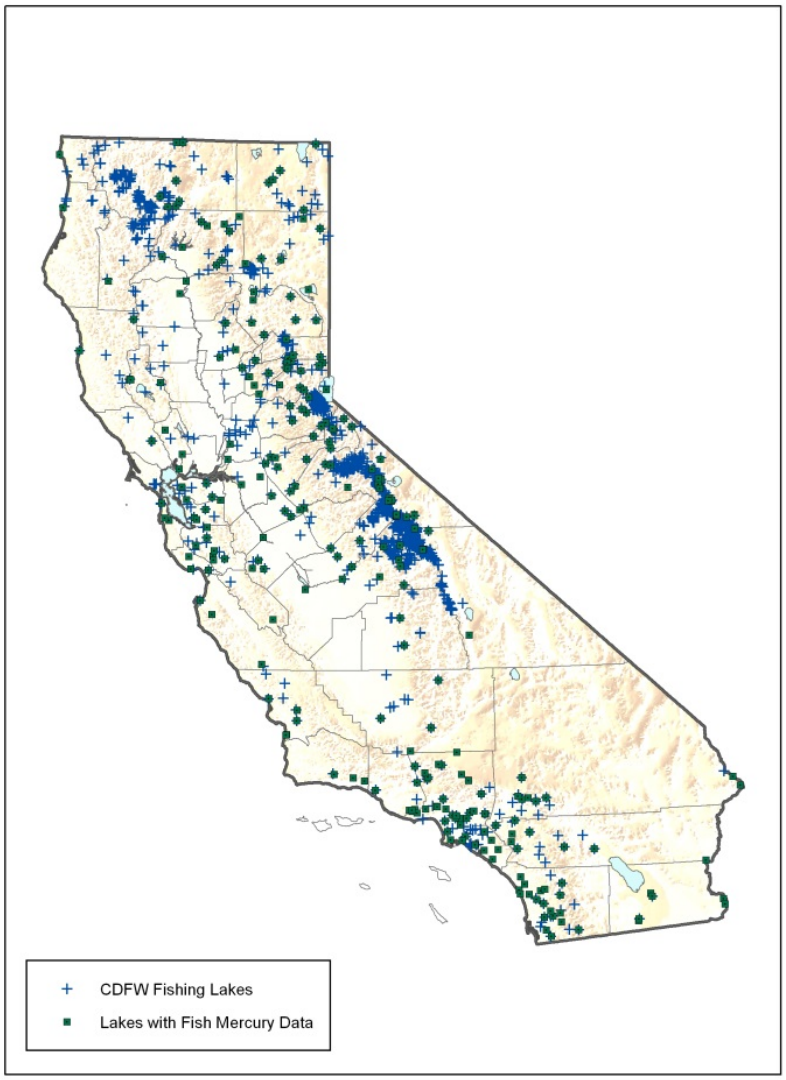
The distribution of data by fish species is shown in Table 4 and Figures 5 to 10. For selected species groups, Figures 5 to 10 show how the lakes with fish mercury data are distributed in comparison to lakes where a species is likely to be found (CDFW, 2012). For bass (Figure 5), catfish (Figure 6), carp (Figure 7), and sunfish (Figure 8), the fishing lakes and sampled lakes show a similar spatial pattern characteristic of the wide geographical range of these species in California (Moyle, 2002). These species were sampled in the jurisdictions of seven or more regional water boards (Table 4). Since the CDFW's Fishing Guide does not include fishing locations for carp, information for catfish was used as the surrogate for comparison. Catfish and carp are distributed in low elevation and foothill water bodies. Rainbow trout[9] were also sampled in seven regions but were mainly collected in Region 5 and 6 (Figure 9). Popular trout fishing locations are also more localized to the northern part of the state. The distributions of fishing and sampled lakes are similar and characteristic of the range of rainbow trout (Moyle, 2002). Brown trout[9] samples were only collected in lakes in the Northern California Sierra Nevada mountains (Regions 5 and 6, Figure 10). The distribution of sampled lakes follows that of lakes where brown trout fishing is popular and the geographic range of this species (Moyle, 2002). The CDFW's Fishing Guide does not include fishing locations for crappie, Sacramento pikeminnow, or Sacramento sucker. According to Moyle (2002), these species are widespread in central and northern California. Some are expected to be found in Southern California reservoirs after being transferred via the California Aqueduct. In the statewide dataset, crappie, Sacramento pikeminnow, and Sacramento sucker were sampled in few regional water board jurisdictions (Table 4).

---

[8] The list is the most current information available. The original list was created at least 15 years ago and has been updated infrequently due to resource constraints.

[9] Hatchery rainbow trout or brown trout were excluded from samples and maps whenever possible. Trout species are mainly found in rivers, but some are established in lakes or stocked recurrently as fingerlings and reared in lakes.

FIGURE 3. FISHING LAKES AND LAKES WITH MERCURY DATA IN THE STATEWIDE ADVISORY DATASET



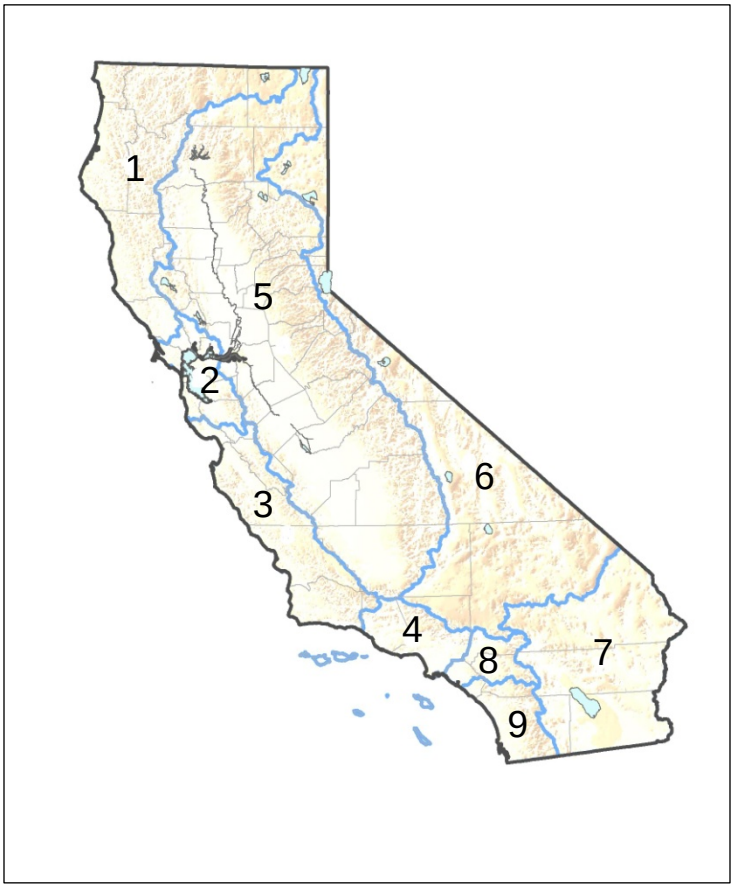
The list of CDFW Fishing Lakes used to make this map came from CDFW (2012). Lakes where only hatchery trout are likely to be found were not included because these fish are short-term residents and do not reflect the ambient contaminant levels in these lakes. There are about 1000 lakes plotted; many are high elevation mountain lakes. Lakes (a total of 272) with fish mercury data for any of the fish species in the statewide advisory dataset are shown.

TABLE 3. DISTRIBUTION OF CALIFORNIA LAKES BY SWRCB WATER BOARD REGIONS

	SWRCB Regional Water Boards[a]								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Percentage of Total California Lakes[b]	6.8	8.8	3.8	1.8	59.8	11.5	3	2.3	2.1

a/ The Regional Water Boards are: 1. North Coast, 2. San Francisco Bay, 3, Central Coast, 4. Los Angeles, 5. Central Valley, 6. Lahontan, 7, Colorado River Basin, 8, Santa Ana, and 9. San Diego.
b/ Based on 8364 total lakes which are 1 hectare or greater in size in California (SWAMP, personal communication).

FIGURE 4. LOCATION OF SWRCB WATER BOARD REGIONS



Regional water board boundaries follow drainage basins and reflect differences in hydrology.

1. North Coast Region
2. San Francisco Bay Region
3. Central Coast Region
4. Los Angeles Region
5. Central Valley Region
6. Lahontan Region
7. Colorado River Basin Region
8. Santa Ana Region
9. San Diego Region

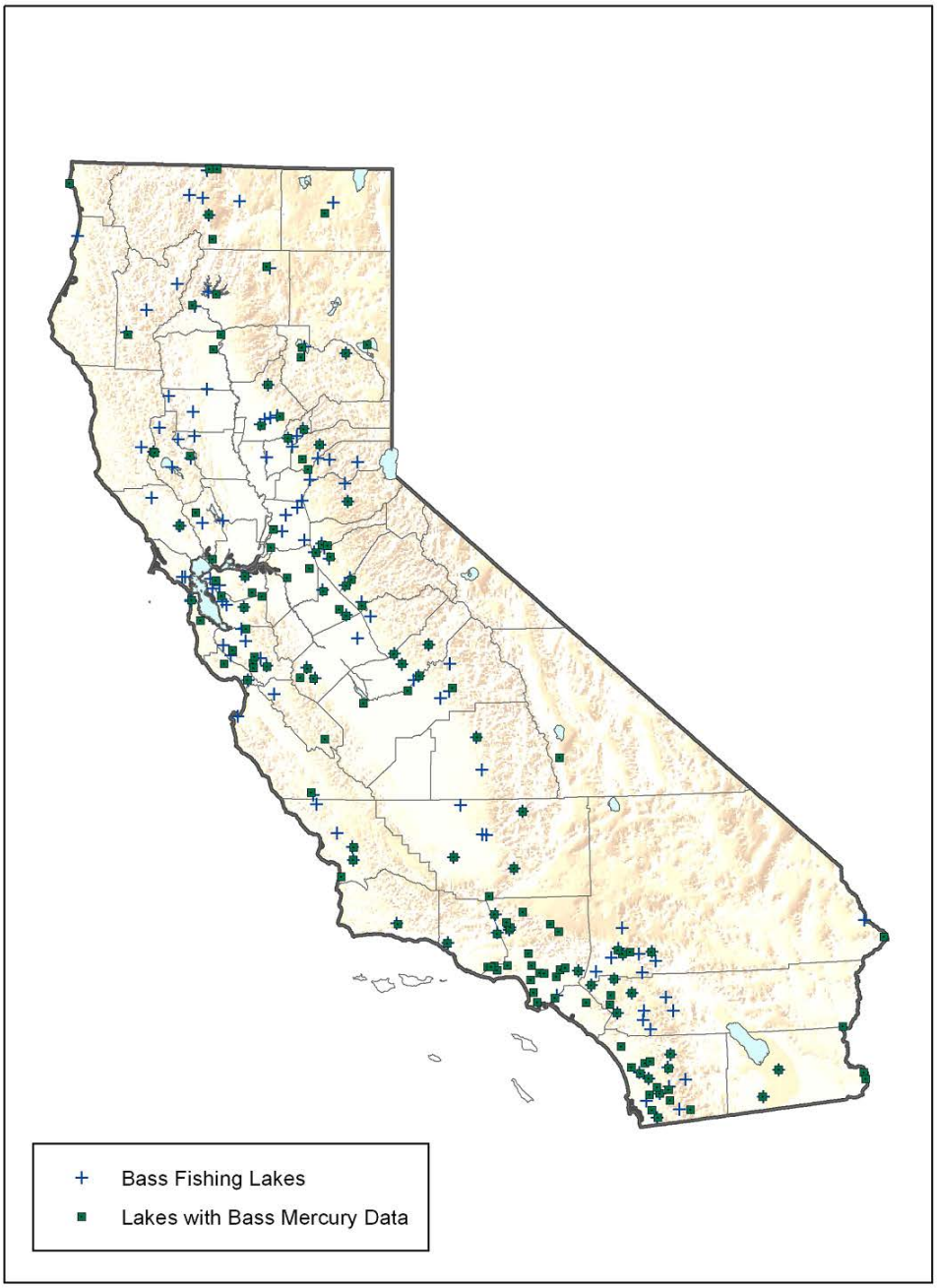
The comparison of fishing lakes and sampled lakes showed that the mercury concentration datasets for bass, bullhead and catfish, carp, sunfish, brown trout, and rainbow trout are representative of the range and distribution of these species in California. The number of samples per species and the number of lakes sampled for these fish were considered adequate to derive statewide advice. However, this was not the case for crappie, Sacramento pikeminnow, and Sacramento sucker, which had far fewer samples, collected mainly from the Central Valley (Region 5).

TABLE 4. DISTRIBUTION OF LAKES WITH FISH MERCURY DATA BY SWRCB WATER BOARD REGIONS

Fish Species	**SWRCB Regional Water Boards[a]**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**All Boards**
	Number of Lakes with Mercury Data									
Bass[b]	7	11	10	24	53	7	6	8	16	142
Bullhead and Catfish	1	3	2	9	20	4	3	3	5	50
Carp	0	6	4	16	28	2	7	8	7	78
Crappie	0	0	0	0	6	0	2	0	0	8
Sacramento pikeminnow	0	0	0	0	4	0	0	0	0	4
Sacramento sucker	0	1	3	0	12	4	0	0	0	20
Sunfish[c]	0	1	4	5	17	0	1	4	2	34
Brown trout	0	0	0	0	14	9	0	0	0	23
Rainbow trout	4	1	3	1	46	30	0	1	0	86

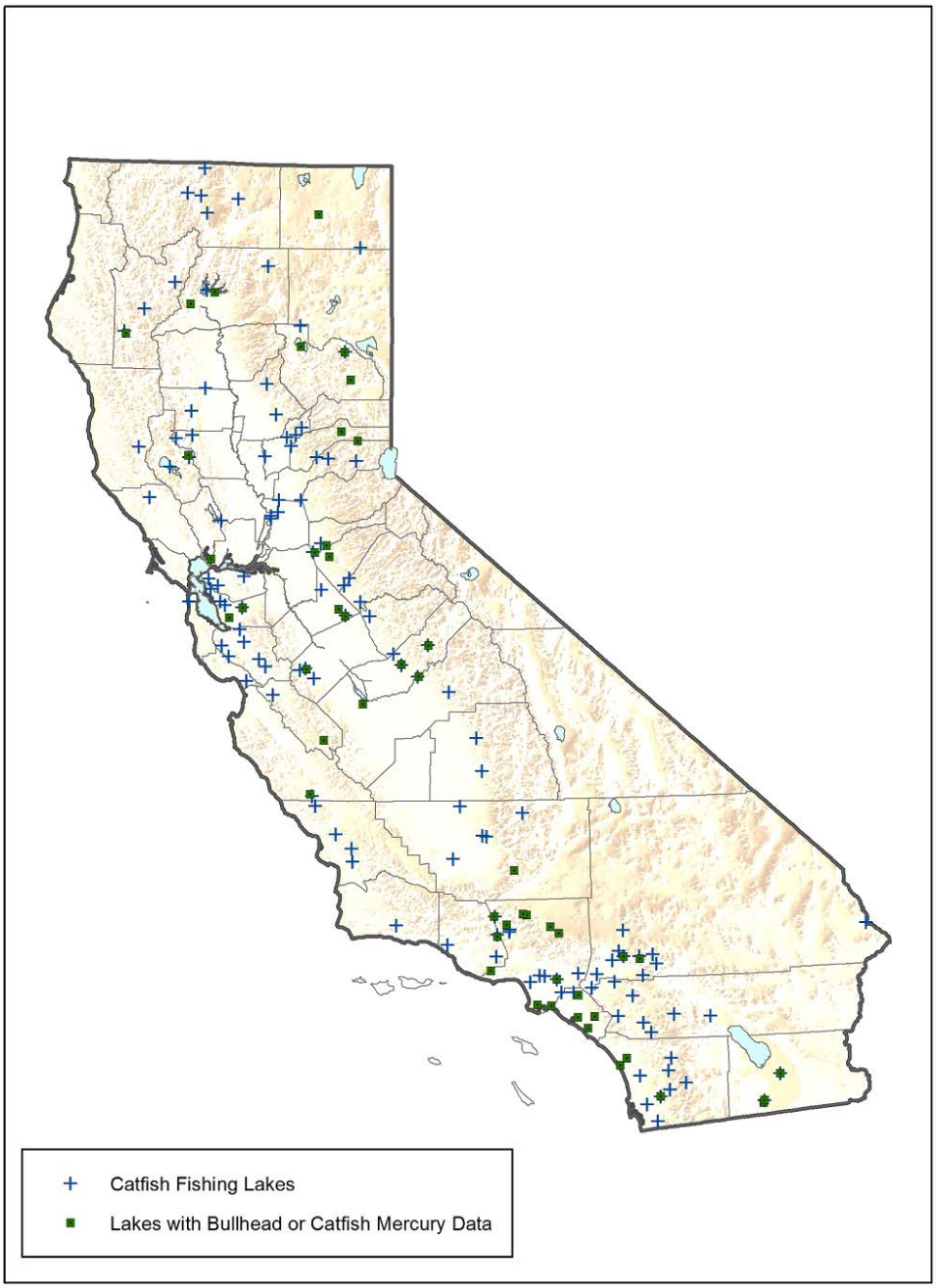
a/ The Regional Water Boards are: 1. North Coast, 2. San Francisco Bay, 3, Central Coast, 4. Los Angeles, 5. Central Valley, 6. Lahontan, 7, Colorado River Basin, 8, Santa Ana, and 9. San Diego.
b/ Bass includes: largemouth bass, smallmouth bass, and spotted bass
c/ Sunfish includes: bluegill, green sunfish, redear sunfish, and pumpkinseed.

FIGURE 5. LAKES WITH BASS MERCURY DATA IN THE STATEWIDE DATASET



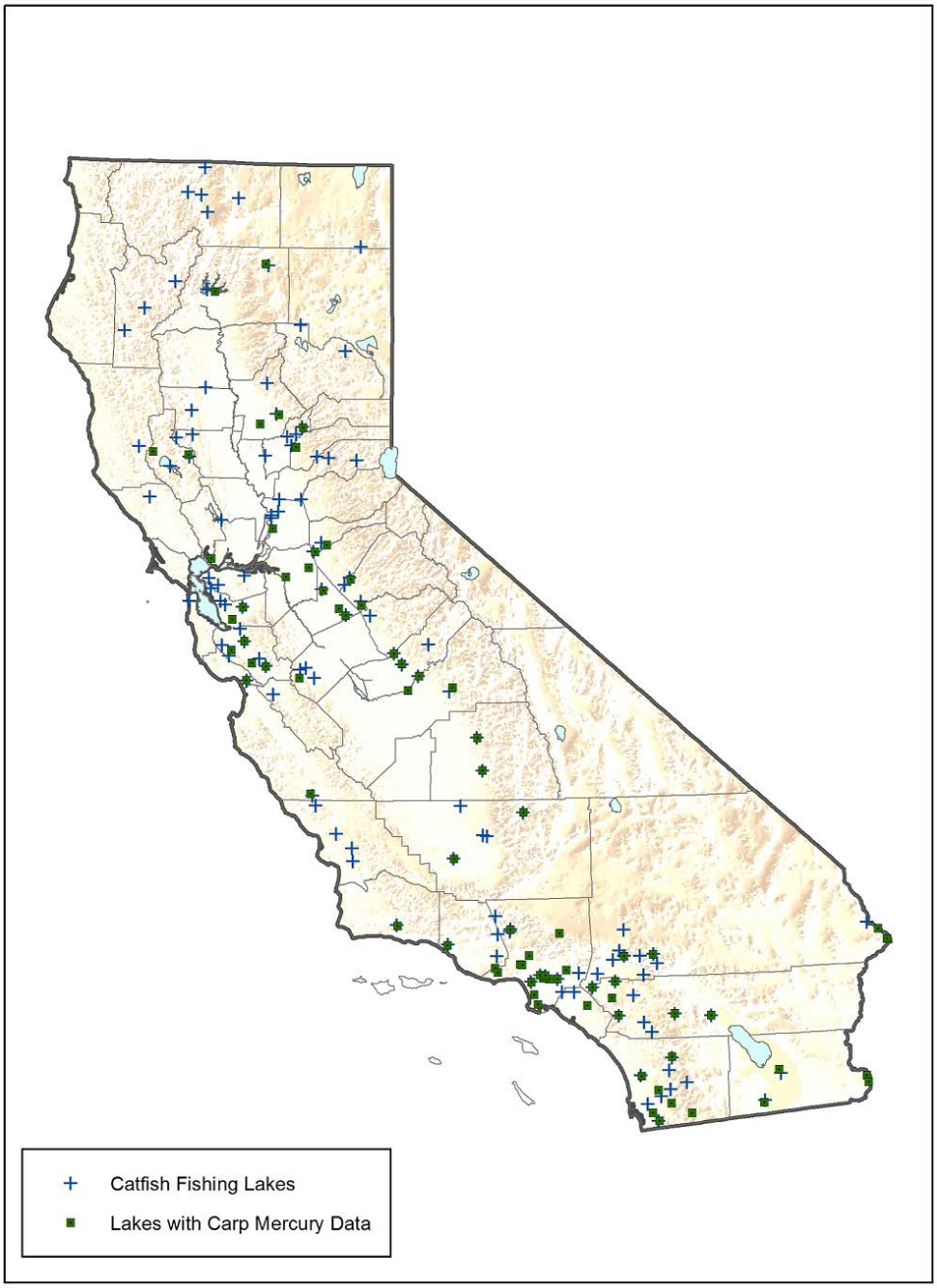
Lakes with mercury data for bass included in the statewide advisory dataset are shown. Bass Fishing Lakes are lakes where people can fish for bass (CDFW, 2012).

FIGURE 6. LAKES WITH BULLHEAD AND CATFISH MERCURY DATA IN THE STATEWIDE DATASET



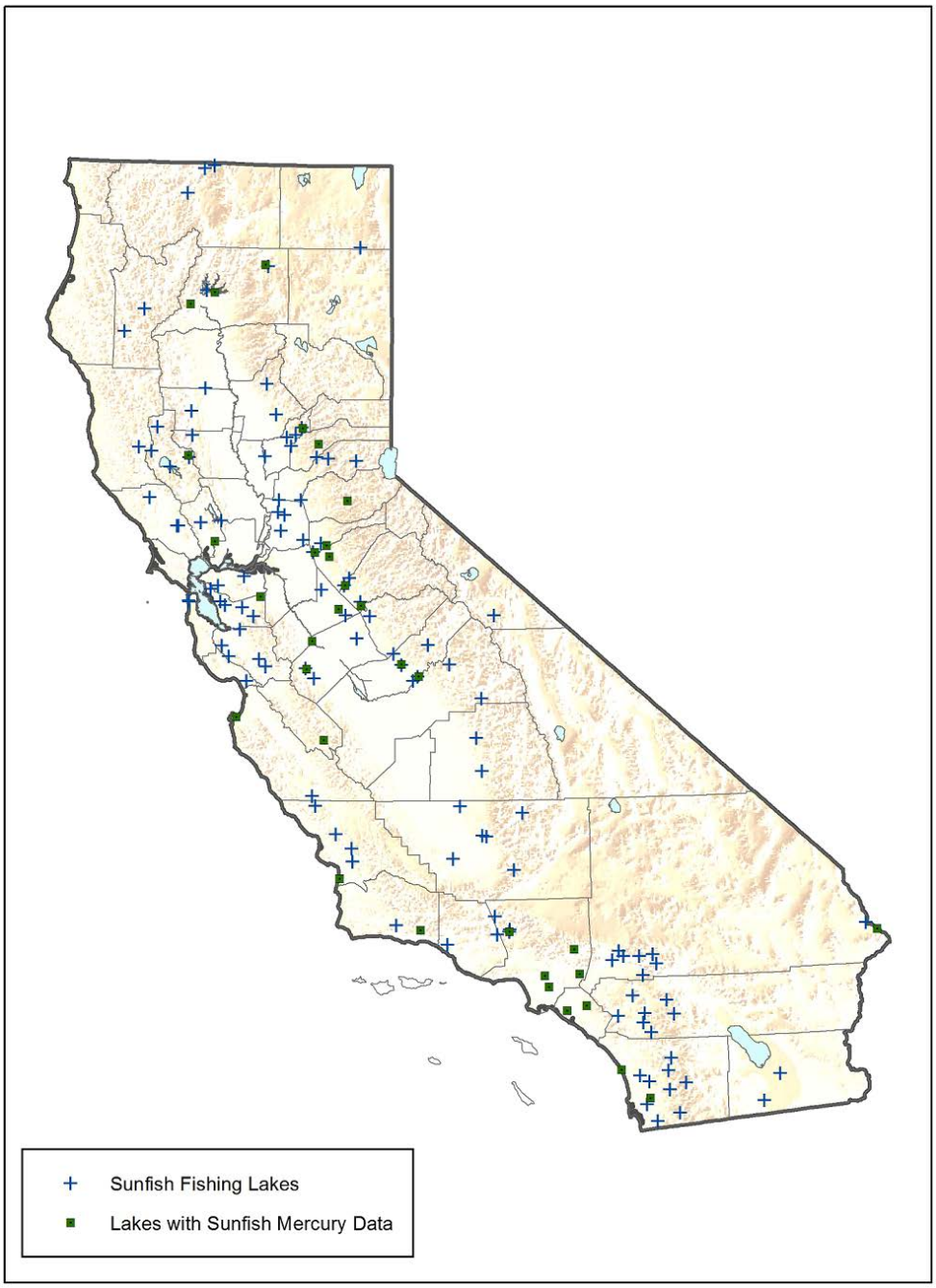
Lakes with mercury data for bullhead or catfish included in the statewide advisory dataset are shown. Catfish Fishing Lakes are lakes where people can fish for catfish (CDFW, 2012).

FIGURE 7. LAKES WITH CARP MERCURY DATA IN THE STATEWIDE DATASET



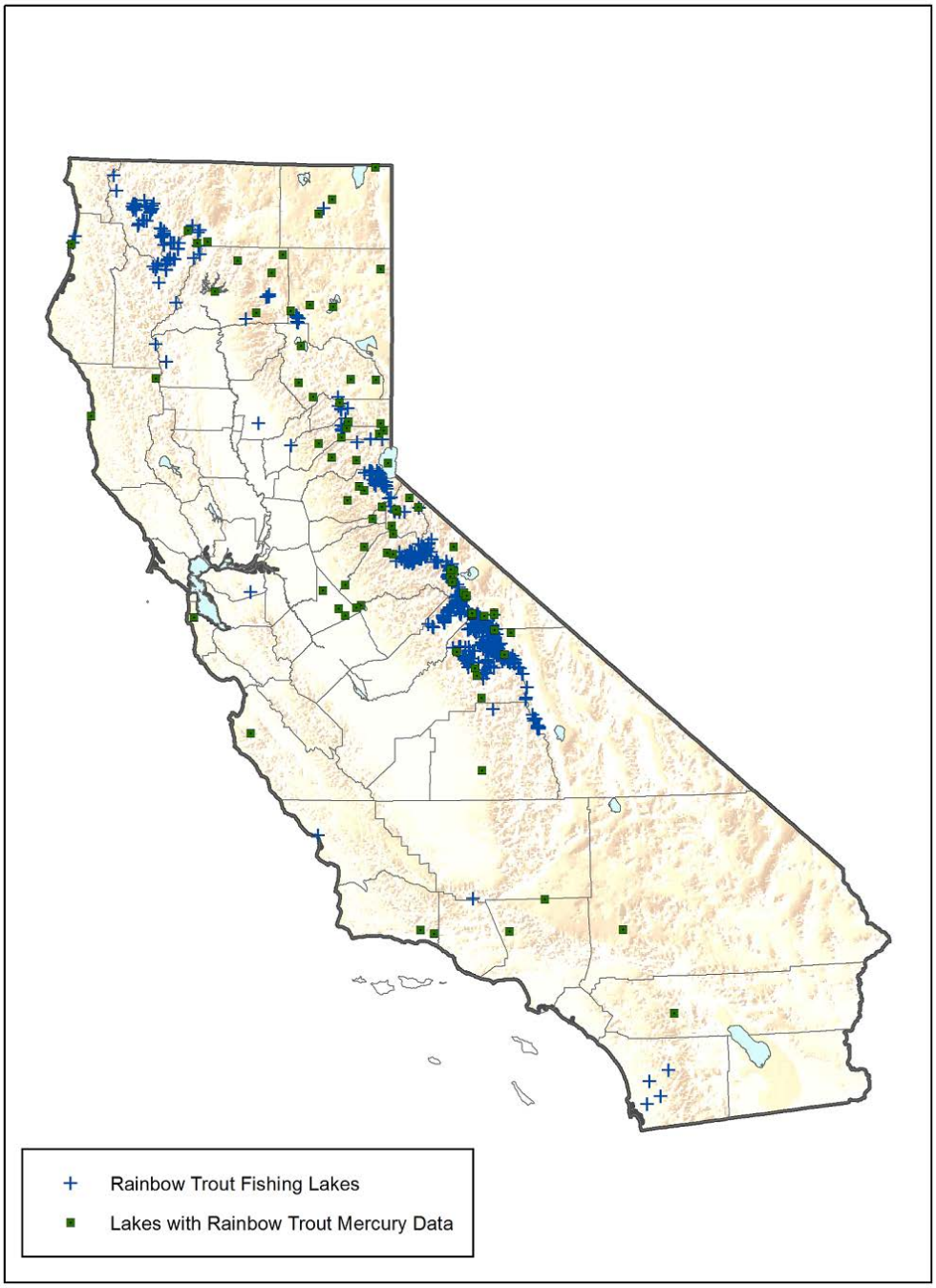
Lakes with mercury data for carp included in the statewide advisory dataset are shown. Because a list of carp fishing lakes was not available from CDFW (2012), catfish fishing lakes were used as surrogate data for this figure. Catfish and carp are distributed in low elevation and foothill water bodies.

FIGURE 8. LAKES WITH SUNFISH MERCURY DATA IN THE STATEWIDE DATASET



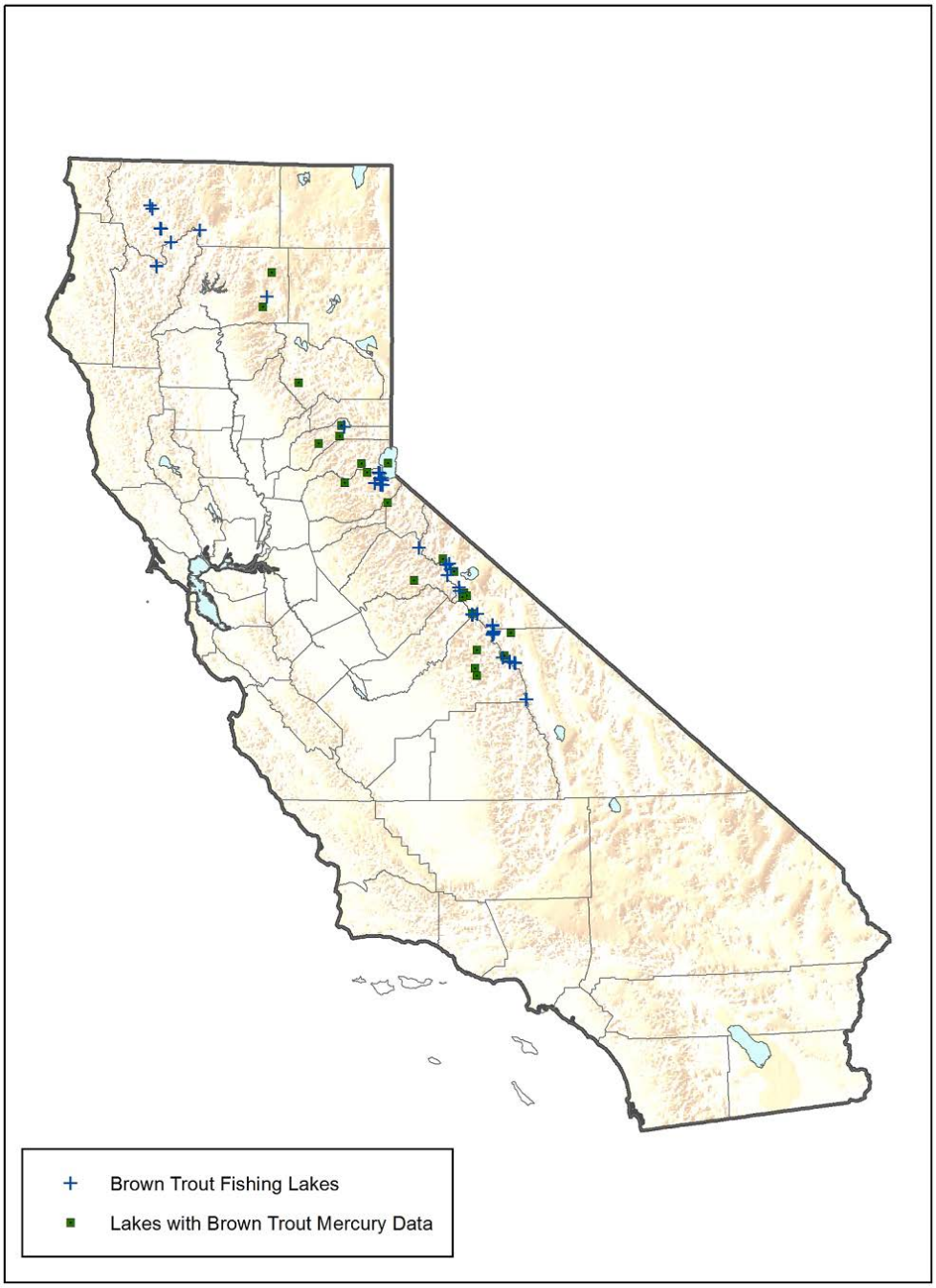
Lakes with mercury data for small sunfish (panfish) included in the statewide advisory dataset are shown. Sunfish Fishing Lakes are lakes where people can fish for small sunfish, also called panfish (CDFW, 2012).

FIGURE 9. LAKES WITH RAINBOW TROUT MERCURY DATA IN THE STATEWIDE DATASET



Lakes with mercury data for rainbow trout included in the statewide advisory dataset are shown. Rainbow Trout Fishing Lakes are lakes where people can fish for rainbow trout (CDFW, 2012). Rainbow trout includes golden trout, Lahontan cutthroat trout, and unspecified trout in the CDFW database.

FIGURE 10. LAKES WITH BROWN TROUT MERCURY DATA IN THE STATEWIDE DATASET



Lakes with mercury data for brown trout included in the statewide advisory dataset are shown. Brown Trout Fishing Lakes are lakes where people can fish for brown trout (CDFW, 2012).

LABORATORY ANALYSIS OF MERCURY IN FISH SAMPLES

In the statewide advisory dataset, the mercury concentrations in fish fillets (muscle tissue) were typically analyzed by laboratories as individual samples for predator species such as bass and as composite samples for the other fish species. Most of the samples were analyzed by one of two CDFW laboratories: Moss Landing Marine Laboratories and Water Pollution Control Laboratory. Total mercury was quantified using cold vapor atomic absorption spectrometry methods in older studies and, more recently, by Direct Mercury Analyzer. The concentration in each sample was reported as wet weight and is expressed as parts per billion (ppb, or nanogram mercury/gram fish) in this report.

ADVISORY TISSUE LEVELS

OEHHA developed Advisory Tissue Levels (ATLs) to guide the development of advice for people eating sport fish (Klasing and Brodberg, 2008). ATLs show maximum numbers of recommended fish servings, on a per week basis, 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[14] 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 ATLs for each chemical, selected from either cancer or non-cancer based risk, are shown in the table below for zero to six servings per week.

OEHHA's advisory process and ATLs also consider the health benefits from fish consumption. There is considerable evidence and scientific consensus that fish consumption is an important part of a healthy well-balanced diet and provides many health benefits (American Heart Association, 2011; Klasing and Brodberg, 2008; Institute of Medicine, 2007; Kris-Etherton et al., 2002). Fish is the significant source of the specific omega-3 fatty acids, docosahexaenoic acid and eicosapentaenoic acid, associated with these beneficial effects (U.S. Department of Agriculture, 2011; Weaver et al., 2008).

[14] 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.

There are two sets of ATLs for methylmercury (Table 5). The ATLs for the sensitive population (women of child-bearing age from ages 18 to 45 years or children ages 1 to 17 years) are established to protect for developmental neurotoxicity. The RfD for this early life-stage endpoint is 3 times lower than that for the general neurotoxicity endpoint used for women over age 45 years and men. For this report, the terms "440 ppb threshold" and "1310 ppb threshold" refer to the no consumption ATLs of methylmercury for the sensitive population, and for women over 45 years and men, respectively.

TABLE 5. ADVISORY TISSUE LEVELS FOR METHYLMERCURY

Consumption Frequency Categories (number of servings per week)[a]	**Population Groups and Advisory Tissue Levels (ppb)**	
	Sensitive Population (Women ages 18 to 45 years and children ages 1 to 17 years)	Women over age 45 years and men
None	>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

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.

ANALYSIS OF MERCURY CONCENTRATION DATA

OEHHA examined tissue mercury concentrations on a sample basis and a lake basis. Statistical analysis was performed using SAS/STAT® software[15].

SAMPLE BASIS

The sample mercury concentrations are the detected values for individual samples, made up of single fish or composites. The percentage of samples exceeding selected ATLs, in particular those for no consumption, was calculated for each fish species. Mercury concentration and fish size, as represented by mean total fish length, was plotted to examine possible relationships between these two parameters that may be useful in the development of size-based consumption advice. Regression analysis was conducted to quantify the relationship when appropriate.

[15] SAS/STAT® software, Version 9.3 of the SAS system for Windows. Copyright © 2002-2010 SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, North Carolina, USA.

LAKE BASIS

The lake mean mercury concentration is the mean (average) mercury concentration for all samples in the same species group collected from the same lake. The individual lake mean was weighted by the number of fish in each sample.

Since the statewide advice applies to all lakes with no existing site-specific advisory, including those with no chemical data, an upper bound estimate of the lake mean mercury concentrations for each species was selected as the health-protective basis to determine the consumption advice. This was done by calculating the mean mercury concentration for each species at each of the no-advisory lakes. OEHHA then determined the 90th percentile value of the lake mean mercury concentration from different sampled lakes for each species in the dataset (Table 6). Lake mean mercury concentrations were plotted in distribution and cumulative frequency graphs in the following section.

TABLE 6. LAKE MEAN MERCURY CONCENTRATIONS IN FISH OF THE STATEWIDE ADVISORY DATASET

Fish	Total Lakes	Lake Mean Mercury Concentrations (ppb)[a]	
		Range	90th Percentile Value of Distribution
Bass[b]	142	13 to1297	699
Bullhead and Catfish	50	5 to 588	346
Carp	78	6 to 554	401
Sunfish[c]	34	20 to 440	260
Brown trout	23	35 to 840	397
Rainbow trout	86	14 to 270	100

a/ Weighted mean mercury concentration of all samples from each lake for the indicated species group. Range is the range of individual mean water body mercury concentration. The 90th percentile value is from the distribution of the means for the different lakes in the dataset.
b/ Bass includes: largemouth bass, smallmouth bass, and spotted bass
c/ Sunfish includes: bluegill, green sunfish, redear sunfish, and pumpkinseed.

DEVELOPMENT OF STATEWIDE CONSUMPTION ADVICE

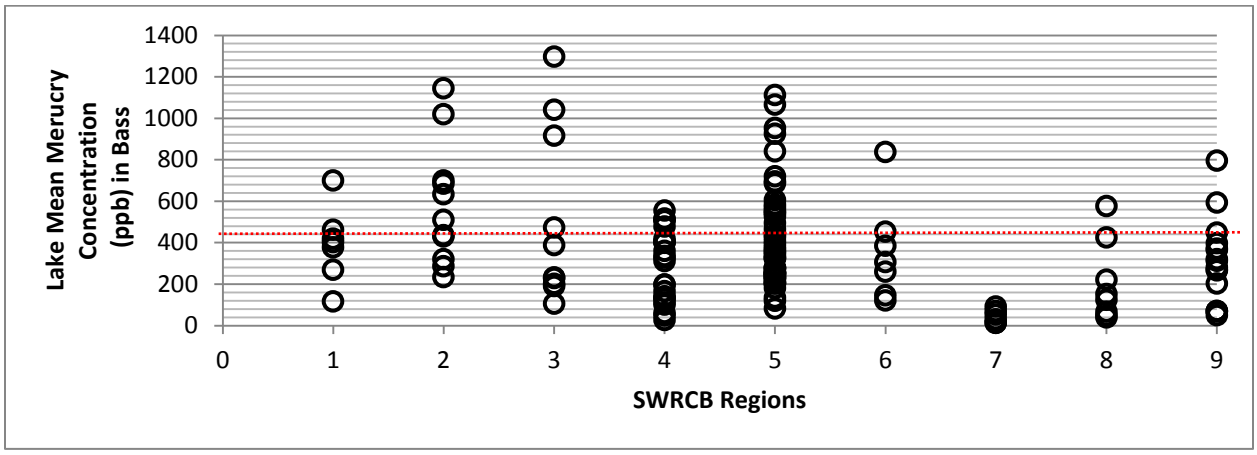
There was a wide range of lake mean mercury concentrations in the fish species evaluated, as shown in Table 6. The mercury concentrations were higher in predatory fish, such as bass, than in other fish species. Moderate mean mercury levels were found in bullhead, catfish, carp, sunfish, and brown trout. However, of these fish species, carp and brown trout had much higher 90th percentile values. Low levels of mercury (90th percentile value of 100 ppb) were found in rainbow trout.

GEOGRAPHIC CONSIDERATION

OEHHA explored developing separate advice based on geographic areas to see if this approach would reduce variability in mercury concentration in fish, leading to a single consumption recommendation within each area. Analyses to establish potential boundaries were conducted using the bass dataset which contained the highest number of lakes sampled. When the state was arbitrarily divided into north-south areas, the mercury levels in bass were highly variable with no distinct difference between the two areas.

OEHHA then considered using regional water board boundaries, which follow drainage basins and could reflect local mercury levels. Figure 11 showed that there was also a wide range of lake mean mercury concentrations between water board regions. All but one region (Region 7) had lakes with bass mercury above the 440 ppb threshold. Lakes with very high mercury levels in bass were mainly in Region 5 (17 of 53 lakes), Region 2 (6 of 11 lakes), and Region 3 (4 of 10 lakes). These water board regions had historic gold or mercury mining activities. However, within each of these regions, there were also lakes with bass containing very low mercury levels, well below the 440 ppb threshold. Eight out of nine regional water boards had multiple lakes where bass mean mercury concentrations were above the 440 ppb threshold. Only lakes in Region 7 (Colorado River basin) had bass that were consistently low in mercury, but few lakes were sampled from this region. OEHHA could not use county lines as boundaries because some counties have few or no fish mercury data. Consequently, a statewide approach was adopted.

FIGURE 11. DISTRIBUTION OF LAKES WITH BASS MERCURY LEVELS AMONG SWRCB WATER BOARD REGIONS



Red dotted line indicates the no consumption threshold of 440 ppb for the sensitive population.

STATEWIDE PROCEDURE

As shown in Figure 2, OEHHA used a multi-step procedure to establish the final consumption advice for eating fish from no-advisory lakes:

(1) Determine the initial advice based on the statewide 90th percentile value of the distribution of lake mean mercury concentrations[16].
(2) For added health protection, the 90th percentile value of fish species is examined further to determine its location within the ATL range for the serving frequency, in particular with respect to the 440 ppb threshold.

   a. If the 90th percentile value is not at the upper end of the ATL range, the initial advice is the final advice.
   b. If the 90th percentile value is at the upper end of the ATL range, the initial advice is adjusted by either of the following methods:
      i. When fish length is a predictor of sample mercury concentration, then the initial advice is revised using fish size limits.
      ii. When fish length is not a predictor, the initial advice is revised by reducing the consumption frequency.

MERCURY CONCENTRATIONS AND BASIS FOR STATEWIDE ADVICE

INDIVIDUAL FISH SPECIES

For the following discussion, the tissue mercury concentrations were compared to the corresponding ATLs for the serving frequencies indicated in Table 5.

BASS

MERCURY CONCENTRATIONS

There were 1734 samples of bass (total 2045 fish) collected from 142 no-advisory lakes (Table 2). For individual single-fish samples (1666 samples), 33% had mercury levels above the 440 ppb threshold and 1% were above the 1310 ppb threshold (Figure 12). Composite samples were not included in this analysis because data were available for many single-fish samples. The data were truncated at a total fish length of 12 inches because, for most lakes, it is not legal to keep bass under 12 inches (CDFW, 2012-2013).

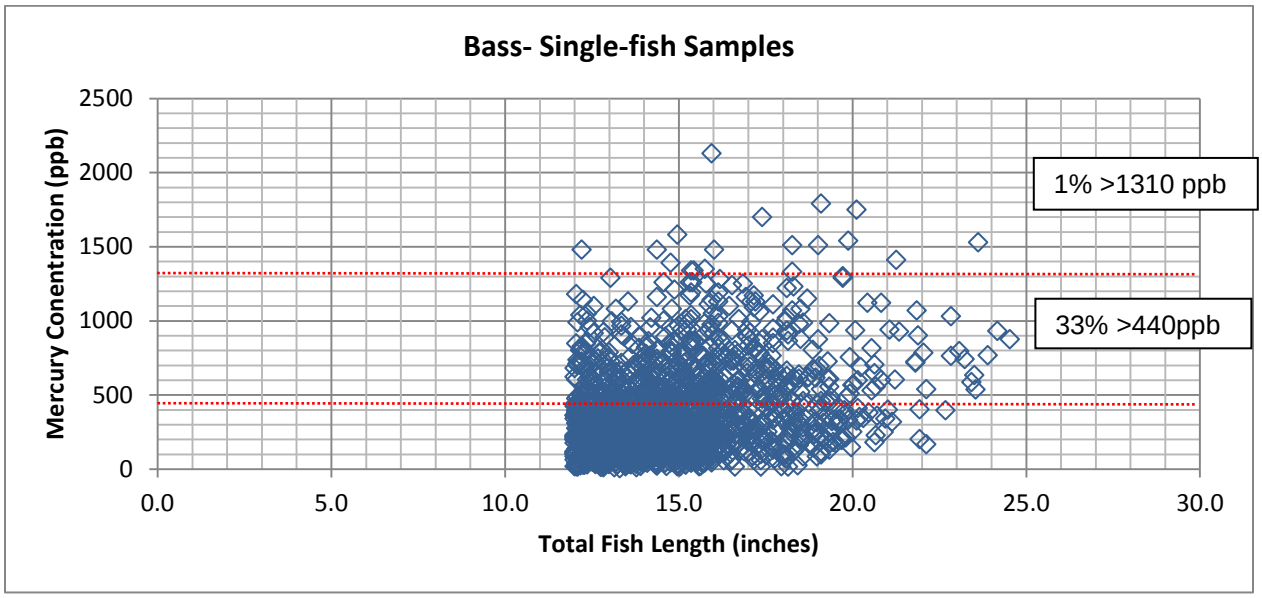
[16] OEHHA will continue to use the mean chemical concentration in fish tissue to develop consumption guidelines for individual water bodies, when tissue data for representative species are available.

The lake mean mercury concentrations for bass ranged from 13 to 1297 ppb, with the 90th percentile value at 699 ppb (Table 6). Figure 13 shows that the distribution of lake mean concentrations was skewed to the right, as commonly seen with environmental data. Forty of 142 lakes (28%) had lake mean concentrations above the 440 ppb threshold. Fifteen lakes had mean mercury concentrations at or above the 699 ppb level.

CONSUMPTION ADVICE

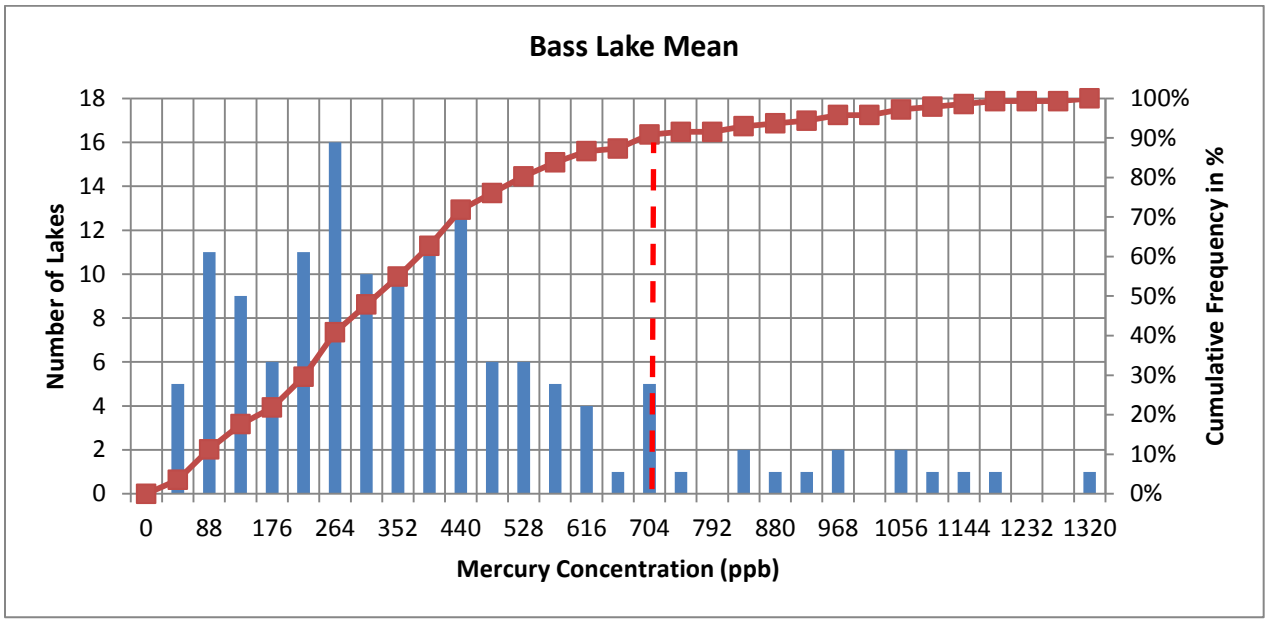
OEHHA recommends that the sensitive population not eat bass from lakes without site-specific advice because the 90th percentile value exceeded the 440 ppb threshold. Women over 45 years old and men can eat one serving of bass per week, based on the 90th percentile value.

FIGURE 12. FISH LENGTH AND MERCURY CONCENTRATIONS OF BASS



Red dotted lines indicate the no consumption thresholds of 440 ppb for the sensitive population and 1310 ppb for women over 45 years and men. Text box shows the % of total plotted samples (n=1666) above the indicated mercury concentrations.

FIGURE 13. DISTRIBUTION OF LAKE MEAN MERCURY CONCENTRATIONS FOR BASS



Symbols: red dash line (the 90th percentile value of 699 ppb), blue bars (number of lakes; placed at the center of the mercury concentration range, referred to as the bin), line with red squares (cumulative frequency of lakes). On the x-axis, the vertical grid lines denote bin limits. Each bin width is 44 ppb, and values are cumulative. The indicated value is the maximum value of the range; for example, "88"= 45 to 88 ppb, and "440"= 397 to 440 ppb.

BULLHEAD AND CATFISH

MERCURY CONCENTRATIONS

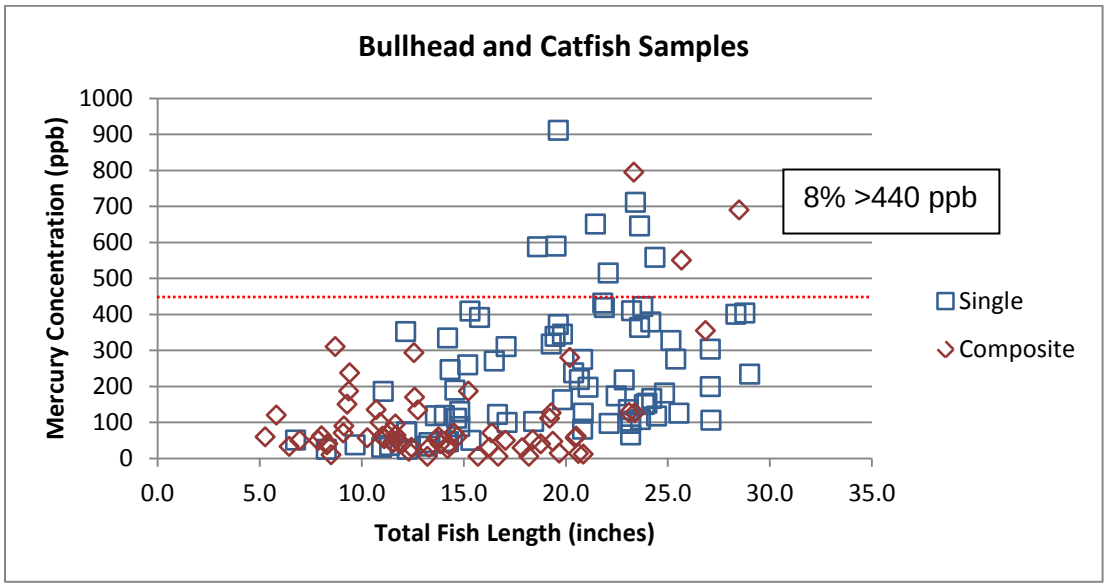
There were 145 samples (total 456 fish) of bullhead and catfish, combined, from 50 no-advisory lakes (Table 2). The individual samples were made up of single-fish or composites; only 8% contained mercury levels above the 440 ppb threshold (Figure 14).

The lake mean mercury concentrations for bullhead and catfish ranged from 5 to 588 ppb, with 90th percentile value at 346 ppb (Table 6). Almost all (96%) of the lake mean mercury concentrations for this fish group were less than 440 ppb (Figure 15). Only two lakes had fish with mean mercury concentrations above the 440 ppb threshold.

CONSUMPTION ADVICE

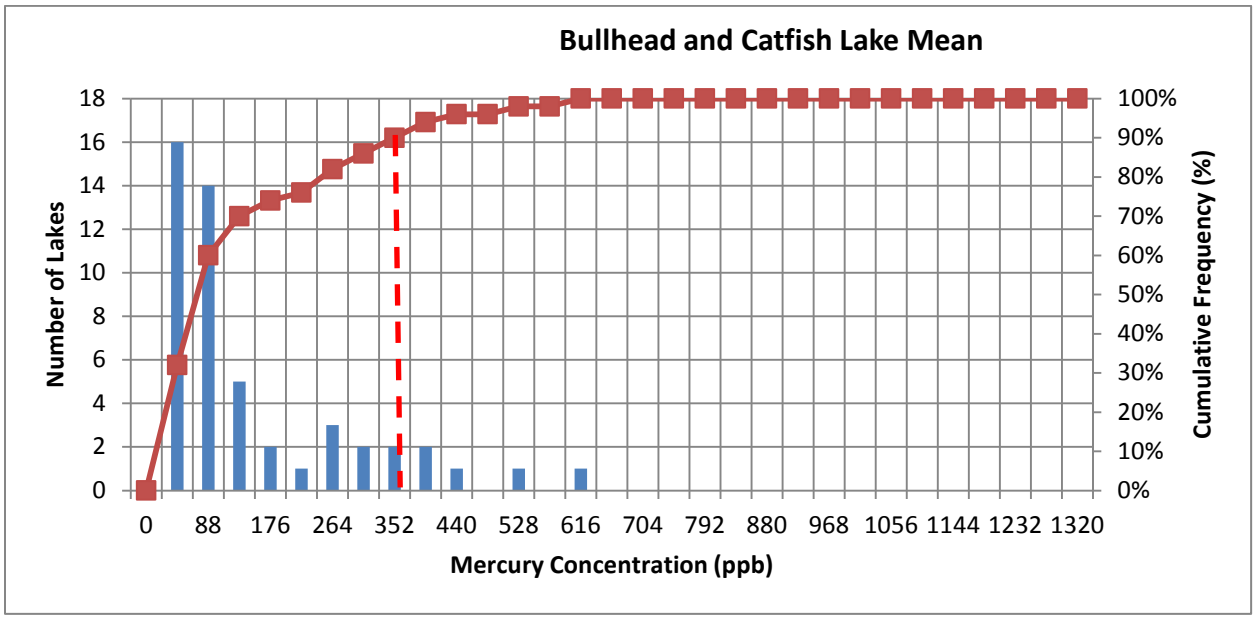
For the sensitive population, OEHHA recommends one serving of bullhead or catfish per week. For women over 45 years old and men, the recommendation is two servings per week. The basis of the advice for both population groups is the 90th percentile value of the lake mean mercury concentrations.

FIGURE 14. FISH LENGTH AND MERCURY CONCENTRATIONS OF BULLHEAD AND CATFISH



Red dotted line indicates the no consumption threshold of 440 ppb for the sensitive population. Text box shows the % of total plotted samples (n=145) above the indicated mercury concentration.

FIGURE 15. DISTRIBUTION OF LAKE MEAN MERCURY CONCENTRATIONS FOR BULLHEAD AND CATFISH



Symbols: red dash line (the 90th percentile value of 346 ppb), blue bars (number of lakes; placed at the center of the mercury concentration range, referred to as the bin), line with red squares (cumulative frequency of lakes). On the x-axis, the vertical grid lines denote bin limits. Each bin width is 44 ppb, and values are cumulative. The indicated value is the maximum value of the range; for example, "88"= 45 to 88 ppb, and "440"= 397 to 440 ppb.

CARP

MERCURY CONCENTRATIONS

There were 246 samples (total 933 fish) of carp collected from 78 no-advisory lakes (Table 2). The individual samples were made up of single-fish or composites; 11% had mercury levels above the 440 ppb threshold (Figure 16). Regression analysis of fish length for all samples and mercury concentrations was performed to see whether size explained the higher concentrations in 11% of the samples. The results showed no significant relationship between these two variables (R^2=0.01, p=0.066). Thus, fish length is not a good predictor of mercury concentration in carp.

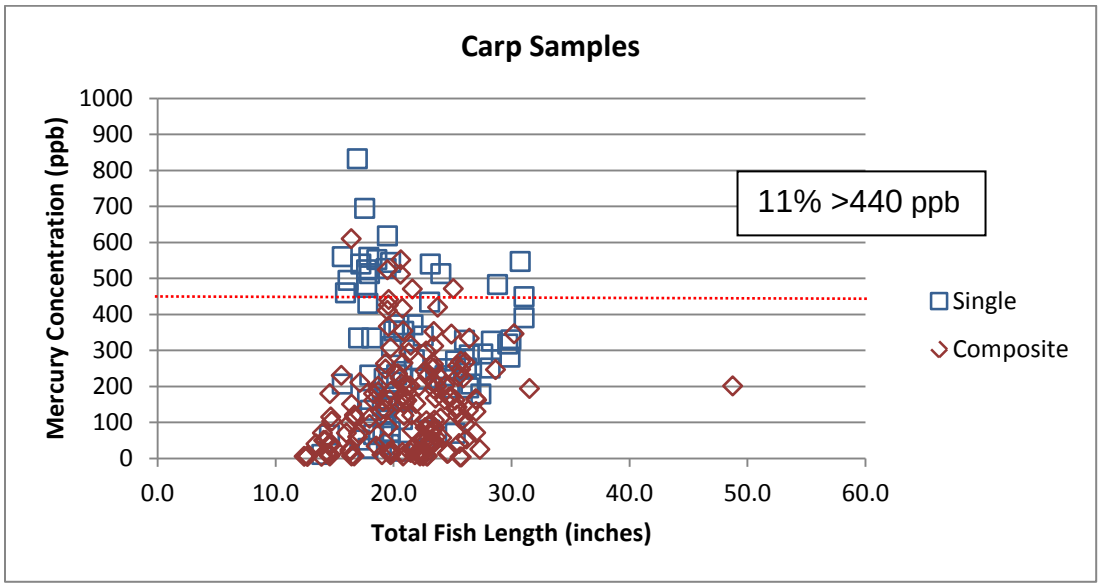
The lake mean mercury concentrations for carp ranged from 6 to 554 ppb, with the 90th percentile value at 401 ppb (Table 6). There were eight lakes with mean mercury levels higher than the 90th percentile value (Figure 17). Four of these lakes had mean mercury concentrations above the 440 ppb threshold.

CONSUMPTION ADVICE

OEHHA recommends that the sensitive population not eat carp. While the 90th percentile value of 401 ppb corresponded to one serving per week, this frequency was reduced to no consumption because (1) the 401 ppb value is at the upper end of the ATL range for one serving per week and (2) adjustment to the advice by fish size was not feasible. On a sample basis, 11% of the samples had mercury concentrations greater than 440 ppb.

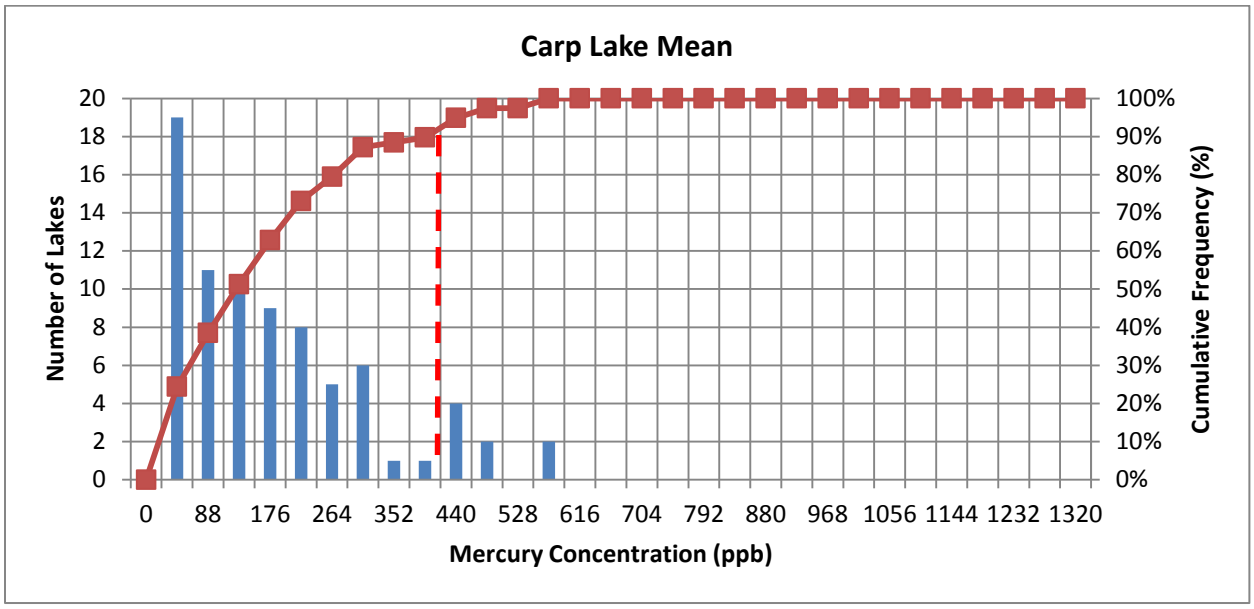
Women over 45 years old and men can eat one serving of carp per week. The 90th percentile value of 401 ppb indicated a consumption frequency of two servings per week (ATL greater than 221 ppb to 440 ppb). However, the frequency for this population was reduced from two to one serving per week for the two reasons noted above.

FIGURE 16. FISH LENGTH AND MERCURY CONCENTRATIONS OF CARP



Red dotted line indicates the no consumption threshold of 440 ppb for the sensitive population. Text box shows the % of total plotted samples (n=246) above the indicated mercury concentration.

FIGURE 17. DISTRIBUTION OF LAKE MEAN MERCURY CONCENTRATIONS FOR CARP



Symbols: red dash line (the 90th percentile value of 401 ppb), blue bars (number of lakes; placed at the center of the mercury concentration range, referred to as the bin), line with red squares (cumulative frequency of lakes). On the x-axis, the vertical grid lines denote bin limits. The indicated value is the maximum value of the range; for example, “88”= 45 to 88 ppb, and “440”= 397 to 440 ppb.

SUNFISH

MERCURY CONCENTRATIONS

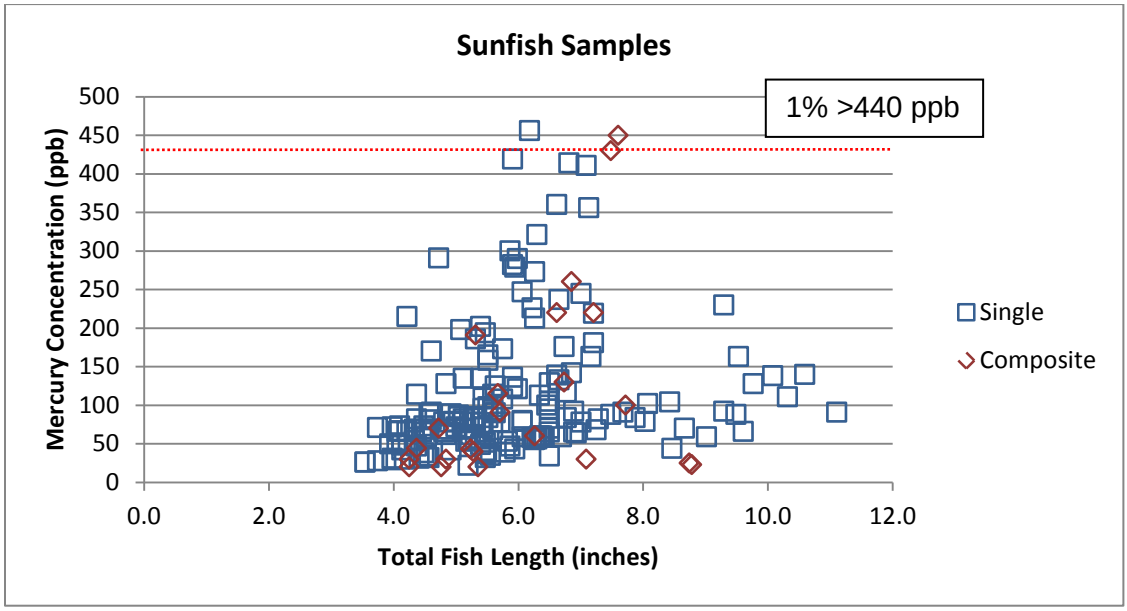
There were 189 samples (total 382 fish) of sunfish, including bluegill, green sunfish, redear sunfish, and pumpkinseed, collected from 34 no-advisory lakes (Table 2). The samples were made up of single-fish or composites; only 1% had mercury levels greater than 440 ppb (Figure 18).

The lake mean mercury concentrations for the 34 no-advisory lakes where sunfish were collected ranged from 20 to 440 ppb, with the 90th percentile value at 260 ppb (Table 6). The mean mercury concentrations from all sampled lakes were at or less than 440 ppb (Figure 19).

CONSUMPTION ADVICE

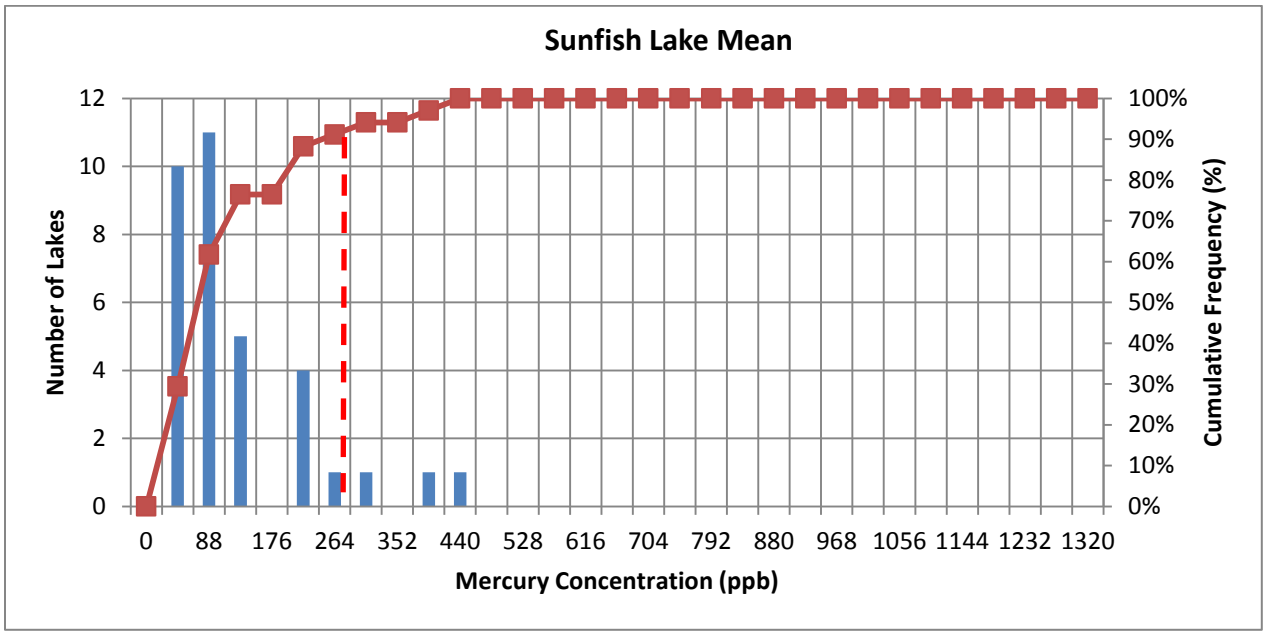
OEHHA recommends that the sensitive population eat no more than one serving of sunfish per week. Women over 45 years old and men can eat sunfish two servings per week. The basis for the advice for both populations is the 90th percentile value of lake mean mercury concentrations.

FIGURE 18. FISH LENGTH AND MERCURY CONCENTRATIONS OF SUNFISH



Red dotted line indicates the no consumption threshold of 440 ppb for the sensitive population.
Text box shows the % of total plotted samples (n=189) above the indicated mercury concentration.

FIGURE 19. DISTRIBUTION OF LAKE MEAN MERCURY CONCENTRATIONS FOR SUNFISH



Symbols: red dash line (the 90th percentile value of 260 ppb), blue bars (number of lakes; placed at the center of the mercury concentration range, referred to as the bin), line with red squares (cumulative frequency of lakes). On the x-axis, the vertical grid lines denote bin limits. The indicated value is the maximum value of the range; for example, "88"= 45 to 88 ppb, and "440"= 397 to 440 ppb.

BROWN TROUT

MERCURY CONCENTRATIONS

There were 43 samples (total 149 fish) of brown trout collected from 23 no-advisory lakes (Table 2). The samples were made up of single-fish or composites; 9% contained mercury levels greater than 440 ppb (Figure 20). Regression analysis of fish length from all samples and mercury concentrations showed 28% of the increase in mercury concentration could be accounted for by an increase in fish length (R^2=0.28) (Figure 21). This relationship was statistically significant ($p<0.001$). A better correlation (R^2=0.57) was obtained when only samples from single fish (16 samples) were considered (graph not shown).

Further examination of the data showed that when fish were at or under 16 inches in length, the mercury levels were lower than the 440 ppb threshold. When brown trout were above 16 inches (40 cm) in length, the tissue mercury levels were more variable, with some samples containing greater than 440 ppb. This difference may be attributed to a change in diet from invertebrates to fish as the brown trout ages, resulting in greater mercury accumulation. Brown trout exceeding 16 inches feed almost exclusively on fish (Moyle, 2002).

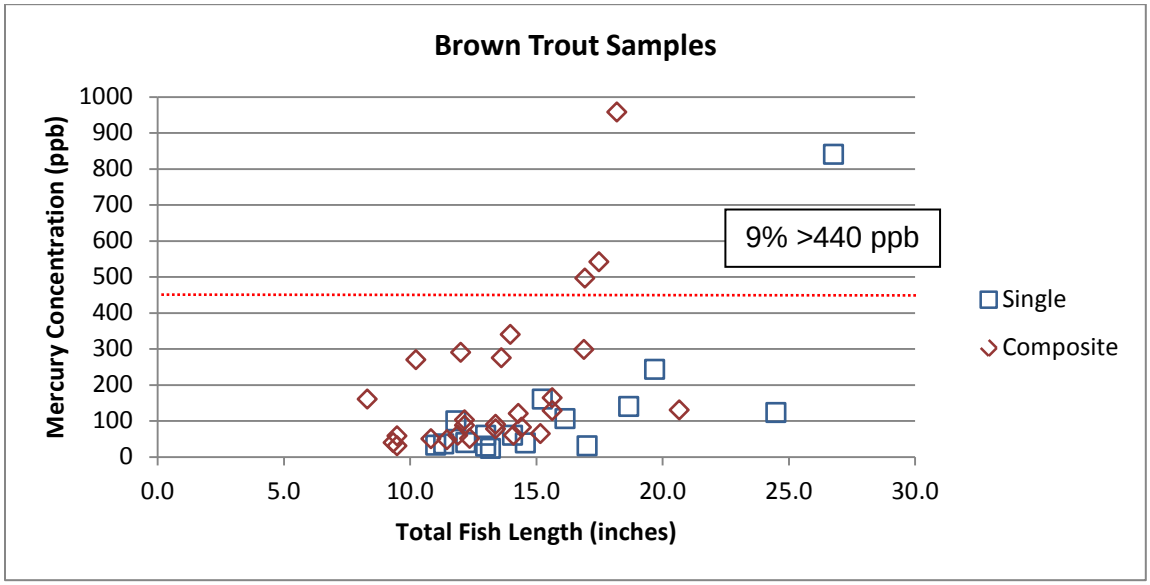
The lake mean mercury concentrations for all sizes of brown trout ranged from 35 to 840 ppb, with the 90th percentile value at 397 ppb (Table 6). The distribution of lake mean concentrations showed a discontinuous pattern. Although brown trout from 91% (21 of 23 lakes) of sampled lakes had mean mercury concentrations lower than 440 ppb, brown trout from two sampled lakes had very high mercury concentrations (Figure 22). Since the 90th percentile value of 397 ppb was at the upper end of the ATLs and analysis of the sample results showed that fish length is a good predictor of mercury concentration of this species, OEHHA also calculated the 90th percentile values for fish at or below and fish over 16 inches. The 90th percentile values are 290 ppb for fish which are at or under 16 inches, and 840 ppb for those which are over 16 inches long.

CONSUMPTION ADVICE

For the sensitive population, OEHHA recommends that large brown trout over 16 inches not be eaten, and that smaller brown trout at or under 16 inches can be eaten one serving per week, based on their respective the 90th percentile values.

Women over 45 years old and men can eat one serving per week of large brown trout over 16 inches or two servings per week of smaller at or under 16 inches brown trout.

FIGURE 20. FISH LENGTH AND MERCURY CONCENTRATIONS OF BROWN TROUT



Red dotted line indicates the no consumption threshold of 440 ppb for the sensitive population. Text box shows the % of total plotted samples (n=43) above the indicated mercury concentration.

FIGURE 21. BROWN TROUT FISH LENGTH AND MERCURY CONCENTRATION CORRELATION

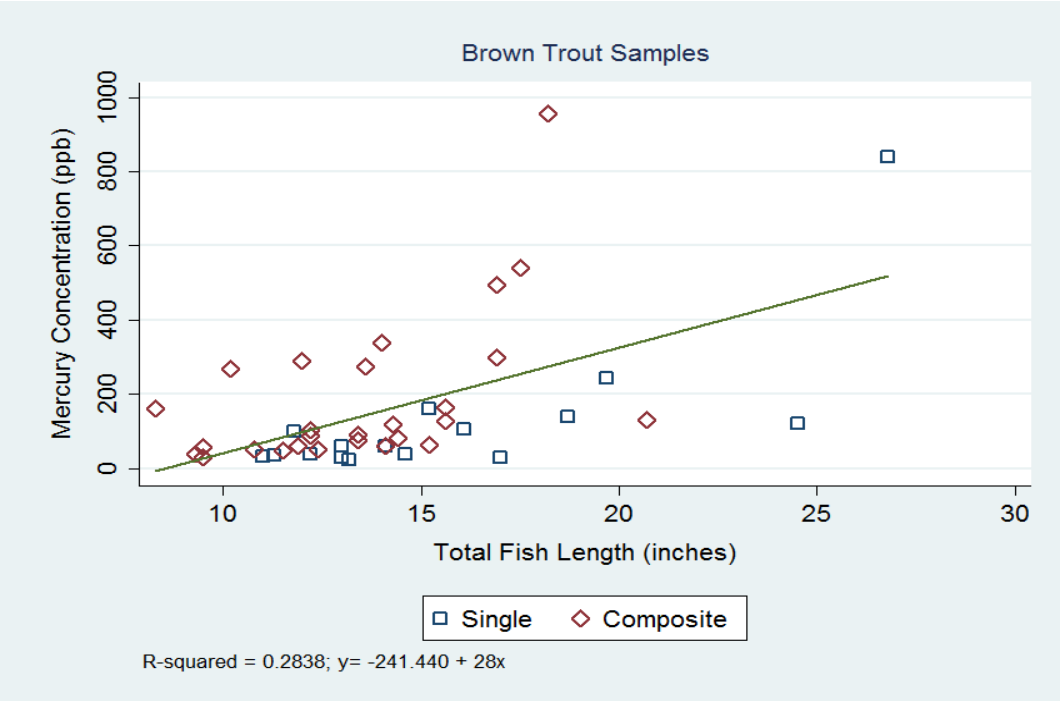
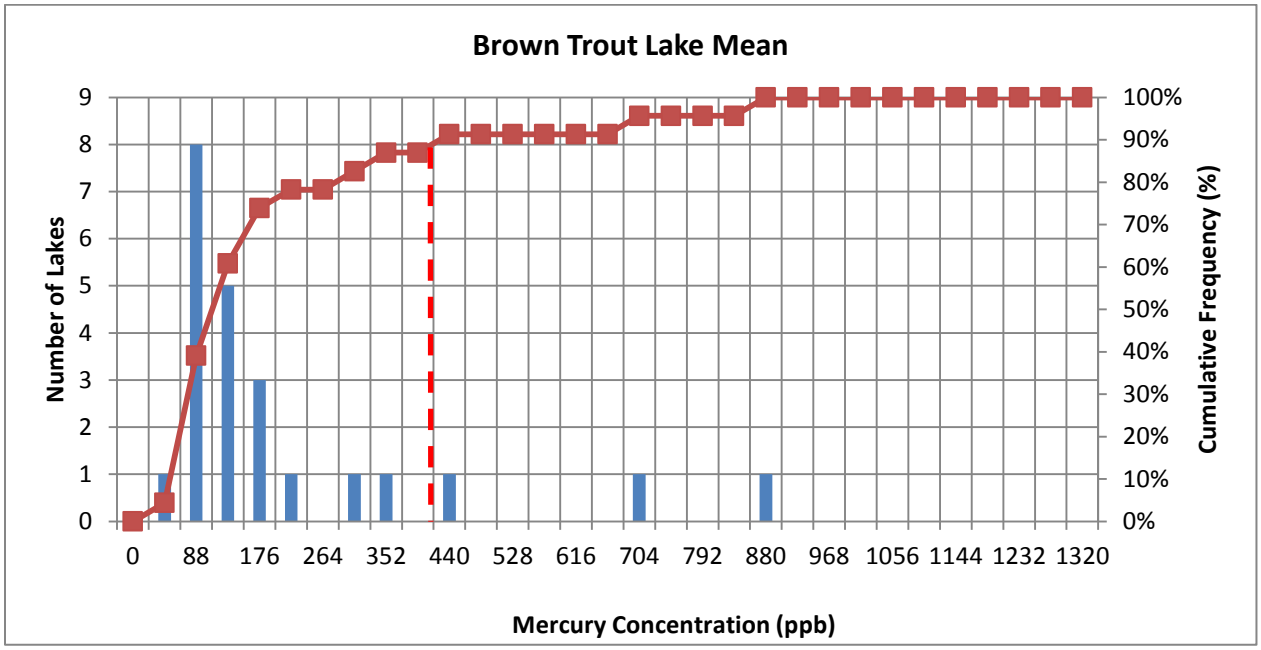


FIGURE 22. DISTRIBUTION OF LAKE MEAN MERCURY CONCENTRATIONS FOR BROWN TROUT



Symbols: red dash line (the 90th percentile value of 397 ppb), blue bars (number of lakes; placed at the center of the mercury concentration range, referred to as the bin), line with red squares (cumulative frequency of lakes). On the x-axis, the vertical grid lines denote bin limits. The indicated value is the maximum value of the range; for example, “88”= 45 to 88 ppb, and “440”= 397 to 440 ppb.

Rainbow Trout

Mercury Concentrations

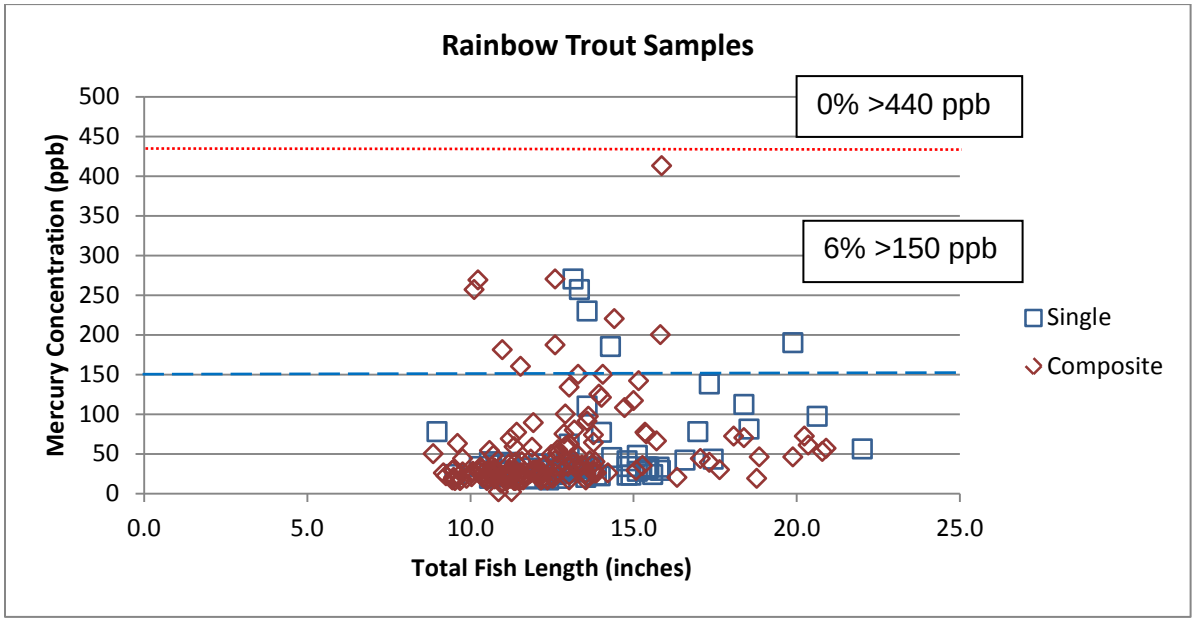
There were 228 samples (total 856 fish) of rainbow trout collected from 86 no-advisory lakes (Table 2). None of the samples, made up of single-fish or composites, showed mercury levels above the 440 ppb threshold. Only 6% of the samples had mercury levels within the ATL range for 1 serving per week for the sensitive population (greater than 150 ppb to 440 ppb) (Figure 23).

The lake mean mercury concentrations for rainbow trout ranged from 14 to 270 ppb, with the 90th percentile value at 100 ppb (Table 6). The mean mercury concentrations from all sampled lakes were less than 440 ppb (Figure 24).

Consumption Advice

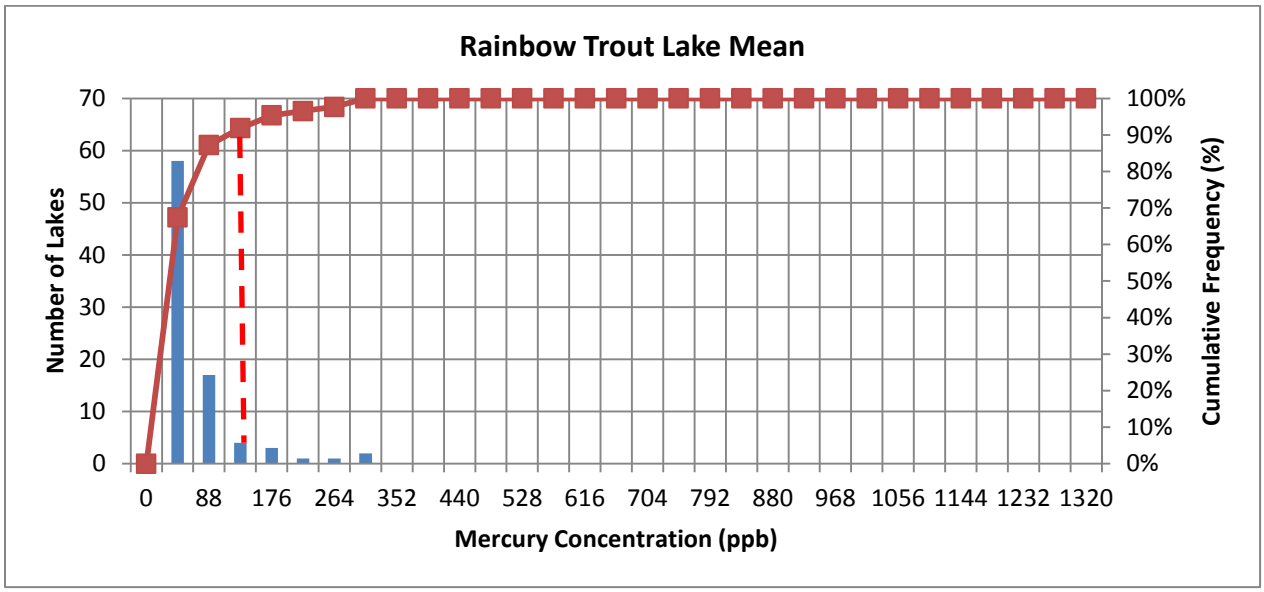
For the sensitive population, OEHHA recommends that rainbow trout can be eaten two servings per week. Women over 45 years old and men can eat rainbow trout six servings per week. The basis for the advice for both populations is the 90th percentile value of the lake mean mercury concentrations.

Figure 23. Fish length and mercury concentrations of rainbow trout



Red dotted line indicates the no consumption threshold of >440 ppb for the sensitive population.
Blue dash line indicates the threshold of >150 ppb for one serving per week for the sensitive population.
Text box shows the % of total plotted samples (n=228) above the indicated mercury concentration.

FIGURE 24. DISTRIBUTION OF LAKE MEAN MERCURY CONCENTRATIONS FOR RAINBOW TROUT



Symbols: red dash line (the 90th percentile value of 100 ppb), blue bars (number of lakes; placed at the center of the mercury concentration range, referred to as the bin), line with red squares (cumulative frequency of lakes). On the x-axis, the vertical grid lines denote bin limits. The indicated value is the maximum value of the range; for example, "88"= 45 to 88 ppb, and "440"= 397 to 440 ppb.

ALL SPECIES SUMMARY

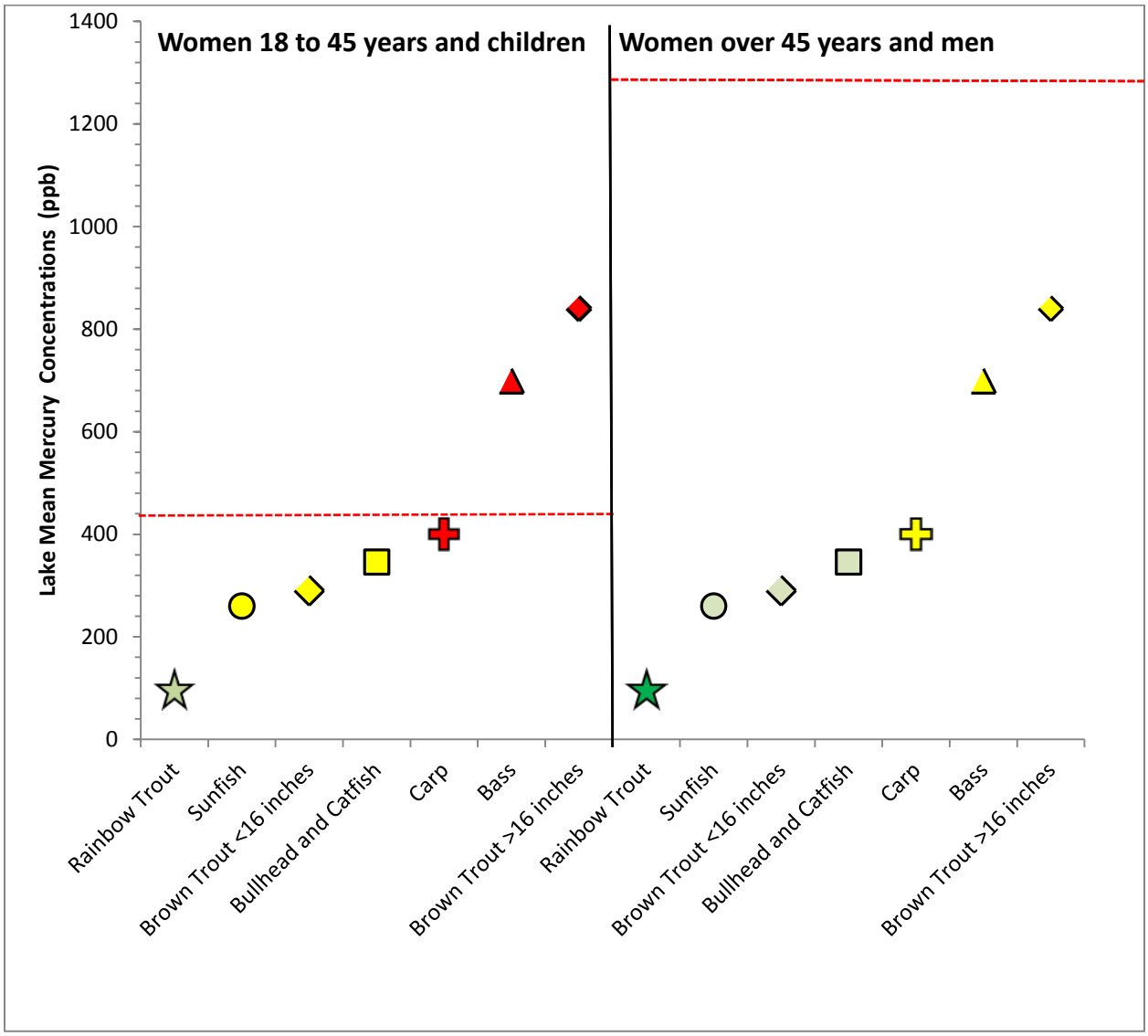
The USEPA/FDA joint federal advisory for mercury in fish states that, if no advice is available for local lakes, rivers and coastal areas, women who might become pregnant, women who are pregnant, nursing mothers, and young children can eat up to one average meal per week of fish caught from local waters (USEPA 2004a). In comparison, the new California statewide advice is more specific regarding fish species with high-mercury levels in California (e.g., bass and carp), and emphasizes consumption of fish that have lower mercury levels and higher omega-3 fatty acid levels. It also provides advice to women over 45 years old and men.

The OEHHA consumption advice is established on a per-week basis. No consumption is recommended when a fish species cannot be eaten at least once a week. When a fish species can be eaten, the consumption advice should not be combined. For example, consumers can choose one fish from the "one serving a week" category to eat that week. Then they should not eat any other fish until the next week. If consumers choose fish that can be eaten two servings per week, for example, they can combine fish species from that group for a total of two servings a week. Then they should not eat any other fish until the next week.

A summary of the 90th percentile values of lake mean mercury concentrations used to develop the consumption advice is presented in Figure 25. The values are the same as those presented in Table 6, with the exception of brown trout. As discussed above, the consumption advice for this fish species included a fish-size limit. The 90th percentile values for brown trout were 290 ppb and 840 ppb, for fish lengths of at or under16 inches and above inches, respectively. Figure 25 and Table 7 present the statewide consumption advice.

For the sensitive population, OEHHA advises that consumers not eat bass, carp, or brown trout over 16 inches because high mercury levels are found in these fish species in a significant number of lakes and reservoirs. This population group can eat one serving per week of other fish species (bullhead, catfish, carp, sunfish, or brown trout at or under 16 inches), the same recommendation given for all fish by the USEPA/FDA joint federal advisory. Rainbow trout can be eaten two servings per week by this population group because this fish has very low mercury levels. Consumption of rainbow trout is recommended because this fish as a member of the salmon family contains relatively high levels of the omega-3 fatty acids (USDA, 2011). Brown trout is also in the salmon family, but only fish at or under 16 inches should be eaten by the sensitive population because of higher mercury levels in larger brown trout. For women over 45 years old and men, OEHHA recommends one serving per week of bass, carp, or brown trout over 16 inches. Other fish can be eaten more frequently: two servings per week of bullhead, catfish, or brown trout at or under 16 inches, or six servings per week of rainbow trout.

FIGURE 25. CONSUMPTION RECOMMENDATIONS FOR TWO POPULATION GROUPS AT STATEWIDE MERCURY CONCENTRATIONS



Statewide mercury concentration is the 90th percentile value of the lake mean mercury concentration for each fish species. Red dotted lines indicates the no consumption thresholds (440 ppb and 1310 ppb) for the two population groups.

Legends
Fish species: Rainbow Trout ☆, Sunfish ○, Brown Trout ◇, Bullhead and Catfish □, Carp ✚, and Bass △.

Recommended serving frequency for species are shown using the following color code:
Do not eat (red), one serving per week (yellow), two servings per week (light-green), and six servings per week (green)

TABLE 7. STATEWIDE CONSUMPTION ADVICE FOR LAKES WITHOUT SITE-SPECIFIC ADVICE

Fish Group		Number of Servings/week	
		Women ages 18 to 45 years and children ages 1 to 17 years	Women over age 45 years and men
Bass		**Do Not Eat**	1
Carp		**Do Not Eat**	1
Brown trout	over 16 inches	**Do Not Eat**	1
	at or under 16 inches	1	2
Bullhead and Catfish		1	2
Sunfish		1	2
Rainbow trout		2	6

FUTURE WORK

Many of the lakes in the statewide advisory dataset require additional data before site-specific advisories can be issued. The full data criteria for advisory development is at least nine fish per fish species and three representative species (Gassel and Brodberg, 2008). Only 3% (eight lakes) met the full data criteria (Table 8). The majority of the lakes (56%, 153 of 272 total lakes) have data for only one fish species. A comprehensive sampling protocol is needed for these lakes. Additional sampling is needed to supplement the existing data for lakes with only two species analyzed (87 lakes) or those with data for three species but insufficient numbers of fish analyzed (24 lakes). OEHHA will coordinate with the state's regional water boards and other entities to plan sample collections for analysis of mercury and other common chemical contaminants in fish. Efforts will be directed toward lakes that were found to contain high-mercury fish as well as those with low-mercury fish. OEHHA will develop advice for eating fish from specific lakes and reservoirs as data become available.

TABLE 8. MERCURY TISSUE DATA COMPLETENESS FOR LAKES IN THE STATEWIDE DATASET

Number of Fish Species Sampled (for Mercury) at the Water Body	Number of Lakes (% total[a]) with:	
	At least 9 fish per species	Less than 9 fish for one or more species
1	110 (40%)	43 (16%)
2	38 (14%)	49 (18%)
3 or more	8 (3%)	24 (9%)

a/ Total = 272 lakes. A list of all the lakes is provided in Appendix I. During the development of this report, site-specific advisories were completed for Lake Oroville and Pyramid Lake, with additional data available to OEHHA not reflected in this Table.

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APPENDIX I. LIST OF LAKES IN THE STATEWIDE DATASET

Tissue mercury data were from fish collected in the following lakes and reservoirs. OEHHA has recently developed advisories for two lakes denoted with the symbol #.

Alondra Park Lake
Antelope Lake
Apollo Lake
Arrowbear Lake
Balboa Lake
Bass Lake
Baum Lake
Beach Lake
Beardsley Lake
Belvedere Park Lake
Bethany Reservoir
Big Bear Lake
Big Lagoon
Big Lake
Big Reservoir
Blue Lakes
Boca Reservoir
Bowman Lake
Bridgeport Reservoir
Briones Reservoir
Brite Valley Lake
Bucks Lake
Buena Vista Lagoon
Butt Valley Reservoir
Butte Lake
Calaveras Reservoir
Camanche Reservoir
Cannon Lake/Carlsbad
Canyon Lake
Caples Lake
Carbon Canyon Park Lake
Castac Lake
Castaic Lagoon
Castaic Lake
Castle Lake
Chesbro Reservoir
Cleone Lake
Collins Lake
Contra Loma Reservoir
Convict Lake
Copco Lake
Courtright Reservoir
Coyote Lake
Crater Lake
Crowley Lake
Crystal Lake
Dead Lake
Dixon Lake
Dodge Reservoir
Don Pedro Reservoir
Duncan Reservoir
Eagle Lake
Eastman Lake
Echo Park Lake
El Capitan Lake
El Dorado Park Lake
El Estero Lake
Elderberry Forebay
Elizabeth Lake
Ellery Lake
Faucherie Lake
Feeley Lake
Ferguson Lake
Fig Lake
Finger Lake
Florence Lake
French Meadows Reservoir
Frenchman Lake
Fuller Lake
Gene Wash Reservoir
Gold Lake
Grant Lake
Grass Valley Lake
Guajome Lake
Gull Lake
Gumboot Lake
Haiwee Reservoir
Hansen Lake
Harbor Park Lake
Heenan Lake
Hell Hole Reservoir
Hensley Lake
Hernandez Reservoir
Hetch Hetchy Reservoir
Hollenbeck Park Lake
Honey Lake
Howard Lake
Hume Lake
Huntington Lake
Ice House Reservoir
Indian Creek Reservoir
Indian Valley Reservoir
Iron Canyon Reservoir
Iron Gate Reservoir
Irvine Lake
Irvine Park Lake
Isabella Lake
Jackson Meadow Reservoir
Jameson Lake
Jenkinson Lake
John Ford Park Lake
June Lake
Kangaroo Lake
Ken Hahn Park Lake
Kidd Lake
La Grange Reservoir
Lago Los Osos
Laguna Niguel Park Lake
Lake Almanor
Lake Alpine
Lake Amador
Lake Arrowhead
Lake Britton
Lake Cachuma
Lake Cahuilla
Lake Calabasas
Lake California
Lake Casitas
Lake Chabot/Solano
Lake Crowley
Lake Cunningham
Lake Davis
Lake Elizabeth
Lake Elsinore
Lake Evans
Lake George
Lake Gibralter
Lake Gregory
Lake Havasu
Lake Hemet
Lake Hennessey
Lake Henshaw
Lake Hodges
Lake Hughes
Lake Jennings
Lake Kaweah
Lake Lindero
Lake Madigan
Lake Mamie
Lake Mary
Lake Mathews
Lake Merced
Lake of the Pines
Lake Oroville #

Lake Piru
Lake Poway
Lake Sabrina
Lake San Antonio
Lake San Marcos
Lake Shastina
Lake Sherwood
Lake Spaulding
Lake Sutherland
Lake Tahoe
Lake Webb
Lake Wildwood
Lake Wohlford
Las Virgenes Reservoir
Lee Lake/Corona Lake
Legg Lake
Lily Lake
Lincoln Park Lake
Little Grass Valley Reservoir
Little Rock Creek Reservoir
Little Rock Reservoir
Loch Lomond Reservoir
Loon Lake
Lopez Lake
Los Banos Reservoir
Los Vaqueros Reservoir
Loveland Reservoir
Lower Bear River Reservoir
Lower Blue Lake
Lower Blue Lake/Alpine
Lower Crystal Springs Reservoir
Lower Otay Lake
Lundy Lake
Malibou Lake
Marsh in Fresno Slough
Mason Park Lake
McArthur Park Lake
McCumber Reservoir
Meadows Slough
Mile Square Park Lake No. 1
Mile Square Park Lake No. 2
Millerton Lake
Modesto Reservoir
Moon Lake
Morena Reservoir
Neary's Lake
New Bullards Bar Reservoir
New Hogan Lake
New Melones Lake
North Battle Creek Reservoir
Oiger Quarry Ponds
O'Neill Forebay
O'Neill Lake
Oso Flaco Lake
Oso Reservoir
Palmdale Lake
Palo Verde Lagoon
Paradise Lake
Pardee Reservoir
Peck Road Water Conservation Park
Perris Reservoir
Pilarcitos Lake
Pine Flat Lake
Pinecrest Lake
Pinto Lake
Pleasant Valley Reservoir
Prado Lake
Prosser Creek Reservoir
Puddingstone Reservoir
Pyramid Lake #
Ramer Lake
Reservoir C
Reservoir F
Rock Creek Lake
Ruth Lake
Sabrina Lake
Saddlebag Lake
San Clemente Reservoir
San Luis Reservoir
San Vicente Reservoir
Santa Fe Reservoir
Santee Lake No. 5
Santo Margarita Lake
Scotts Flat Reservoir
Senator Wash Reservoir
Sepulveda Lake
Shadow Cliffs Reservoir
Shasta Lake
Silver Lake/Amador
Silver Lake/Mono
Silverwood Lake
Simms Pond
Siskiyou Lake
Spicer Meadow Reservoir
Spring Lake
Spring Valley Lake
Stampede Reservoir
Stump Meadow Lake
Success Lake
Sunbeam Lake
Sweetwater Reservoir
Thermalito Afterbay
Tioga Lake
Toluca Lake
Tulloch Reservoir
Tunnel Reservoir
Turlock Lake
Twin Lakes
Union Valley Reservoir
Unnamed Lake 1/Fresno
Unnamed Lake 2/San Joaquin
Upper Blue Lake
Upper San Leandro Reservoir
Upper Twin Lake
Uvas Reservoir
Vasona Reservoir
Virginia Lakes
West Valley Reservoir
Westlake Lake
Whale Rock Reservoir
Whiskeytown Lake
White Pines Lake
Wiest Lake
Wishon Reservoir
Woodward Reservoir
Yorba Park Lake
Yosemite Lake
Zayak/Swan Lake