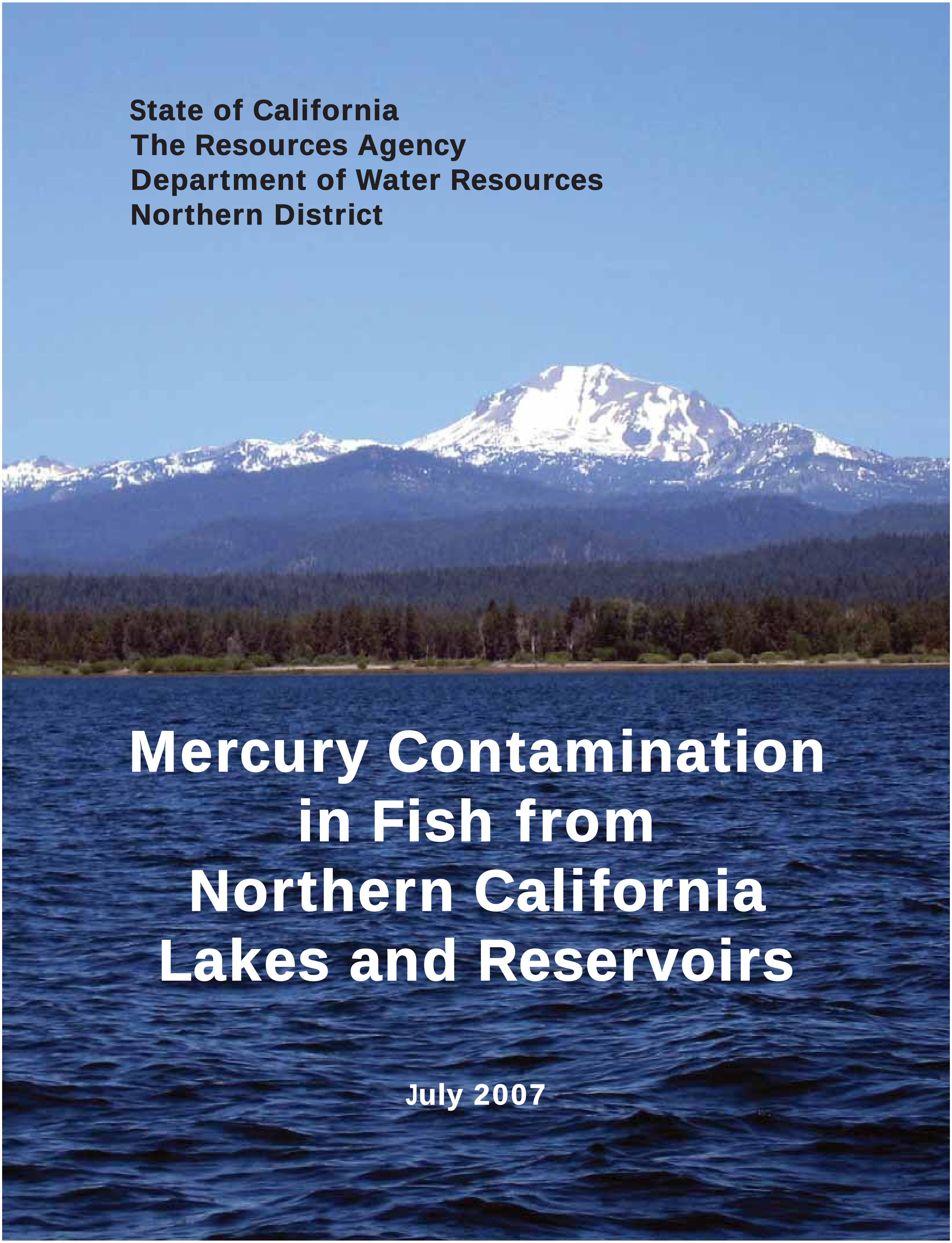

State of California
The Resources Agency
Department of Water Resources
Northern District

Mercury Contamination in Fish from Northern California Lakes and Reservoirs

July 2007

Cover photograph taken at Lake Almanor by Scott McReynolds

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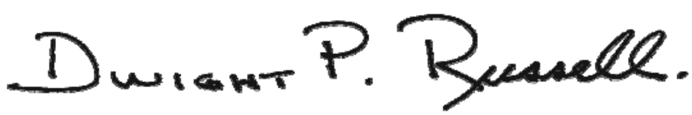
Foreword

The Department of Water Resources has responsibility assigned by Section 229 of the California Water Code to "investigate the quality of all waters within the State as related to all sources of pollution of whatever nature." The Clean Water Act defines water quality in terms of the physical, chemical, and biological integrity of the nation's waters. The Northern District of DWR, therefore, conducts investigations of the physical, chemical, and biological characteristics of waters in northern California to meet responsibilities assigned by the California Water Code.

Aquatic life is often used to evaluate water quality. The U.S. Environmental Protection Agency, rather than adopting a criterion for mercury in water, established a water quality criterion for mercury based on concentrations of mercury in fish.

Mercury contamination in water and biota has become a major issue in California. However, relatively little is known about the extent of mercury contamination of the state's waters, except in a relatively few well studied areas. Therefore, DWR undertook this study to contribute to the knowledge of mercury contamination in northern California lakes and reservoirs.



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Introduction

Mercury contamination in fish has been identified as a national problem, with virtually all fish, whether from fresh water or the ocean, containing mercury at some level in their flesh (OEHHA 1987). Historic gold and mercury mining have been implicated in elevated levels of mercury in aquatic biota in several areas of northern California (Alpers and Hunerlach 2000). Researchers from U.C. Davis identified elevated concentrations of mercury in biota in both the Feather and Yuba River watersheds (Slotton et al. 1995). The U.S. Geological Survey identified elevated mercury concentrations in edible fish tissue in the South Yuba, Deer Creek, and Bear River watersheds (May et al. 2000). Fish from Trinity Lake in the Trinity River watershed were found to contain mercury at concentrations up to four times the U.S. Environmental Protection Agency water quality criterion (May et al. 2002).

Consumption advisories due to elevated mercury concentrations in edible fish tissue have been issued in 42 states, including California. The California Office of Environmental Health Hazard Assessment (OEHHA) has provided consumption advice for several water bodies in northern California from which high levels of mercury have been identified in fish.

Mercury contamination in fish is thought to be widespread in water bodies throughout northern California due to mercury mining and use of mercury in gold mining operations, as well as other sources of mercury such as atmospheric deposition. However, no surveys have been conducted to determine the significance of mercury contamination in northern California lakes and reservoirs. This study was undertaken to provide an initial database to evaluate the extent of mercury contamination in fish from lakes and reservoirs in northern California.

Methods

Twenty lakes and reservoirs in northern California were selected for collection of fish for mercury analysis (Table 1). In some of the larger lakes and reservoirs, fish were collected from more than one area. Sampling was conducted during the spring and summer of 2000 and 2001. Methods to collect fish included gill nets, boat electroshocking, hooks and lines, seines, and trot lines, except at Eagle Lake where fish were obtained from the Department of Fish and Game (DFG) egg taking station on Pine Creek.

Species collected from the lakes and reservoirs included largemouth (LMB) (*Micropterus salmoides*), smallmouth (SMB) (*Micropterus dolomieui*), and spotted (SPB) (*Micropterus punctulatus*) bass, rainbow (RBT) (*Oncorhynchus mykiss*) and brown (BT) (*Salmo trutta*) trout, channel (CHC) (*Ictalurus punctatus*) and white (WHC) (*Ictalurus catus*) catfish, brown bullhead (BRB) (*Ictalurus nebulosus*), yellow perch (YP) (*Perca flavescens*), and bluegill (BG) (*Lepomis macrochirus*). Total length and weight of each fish were measured in the field. Fish were immediately wrapped in aluminum foil, placed in a plastic bag, and placed on dry ice. Fish were kept frozen until delivered to the laboratory for analysis.

Composites for muscle tissue analysis of mercury concentration were made from fish of each species of approximately the same size (i.e., no more than about 25 percent difference in length between the smallest and largest individual). Generally, from three to five fish for each species were composited. When only a single exceptionally large fish of a particular species was obtained from a lake or reservoir, the individual fish was submitted for tissue analysis. In a few instances, only two fish of a particular species could be obtained and were submitted as a composite. Where possible, more than one size class of fish was collected. Planted fish were avoided unless they are sufficiently large to indicate that they had resided in the lake for at least two years.

Table 1. Northern California lakes and reservoirs monitored for mercury contamination in fish

Lake or Reservoir	County	Species[1]
Antelope Lake	Plumas	LMB
Bucks Lake	Plumas	RBT,BT
Lake Almanor	Plumas	SMB,BT
Little Grass Valley Reservoir	Plumas	BT
Frenchman Lake	Plumas	RBT
Sly Creek Reservoir	Butte	BT
Lake Oroville	Butte	LMB,SPB
Lake Britton	Shasta	SMB,CHC
Shasta Lake	Shasta	SPB,CHC
Whiskeytown Lake	Shasta	LMB
Eagle Lake	Lassen	RBT
Mountain Meadows Reservoir	Lassen	LMB,BRB
Copco Lake	Siskiyou	YP
Lake Shastina	Siskiyou	LMB
Trinity Lake	Trinity	SMB,WHC
Ruth Lake	Trinity	RBT,BG
East Park Reservoir	Colusa	LMB,CHC
Stony Gorge Reservoir	Glenn	LMB,CHC
Blue Lakes	Lake	LMB
Indian Valley Reservoir	Lake	LMB,CHC

[1]LMB-largemouth bass; SPB-spotted bass; BT-brown trout; CHC-channel catfish; RBT-rainbow trout; BRB-brown bullhead; SMB-smallmouth bass; YP-yellow perch; WHC-white catfish; BG-bluegill

Methylmercury is assumed to be the form of mercury available for bioaccumulation in the food web. Most mercury in fish tissues is in the methylmercury fraction. Total mercury, however, is typically analyzed from fish tissue and is assumed to represent the methylmercury content of tissues. Therefore, laboratory analyses were performed for total recoverable mercury by the DFG Water Pollution Control Laboratory in Rancho Cordova, California, West Coast Analytical Services in Sante Fe Springs, California, or Frontier Geosciences in Seattle, Washington. Analytical procedures of the DFG laboratory generally followed those used in the Toxic Substances Monitoring Program conducted by the State Water Resources Control Board and DFG (SWRCB 1996), and consisted of fish tissue digestion with concentrated nitric acid, followed by stannous chloride reduction of mercury, and analysis by cold-vapor atomic absorption spectroscopy (Dave Crane, DFG, pers. comm.). West Coast Analytical Services analysis differed by performing mercury analysis using inductively coupled plasma-mass spectrometry (Louis Albanese, WCAS, pers. comm.). Frontier Geosciences used a modified U.S. Environmental Protection Agency (EPA) method 1631, which included digestion in a 70:30 nitric:sulfuric acid mixture followed by analysis by cold-vapor atomic absorption spectroscopy (Frank Colich, FGS, pers. comm.).

Fish tissue results were compared to the OEHHA screening value and EPA water quality criterion for mercury. The OEHHA established a 0.3 mg/kg screening value for the California Lakes Study to identify chemical contaminants in fish tissue at concentrations that may be of human health concern for frequent consumers of sport fish (OEHHA 1999). The screening values are not intended to serve as levels at which fish consumption advisories would be issued, but to identify fish species and chemicals from a limited set of data for which more intensive sampling, analysis, or health evaluation are warranted.

As required by Section 304(a) of the Clean Water Act, the EPA revised the water quality criteria for mercury in 2001 to reflect the latest scientific knowledge on effects to health (EPA 2001). The EPA determined that the major pathway for human exposure to methylmercury was through consumption of contaminated fish. Therefore, the EPA concluded that a fish tissue residue water quality criterion for methylmercury was more appropriate than a water column-based water quality criterion. The fish tissue residue criterion for protection of human health was calculated to be 0.3 mg methylmercury/kg of fish.

Results

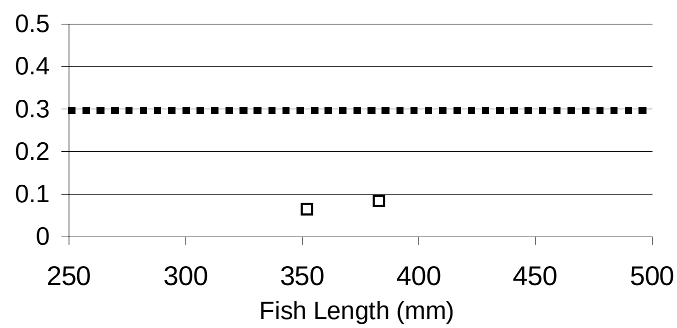
Mercury was reported by the laboratories in tissues of fish from each lake or reservoir sampled. However, variation in mercury concentration was found in different species as well as from different lakes and reservoirs (Appendix 1).

Antelope Lake

Largemouth bass were collected from Antelope Lake near the dam.

The two size classes of bass that were collected were similar to the larger size classes of bass collected from other lakes and reservoirs that contained elevated concentrations of mercury. However, both size classes of bass from Antelope Lake contained tissue mercury concentrations at levels much less than the OEHHA screening value and EPA criterion (Figure 1), indicating that mercury contamination of fish in this reservoir is not a health concern.

Figure 1. Tissue mercury concentrations in largemouth bass from Antelope Lake



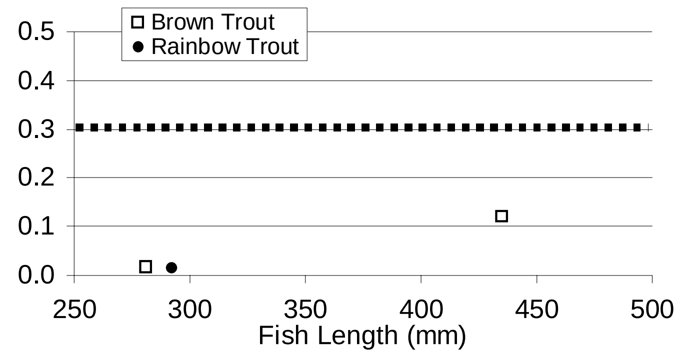
0.3 = EPA fish tissue criterion for mercury (mg/kg)

Bucks Lake

Both brown and rainbow trout were obtained from Bucks Lake near Sandy Point. Two size classes of brown trout, but only one size class of rainbow trout, were obtained.

The average length of fish in the smaller brown trout composite was similar to that in the rainbow trout composite, and both contained similar levels of mercury (Figure 2). Mercury levels in both brown trout and the rainbow trout composites were much less than the OEHHA screening value and EPA criterion.

Figure 2. Tissue mercury concentrations in brown and rainbow trout from Bucks Lake



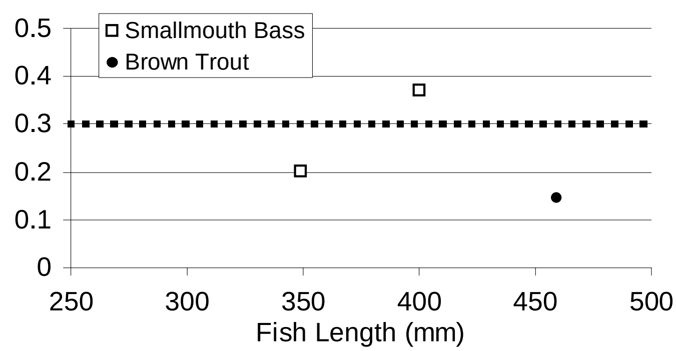
0.3 = EPA fish tissue criterion for mercury (mg/kg)

Lake Almanor

Two size classes of smallmouth bass and one size class of brown trout were obtained from Lake Almanor near the dam.

Tissue from the larger size class of smallmouth bass contained mercury at concentrations in excess of the OEHHA screening value and EPA criterion (Figure 3). The brown trout, though larger than the bass, contained much less tissue mercury.

Figure 3. Tissue mercury concentrations in smallmouth bass and brown trout from Lake Almanor



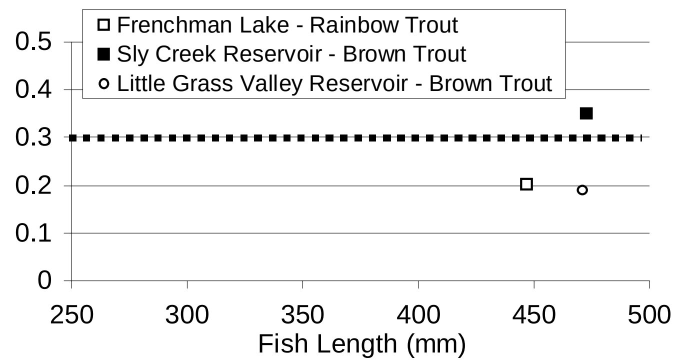
0.3 = EPA fish tissue criterion for mercury (mg/kg)

Little Grass Valley Reservoir

The Little Grass Valley Reservoir was sampled near the entrance of the South Fork Feather River, where a single size class of brown trout was obtained.

Brown trout collected from this reservoir were similar in size to the brown trout collected from other reservoirs. However, the composite of brown trout from Little Grass Valley Reservoir did not contain mercury at a level that exceeded the screening value or criterion (Figure 4).

Figure 4. Tissue mercury concentrations in trout from Little Grass Valley Reservoir, Frenchman Lake, and Sly Creek Reservoir



0.3 = EPA fish tissue criterion for mercury (mg/kg)

Frenchman Lake

Rainbow trout were collected from Frenchman Lake near the dam.

The tissue mercury level from the composite of large sized trout did not exceed the screening value or criterion (Figure 4).

Sly Creek Reservoir

Brown trout were obtained from the Sly Creek Arm of Sly Creek Reservoir.

The brown trout were similar in size to the rainbow trout obtained from Frenchman Lake, though slightly longer but weighed slightly less, and slightly larger than the brown trout obtained from Little Grass Valley Reservoir. However, the composite of brown trout from Sly Creek Reservoir contained tissue mercury at a level slightly in excess of the OEHHA screening value and EPA criterion (Figure 4).

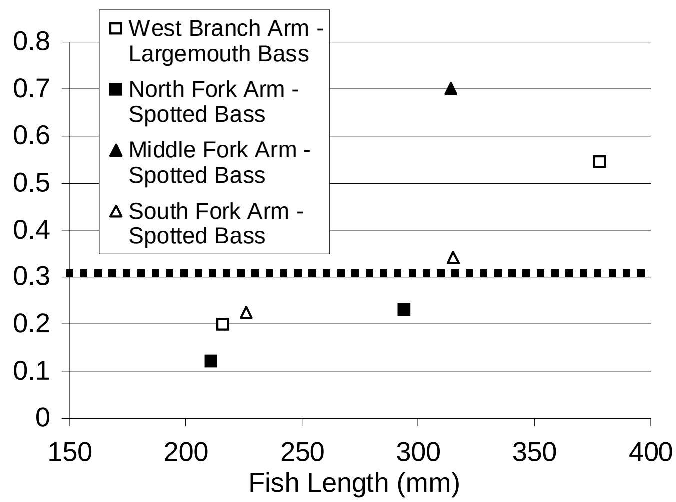
Lake Oroville

Both largemouth and spotted bass were collected from Lake Oroville. Largemouth bass were collected from the West Branch Arm near the Lime Saddle Marina, and spotted bass were collected from the Middle Fork Arm near the main reservoir body, South Fork Arm near McCabe Cove, and the North Fork Arm near Bloomer Cove. Two size classes of bass were collected from the West Branch and North and South Fork arms.

Mercury concentrations exceeded the OEHHA screening value and EPA water quality criterion of 0.3 mg/kg in largemouth bass from the West Branch Arm and spotted bass from the Middle and South Fork arms (Figure 5). Only the larger size class of bass from these three areas contained mercury at concentrations that exceeded the screening value and criterion.

Neither size classes of spotted bass from the North Fork Arm exceeded the screening value or criterion, but they were not as large as the fish exceeding these levels in the other arms. The composite of spotted bass from the Middle Fork Arm had a tissue mercury concentration that was twice that of similarly sized spotted bass from the South Fork Arm, and about a quarter more tissue mercury than much larger largemouth bass from the West Branch Arm.

Figure 5. Tissue mercury concentrations in largemouth and spotted bass from Lake Oroville



0.3 = EPA fish tissue criterion for mercury (mg/kg)

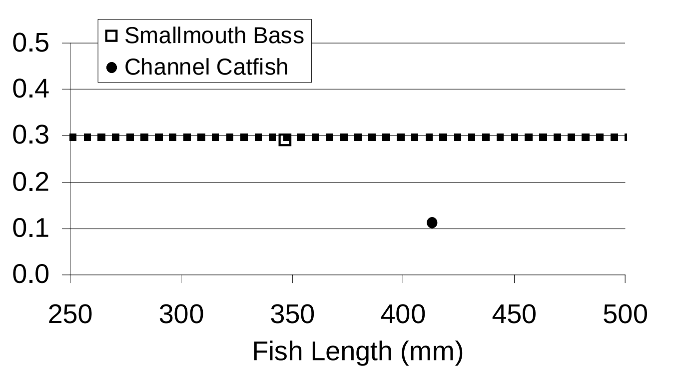
Oroville Reservoir has a “slot limit” for sport fishing, in which bass between 305 and 380 mm (12 and 15 inches) cannot be kept. The data indicate that smaller legally kept fish may not pose a health hazard, and the larger legally kept fish exceed limits for health concerns.

Lake Britton

Smallmouth bass and channel catfish were collected from Lake Britton near the Highway 89 bridge.

The tissue mercury concentration in the smallmouth bass composite was just below the OEHHA and EPA criterion, and the concentration in the catfish composite was much less than these values (Figure 6).

Figure 6. Tissue mercury concentrations in smallmouth bass and channel catfish from Lake Britton

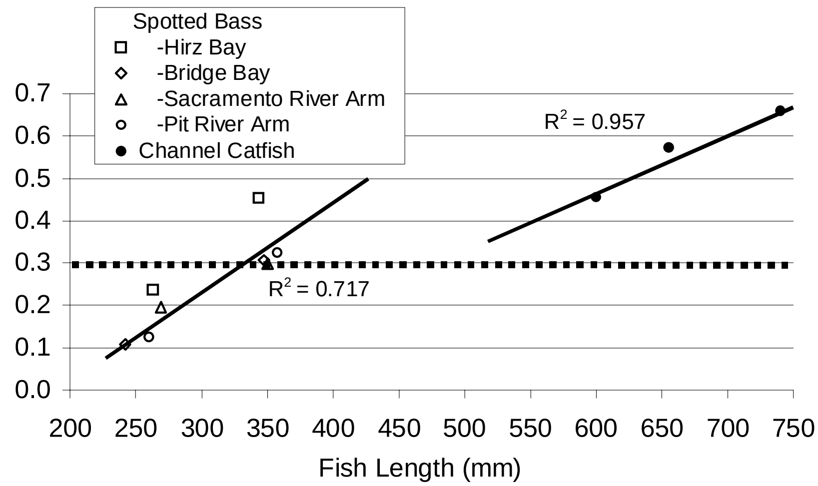


0.3 = EPA fish tissue criterion for mercury (mg/kg)

Shasta Lake

Fish collected from Shasta Lake included spotted bass from Hirz Bay, Bridge Bay, Sacramento River Arm, and Pit River Arm, and channel catfish from the Pit River Arm of the reservoir. Two size classes of bass were collected which were similar in size at each monitoring site. The three catfish were analyzed individually for tissue mercury concentrations.

Figure 7. Tissue mercury concentrations in spotted bass and channel catfish from Lake Shasta



0.3 = EPA fish tissue criterion for mercury (mg/kg)

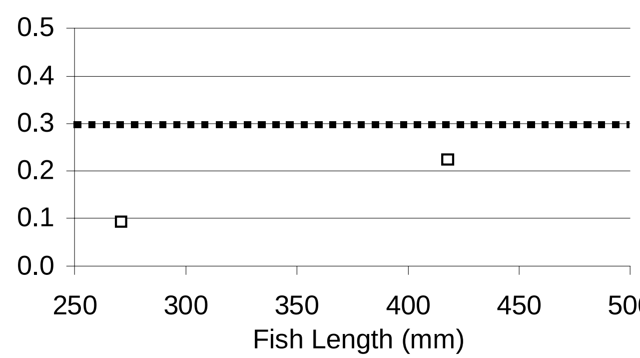
The larger size class of spotted bass from each sampling site and all of the channel catfish exceeded the OEHHA screening value and EPA criterion, with highest mercury concentrations found in the catfish (Figure 7). Both the bass composites and individual catfish tissue mercury concentrations display an increasing trend with size of fish. Highest tissue mercury concentrations in the bass were found from fish collected at Hirz Bay, which is in the upper McCloud River Arm of Shasta Lake.

Whiskeytown Lake

Two size classes of largemouth bass were collected from the Whiskey Creek Arm of Whiskeytown Lake.

Though the larger size class of largemouth bass contained a greater tissue concentration of mercury than the smaller size class of fish, neither size class contained mercury at levels that exceeded either the screening value or criterion (Figure 8).

Figure 8. Tissue mercury concentrations in largemouth bass from Whiskeytown Lake



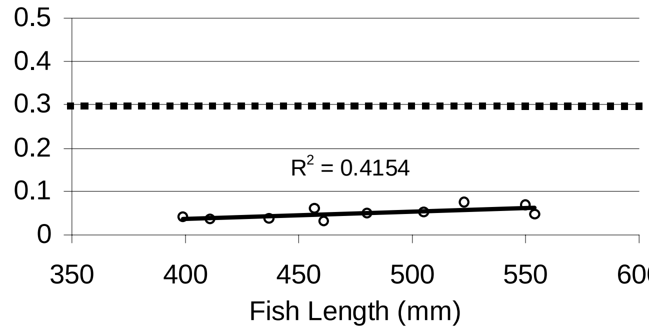
0.3 = EPA fish tissue criterion for mercury (mg/kg)

Eagle Lake

Ten very large Eagle Lake rainbow trout were obtained from the DFG egg taking station on Pine Creek, which is the major tributary to Eagle Lake and principal spawning stream for this strain. However, little natural spawning presently occurs due to dewatering of the creek by upstream irrigation diversions.

The fish were individually analyzed for mercury, and then the results were composited for the two size classes of fish. Both size classes of the rainbow trout contained only minute levels of mercury in the fish tissues.

Figure 9. Tissue mercury concentrations in individual Eagle Lake rainbow trout

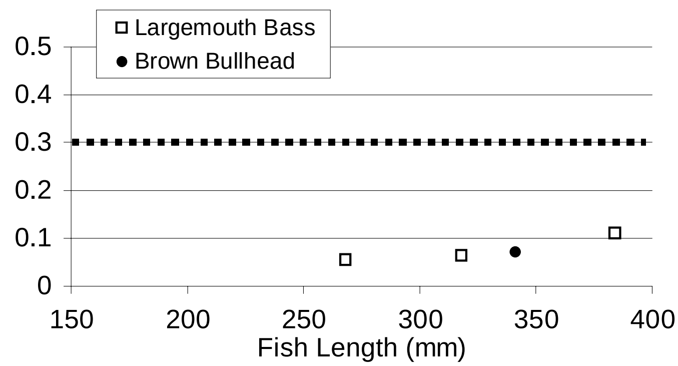


Little difference in tissue mercury concentration is apparent between the individual Eagle Lake rainbow trout (Figure 9). Mercury does not appear to bioaccumulate to any significant extent in these fish, with larger fish having no significantly greater contaminant load than smaller fish.

Mountain Meadows Reservoir

Fish comprising three size classes of largemouth bass and one brown bullhead size class were collected from Mountain Meadows Reservoir near the inlet of Goodrich Creek.

Figure 10. Tissue mercury concentrations in largemouth bass and brown bullhead from Mountain Meadows Reservoir



0.3 = EPA fish tissue criterion for mercury (mg/kg)

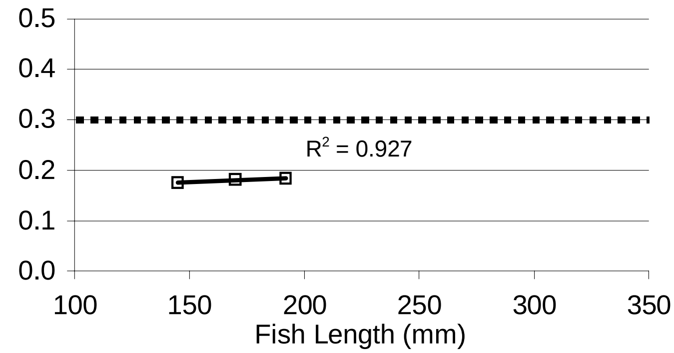
None of the composites contained tissue mercury at levels exceeding either the OEHHA screening value or EPA criterion (Figure 10), even though two of the size classes were as large as ones from other reservoirs that did exceed the screening value and criterion.

Copco Lake

Copco Lake was sampled near the confluence of Milk Creek. Three size classes of yellow perch were composited for tissue analysis of mercury.

Concentrations of mercury in tissues of the yellow perch were less than the screening value and criterion (Figure 11). The concentration of tissue mercury showed an increasing trend with increasing size of the yellow perch, though the sample size (three composites) is small but the size range is relatively large.

Figure 11. Tissue mercury concentrations in yellow perch from Copco Lake



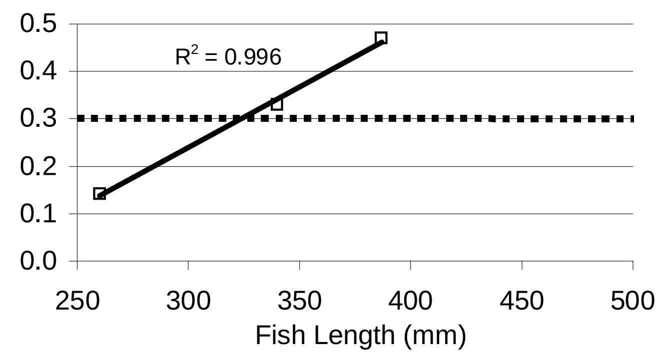
0.3 = EPA fish tissue criterion for mercury (mg/kg)

Lake Shastina

Largemouth bass were collected from Lake Shastina near the dam. Three size classes of bass were collected.

The larger size classes of largemouth bass from Lake Shastina exceeded both the OEHHA screening value and EPA criterion (Figure 12). Tissue mercury concentration displays a very high correlation with size of fish.

Figure 12. Tissue mercury concentrations in largemouth bass from Lake Shastina



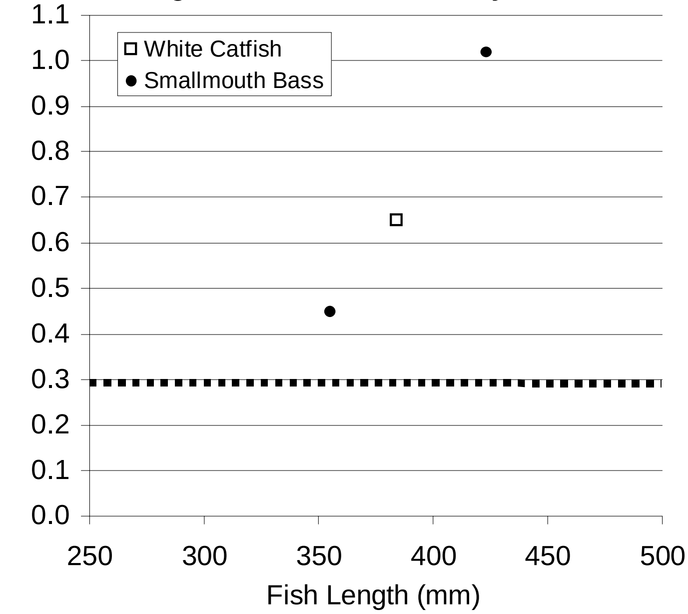
0.3 = EPA fish tissue criterion for mercury (mg/kg)

Trinity Lake

White catfish and two size classes of smallmouth bass were obtained from Trinity Lake near Trinity Center.

Tissues from both the white catfish and smallmouth bass composites contained mercury well in excess of the OEHHA screening value and EPA criterion (Figure 13). The larger size class of smallmouth bass, with a concentration of over 1.0 mg of mercury per kg of body weight, contained the highest tissue mercury concentration found from any of the lakes assessed in this study.

Figure 13. Tissue mercury concentrations in white catfish and largemouth bass from Trinity Lake



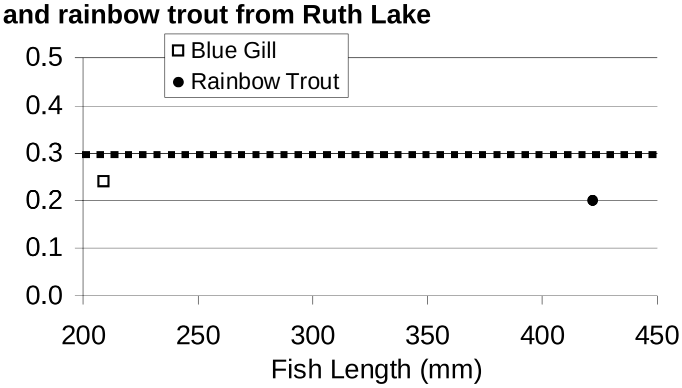
0.3 = EPA fish tissue criterion for mercury (mg/kg)

Ruth Lake

Both blue gill and rainbow trout were collected from a mid-point area of Ruth Lake.

Concentrations of mercury in tissues from both the blue gill and rainbow trout composites did not exceed the screening value or criterion (Figure 14).

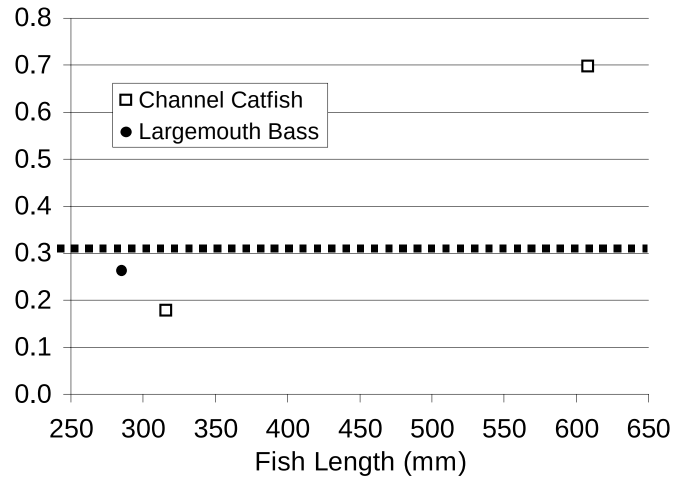
Figure 14. Tissue mercury concentrations in blue gill and rainbow trout from Ruth Lake



0.3 = EPA fish tissue criterion for mercury (mg/kg)

East Park Reservoir

Figure 15. Tissue mercury concentrations in channel catfish and largemouth bass from East Park Reservoir



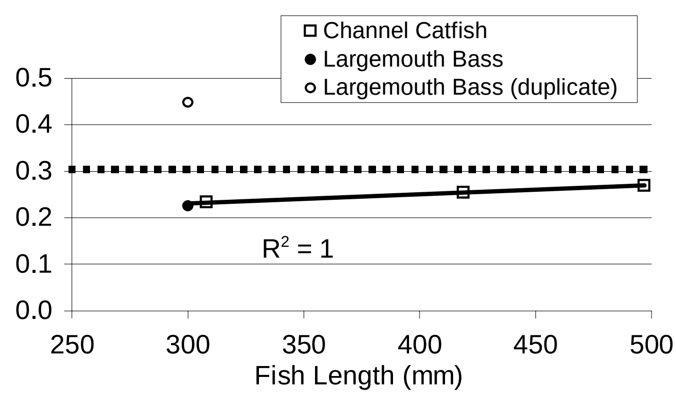
0.3 = EPA fish tissue criterion for mercury (mg/kg)

Both channel catfish and largemouth bass were obtained from East Park Reservoir. Sufficient catfish for a composite and one exceptionally large catfish that was analyzed individually were obtained from the southern portion of the reservoir near Lodoga. A single size class of largemouth bass was composited from fish obtained near the dam at the northern end of the reservoir.

Neither the catfish nor bass composites exceeded the OEHHA screening value or EPA criterion, though mercury levels in the small sized bass did approach these limits (Figure 15). However, the very large individual channel catfish contained tissue mercury at over twice the level of the screening value and criterion.

Stony Gorge Reservoir

Figure 16. Tissue mercury concentrations in channel catfish and largemouth bass from Stony Gorge Reservoir



0.3 = EPA fish tissue criterion for mercury (mg/kg)

Fish were collected from Stony Gorge Reservoir near the inlet of Stony Creek at the south end of the reservoir. One group of similarly sized channel catfish was composited, and two other larger fish were analyzed individually. Largemouth bass were also collected and formed into a composite.

Mercury concentrations in tissues of channel catfish were less than the screening value and criterion (Figure 16). Little differences in concentrations of mercury in tissues were identified in the composite and larger individual channel catfish analyses. However, an excellent correlation exists between mercury concentration in channel catfish tissue and size of fish. Stony Gorge Reservoir is downstream from East Park Reservoir, from which the similarly sized catfish composite was found to contain a similar tissue concentration of mercury. However, the much larger individual channel catfish from East Park Reservoir, which was significantly larger than the larger individual catfish from Stony Gorge Reservoir, contained mercury well in excess of the screening value and criterion. Larger channel catfish from Stony Gorge Reservoir, therefore, may be expected to contain mercury concentrations that exceed the screening value and criterion.

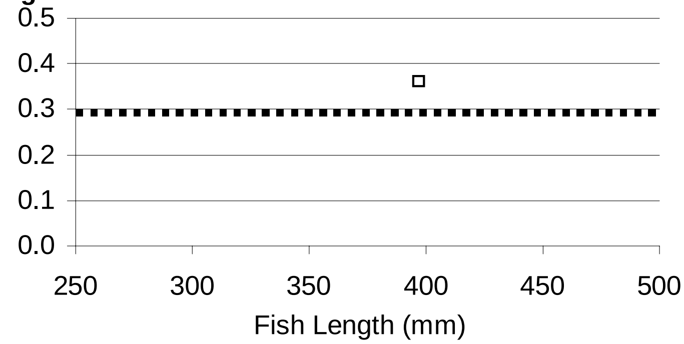
A duplicate analysis was performed from the largemouth bass composite. One analysis indicated tissue mercury was less than the screening value and criterion, but the other analysis indicated that these levels were exceeded.

Blue Lakes

Largemouth bass were collected and composited from the western arm of Blue Lakes.

Mercury analyzed from composited largemouth bass tissues from Blue Lakes exceeded the OEHHA screening value and EPA criterion (Figure 17).

Figure 17. Tissue mercury concentration in largemouth bass from Blue Lakes



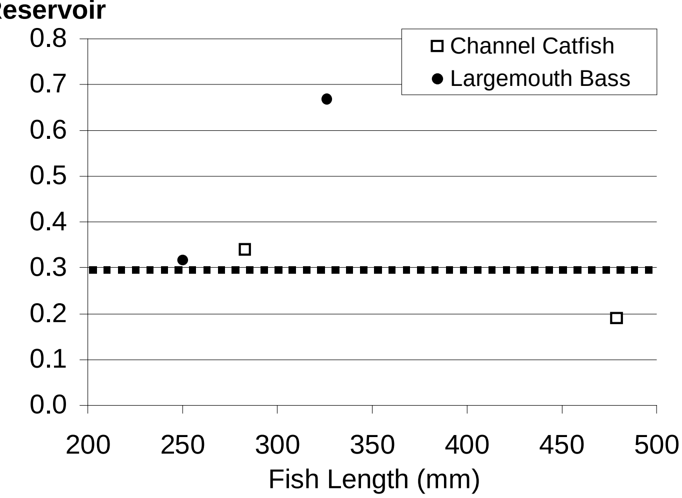
0.3 = EPA fish tissue criterion for mercury (mg/kg)

Indian Valley Reservoir

Channel catfish and largemouth bass were collected from Indian Valley Reservoir near the spillway. In addition to a composite of catfish, one larger individual catfish was also submitted for tissue analysis. Two size classes of bass were composited.

While the small size class of channel catfish exceeded the OEHHA screening value and EPA criterion, the much larger individual catfish did not (Figure18). Both size classes of largemouth bass exceeded the screening value and criterion, with the larger bass significantly higher than the smaller fish.

Figure 18. Tissue mercury concentrations in channel catfish and largemouth bass from Indian Valley Reservoir



0.3 = EPA fish tissue criterion for mercury (mg/kg)

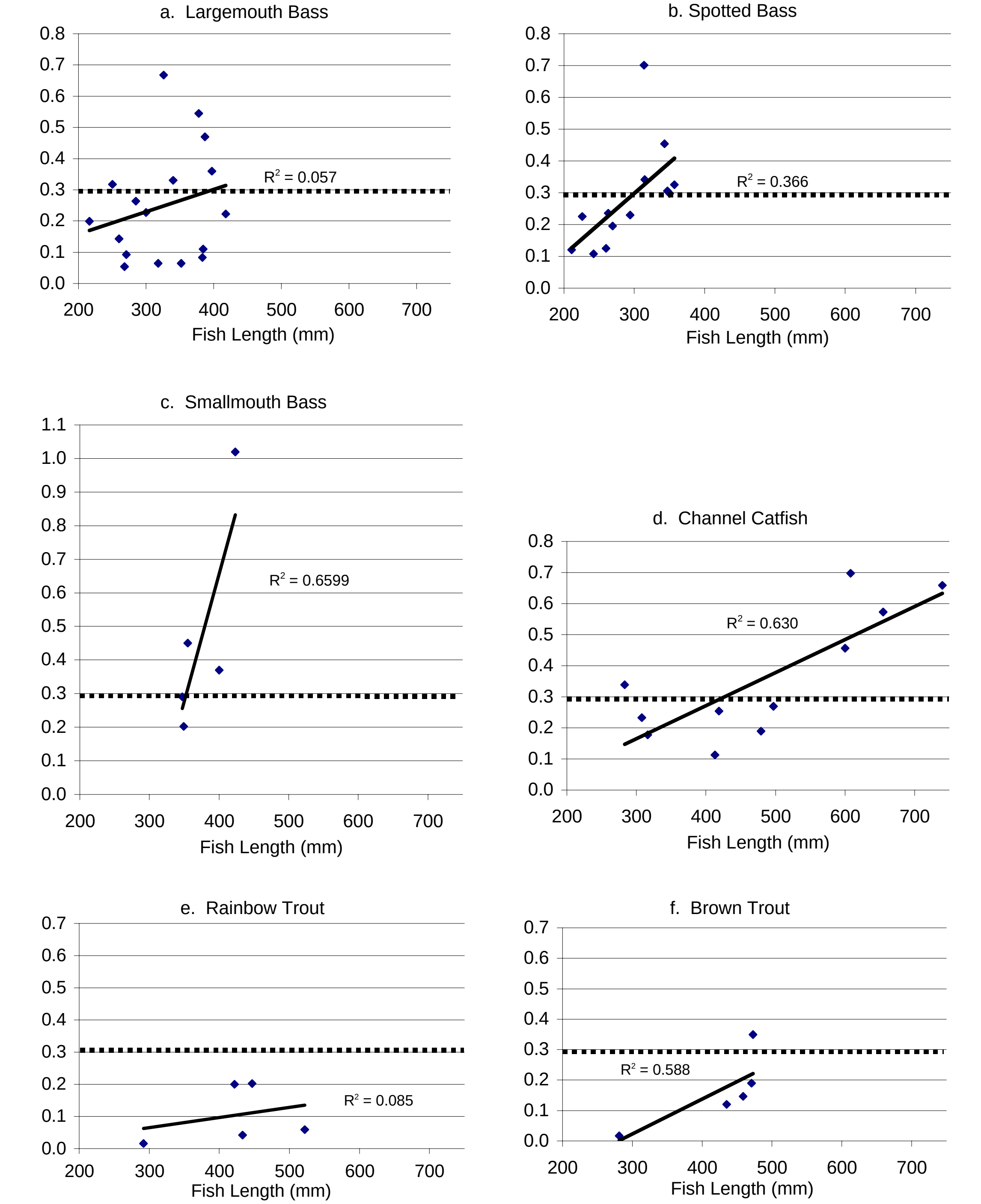
Discussion

Larger fish collected from the lakes and reservoirs tended to have higher concentrations of tissue mercury. Other studies have also indicated increasing tissue mercury concentration with fish size (May et al. 2000). In addition to fish size, mercury concentration is dependent on the water body from which a particular species of fish was obtained. The same species from one water body often displays very different mercury concentrations in another water body. Little correlation exists for any particular species collected from all water bodies and mercury concentration (Figure 19), indicating that the water body from which fish were obtained also affects mercury levels.

The type of species of fish also affects mercury concentration. Certain species tended to display tissue mercury concentrations higher than other species, even though a particular species from a lake or reservoir may have had tissue mercury concentrations higher than the same species from other water bodies (Figure 20). The bass species, especially spotted bass followed next by smallmouth bass, display higher concentrations of mercury at smaller fish sizes than the other species do, though catfish species also tended to have high concentrations of mercury. Trout species display the lowest bioaccumulation of mercury from the lakes and reservoirs. However, bass and catfish species were usually obtained from lakes or reservoirs different from those in which the trout species were obtained because their habitat requirements differ. The trophic position of fish is important in mercury bioaccumulation levels (Goldman and Slotton 1996). In other studies, highest mercury concentrations were found in largemouth, smallmouth, and spotted bass, which are considered top predators, from Camp Far West Reservoir and Lake Combie in the Bear River watershed and Lake Englebright in the South Yuba watershed (May et al. 2000). Mercury concentrations in these fish exceeded the OEHHA screening value and EPA criterion in 88 percent of the bass sampled. Channel catfish, which is a benthic omnivore, and bluegill, which is an intermediate trophic level predator, generally had lower concentrations of tissue mercury than did the bass from these watersheds. Both brown and rainbow trout, which are primarily insectivores, collected from streams contained mercury concentrations generally lower than the bass and catfish collected from the reservoirs, though trout from several sites still had elevated levels of tissue mercury.

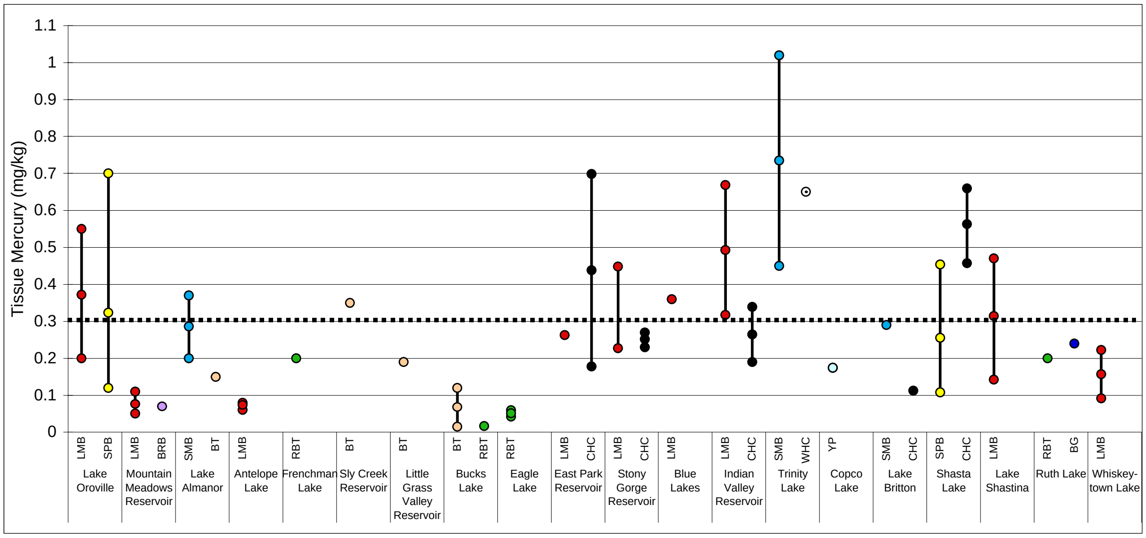
Lakes or reservoirs with elevated tissue mercury concentrations in fish have been associated with extensive past gold or mercury mining activity in their watersheds (Alpers and Hunerlach 2000, Goldman and Slotton 1996, May et al. 2000, 2002). Bass or catfish with very high tissue mercury concentrations were collected from Lake Oroville and Trinity Lake, both of which are in watersheds with extensive past gold mining activity (Figure 21). However, bass or catfish with elevated tissue mercury concentrations were also collected from Shasta Lake and Lake Almanor, which had only slight past gold mining activity in their watersheds, and East Park, Stony Gorge, and Indian Valley reservoirs, Blue Lakes, and Lake Shastina, which are not identified as having gold or mercury mining operations in the upstream watersheds. Conversely, the Little Grass Valley Reservoir and Bucks Lake watersheds had extensive past mining activity, but trout collected from these water bodies had low tissue mercury concentrations, which may indicate the effect of species type on mercury bioaccumulation. In addition, some reservoirs may act as mercury sinks, in which mercury produced in the upstream watershed becomes buried with sediments and unavailable for methylation. However, trout from Sly Creek Reservoir, which is downstream from Little Grass Valley Reservoir and extensive past mining activity, did have elevated tissue mercury concentrations. Whiskeytown Reservoir lies in a watershed that had extensive gold mining activity and also receives diversions from the Trinity River watershed, which also had extensive gold mining activity. However, bass from Whiskeytown Reservoir had low concentrations of mercury, which indicates that factors other than past gold mining activity also affect fish tissue bioaccumulation of mercury.

Figure 19. Relationships between mercury concentration and fish size for fish species collected from all sites



0.3 = EPA fish tissue criterion for mercury (mg/kg)

Figure 20. Range of tissue mercury concentrations of fish composites (maximum, mean, and minimum composite concentrations)

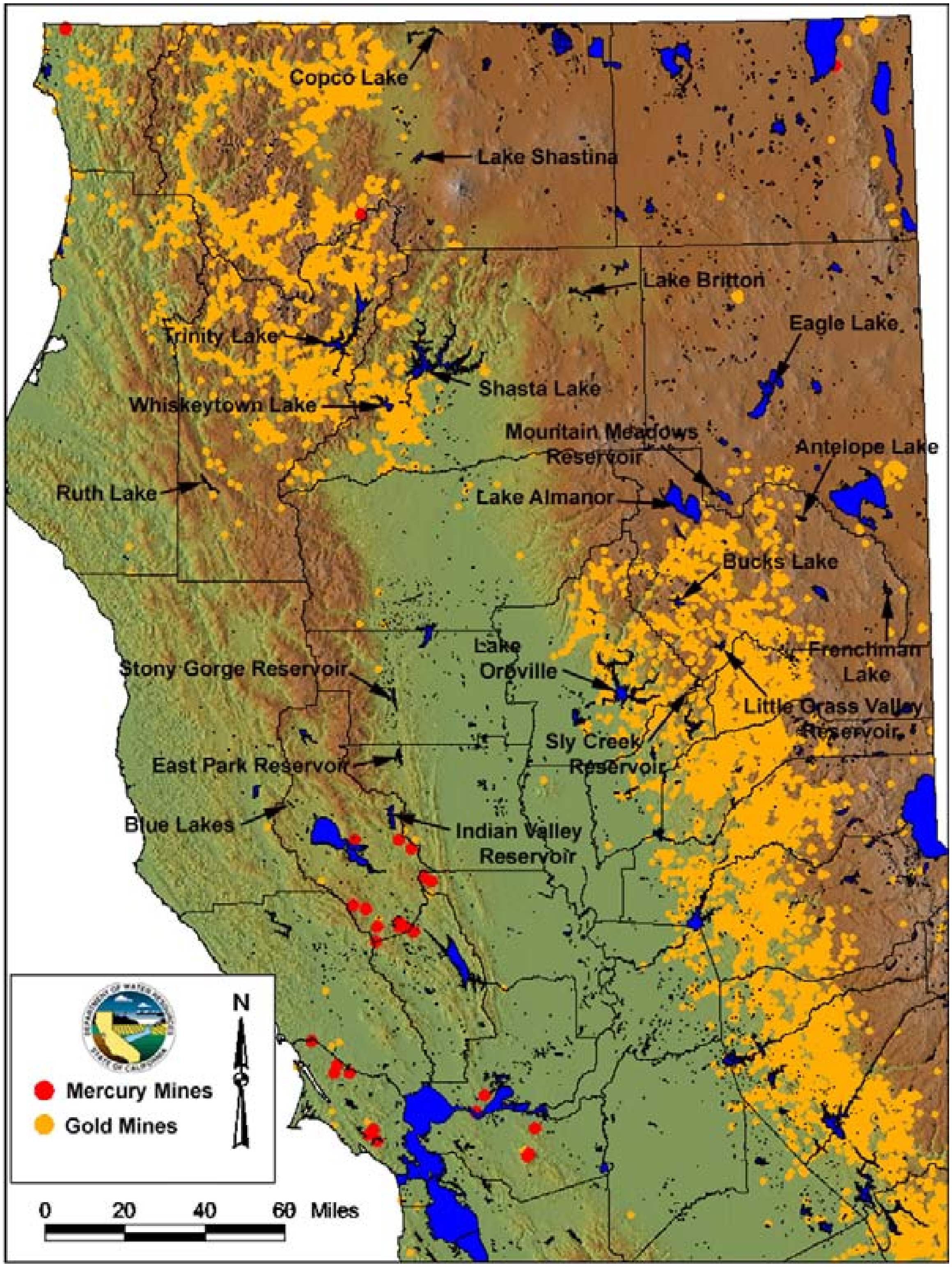


Many potential sources for mercury contamination of lakes and reservoirs exist (Jones and Slotton 1996). Mercury is a natural element that is abundant throughout the environment, with many soils and rocks having low concentrations of mercury ranging from a few to a few hundred parts per billion, such as serpentine which may contain from 150 to 300 ppb of mercury (Ron Churchill, California Geological Survey, pers. comm.). Erosion and leaching carries minute quantities of mercury to downstream water bodies. Numerous factors affect mercury availability and bioaccumulation, in addition to species of fish, in both areas of extensive past gold or mercury mining activity as well as areas with little or no past mining activity, including the length of the aquatic food chain, water acidity and temperature, and dissolved organic material (EPA 2001). Sulfate availability appears important to the methylation process, so that even in low mercury but rich sulfate environments significant bioaccumulation can occur due to efficient methylation.

Wildfires can release significant concentrations of mercury stored in foliage and ground litter to the atmosphere (NCAR 2001, ACS 2003). Earth movement, volcanoes, vents, hot springs, and ocean and soil emissions are also sources of mercury to the atmosphere (Jones and Slotton 1996).

Anthropogenic sources of mercury include use in many manufacturing industries and products, such as thermometers, electrical equipment, lamps, dental amalgams, pharmaceuticals, and fungicides. Atmospheric deposition from burning of coal is a significant source of mercury in the eastern United States, and has recently been identified in California. Researchers from the University of Santa Cruz have identified long-range transport of mercury across the North Pacific from Asia, where coal combustion is heavily relied upon for fuel (Steding and Flegal 2002).

Figure 21. Lakes and reservoirs monitored and historical mercury and gold mines in northern California (data from California Department of Conservation, Division of Mines and Geology)



Gaseous elemental mercury released to the atmosphere can be transported around the globe before becoming transformed into highly water soluble ionic mercury through chemical processes and deposited with rain or dry deposition to land and water bodies. Methylation can further transform the ionic inorganic mercury into organic mercury, which may then bioaccumulate in organisms. Though many sources of mercury exist, concerns about environmental contamination in California generally focus on aquatic sources due to extensive natural mercury deposits, natural hydrothermal activity in many areas where mercury occurs, mercury mining, and subsequent extensive use of mercury in gold mining since the mid-1800s.

Other studies have identified many other lakes, reservoirs, and streams in northern California from which aquatic organisms have elevated concentrations of tissue mercury. In 1987, the Central Valley Regional Water Quality Control Board completed a regional mercury assessment that identified elevated mercury levels in tissues of fish from the Colusa Basin Drain, Cache Creek, Clear Lake, North Fork Yuba River downstream from Bullards Bar Reservoir, Feather River downstream from Lake Oroville, Lower American River, Lake Berryessa, Beach Lake, and Sacramento River at Hood in the Sacramento River watershed (CVRWQCB 1987). In addition, the Toxic Substances Monitoring Program identified fish with elevated mercury levels exceeding the EPA criterion from the North Fork and lower American River, Camp Far West Reservoir, Lake Wildwood, and Bullards Bar Reservoir (SWRCB 1996). The USGS identified elevated mercury levels in fish from Lake Englebright in the South Yuba River watershed, Camp Far West Reservoir, Lake Combie, and Bear River in the Bear River watershed, and Little Deer and Deer Creek in the Deer Creek watershed (May et al. 2000). Historical gold and mercury mining were identified as sources of continuing mercury contamination in Trinity Lake and the upper Trinity River watershed (May et al. 2002). Researchers from the University of California at Davis identified increasing levels of mercury concentrations with increasing trophic feeding level in aquatic invertebrates from the upper forks of the Yuba River, North and Middle forks of the Feather River, Bear River, and the North and Middle forks of the American River (Slotton et al. 1995). However, mercury concentrations in trout from these streams were uniformly below health standards. Foothill reservoirs were identified as interceptors of mercury, with much lower levels of mercury in the biota downstream from the dam as compared to levels in upstream biota.

Elevated concentration of mercury in fish tissues has resulted in recommendations by OEHHA to limit consumption of various fish species in numerous water bodies. In northern California, consumption advisories have been issued for Black Butte Reservoir in Glenn and Tehama counties, Lake Pillsbury and Clear Lake in Lake County, Lake Berryessa in Napa County, Lake Herman in Solano County, Camp Far West, Rollins, and Scotts Flat reservoirs and Lake Englebright and Combie in the northern Sierra Nevada foothills of Yuba, Placer, and Nevada counties, and the San Francisco Bay and Delta region (OEHHA 1987, 2000, 2002, 2003a, 2003b). OEHHA has also issued interim fish consumption advisories for the Trinity River watershed in Trinity County, which includes Trinity Lake, Trinity River upstream from Trinity Lake, Coffee Creek, Carrville Pond, and the East Fork Trinity River and its tributaries (OEHHA 2002); Tomales Bay in Marin County; and San Pablo Reservoir in Contra Costa County. OEHHA issued provisional guidelines for Stony Gorge and East Park reservoirs (OEHHA 2004).

Conclusion

Mercury contamination in fish is becoming an increasingly important issue in California and the nation. Recent studies have linked health effects from eating fish with elevated concentrations of mercury. Fish with elevated levels of mercury have been identified in many water bodies in California, though fish from many other water bodies have not been evaluated.

All fish can be expected to have some level of mercury in their tissues due to a variety of sources and ready bioaccumulation of mercury. This study identifies lakes and reservoirs in northern California with elevated levels of mercury in fish tissues. The number of samples from individual lakes or reservoirs is not sufficient for OEHHA to issue consumption advisories, but this study does provide information to focus future efforts to determine the need for advisories. Most of the lakes and reservoirs from which fish were found to contain elevated levels of mercury contamination in this and other studies are in watersheds with historical mercury or gold mining. Mercury contamination was also found in this study in lakes and reservoirs in watersheds that lack historical mercury or gold mining, indicating that focusing monitoring efforts in watersheds in which historical mercury or gold mining occurred will not adequately identify all impaired water bodies. Sources of mercury in these water bodies in which historical mercury or gold mining did not occur may be related to natural background sources or anthropogenic activities.

Certain fish species bioaccumulate mercury to a lesser extent than do other species. Fishery resource managers can use this information for targeting certain species for recreational fishing enhancement. Recreational anglers can use this information to determine which species to practice catch-and-release fishing and which species to target for consumption.

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Appendix 1. Results of Fish Tissue Analyses for Mercury

*OEHHA screening value and EPA criterion is 0.3 mg/kg

Collection Site	Species	Number of Fish in Composite	Average Total Length (mm)	Average Weight (gms)	Mercury (mg/Kg)
Antelope Lake					
nr dam	LMB	3	352	812	0.06
nr dam	LMB	3	383	1105	0.08
Bucks Lake					
nr Sandy Point	BT	3	281	227	0.02
nr Sandy Point	BT	3	435	916	0.12
nr Sandy Point	RBT	5	292	255	0.02
Lake Almanor					
near Dam	SMB	3	349	708	0.20
near Dam	SMB	3	400	1095	0.37
near Dam	BT	4	459	1133	0.15
Little Grass Valley Reservoir					
nr South Fork	BT	4	471	1161	0.19
Frenchman Lake					
nr dam	RBT	3	447	1360	0.20
Sly Creek Reservoir					
Sly Creek Arm	BT	5	473	1218	0.35
Lake Oroville					
West Branch Arm nr Lime Saddle	LMB	4	216	135	0.20
West Branch Arm nr Lime Saddle	LMB	3	378	916	0.55
North Fork Arm nr Bloomer Cove	SPB	4	211	78	0.12
North Fork Arm nr Bloomer Cove	SPB	5	294	329	0.23
Middle Fork Arm nr mouth	SPB	5	314	453	0.70
South Fork Arm nr McCabe Cove	SPB	5	226	130	0.23
South Fork Arm nr McCabe Cove	SPB	5	315	408	0.34
Lake Britton					
nr Highway 89 Bridge	SMB	5	347	782	0.29
nr Highway 89 Bridge	CHC	2	413	1034	0.11
Shasta Lake					
at Hirz Bay	SPB	5	263	236	0.24
at Hirz Bay	SPB	5	343	602	0.45
at Bridge Bay	SPB	4	242	163	0.11
at Bridge Bay	SPB	5	347	572	0.31
Sacramento River Arm	SPB	3	269	255	0.20
Sacramento River Arm	SPB	3	350	755	0.30
Pit River Arm	SPB	5	260	252	0.13
Pit River Arm	SPB	5	357	681	0.33

Appendix 1. Results of fish tissue analyses for mercury, continued

Collection Site	Species	Number of Fish in Composite	Average Total Length (mm)	Average Weight (gms)	Mercury (mg/Kg)
Shasta Lake, continured					
Pit River Arm	CHC	1	600	3440	0.457
Pit River Arm	CHC	1	655	4500	0.573
Pit River Arm	CHC	1	740	5017	0.659
Whiskeytown Lake					
Whiskey Creek Arm	LMB	4	271	305	0.09
Whiskey Creek Arm	LMB	5	418	1,467	0.22
Eagle Lake					
at Pine Creek egg taking station	RBT	5	433	992	0.04
at Pine Creek egg taking station	RBT	5	522	1,688	0.06
Mountain Meadows Reservoir					
nr Goodrich Creek	LMB	5	268	324	0.05
nr Goodrich Creek	LMB	4	318	588	0.06
nr Goodrich Creek	LMB	3	384	990	0.11
nr Goodrich Creek	BRB	5	341	859	0.07
Copco Lake					
nr Milk Creek	YP	5	145	44	0.18
nr Milk Creek	YP	5	170	66	0.18
nr Milk Creek	YP	3	192	109	0.18
Lake Shastina					
nr dam	LMB	4	260	340	0.14
nr dam	LMB	3	340	652	0.33
nr dam	LMB	3	387	1,275	0.47
Trinity Lake					
nr Trinity Center	WHC	6	384	1072	0.65
nr Trinity Center	SMB	6	355	864	0.45
nr Trinity Center	SMB	6	423	1586	1.02
Ruth Lake					
mid-lake	BG	6	209	250	0.24
mid-lake	RBT	2	422	977	0.20
East Park Reservoir					
nr Lodoga	CHC	5	316	408	0.18
nr Lodoga	CHC	1	608	4221	0.70
nr dam	LMB	3	285	415	0.26

Appendix 1. Results of fish tissue analyses for mercury, continued

Collection Site	Species	Number of Fish in Composite	Average Total Length (mm)	Average Weight (gms)	Mercury (mg/Kg)
Stony Gorge Reservoir					
south end	CHC	5	308	368	0.23
south end	CHC	1	419	1020	0.25
south end	CHC	1	497	2578	0.27
south end	LMB	3	300	444	0.227/0.448a
Blue Lakes					
Upper Blue Lake - west end	LMB	5	397	1224	0.36
Indian Valley Reservoir					
nr spillway	CHC	4	283	290	0.34
nr spillway	CHC	1	479	1303	0.19
nr spillway	LMB	3	250	236	0.32
nr spillway	LMB	4	326	510	0.67

a - duplicate analysis

Metric Conversion Table

Quantity	*To Convert from Metric Unit*	*To Customary Unit*	*Multiply Metric Unit By*	*To Convert to Metric Unit Multiply Customary Unit By*
Length	millimeters (mm)	inches (in)	0.03937	25.4
	centimeters (cm) for snow depth	inches (in)	0.3937	2.54
	meters (m)	feet (ft)	3.2808	0.3048
	kilometers (km)	miles (mi)	0.62139	1.6093
Area	square millimeters (mm^2)	square inches (in^2)	0.00155	645.16
	square meters (m^2)	square feet (ft^2)	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	square kilometers (km^2)	square miles (mi^2)	0.3861	2.590
Volume	liters (L)	gallons (gal)	0.26417	3.7854
	megaliters (ML)	million gallons (10*)	0.26417	3.7854
	cubic meters (m^3)	cubic feet (ft^3)	35.315	0.028317
	cubic meters (m^3)	cubic yards (yd^3)	1.308	0.76455
	cubic dekameters (dam^3)	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic meters per second (m^3/s)	cubic feet per second (ft^3/s)	35.315	0.028317
	liters per minute (L/mn)	gallons per minute (gal/mn)	0.26417	3.7854
	liters per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megaliters per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic dekameters per day (dam^3/day)	acre-feet per day (ac-ft/day)	0.8107	1.2335
Mass	kilograms (kg)	pounds (lbs)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb.)	1.1023	0.90718
Velocity	meters per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Power	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0.14505	6.8948
	kilopascals (kPa)	feet head of water	0.32456	2.989
Specific capacity	liters per minute per meter drawdown	gallons per minute per foot drawdown	0.08052	12.419
Concentration	milligrams per liter (mg/L)	parts per million (ppm)	1.0	1.0
Electrical conductivity	microsiemens per centimeter (µS/cm)	micromhos per centimeter (µmhos/cm)	1.0	1.0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1.8X°C)+32	0.56(°F-32)

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STATE OF CALIFORNIA