Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining:

The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999

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CONVERSION FACTORS, VERTICAL DATUM, ACRONYMS and ABBREVIATIONS, and CHEMICAL ELEMENTS

Conversion Factors

Multiply	By	To obtain
mg/kg (milogram per kilogram)	0.03200	ounce (avoirdupois) per ton
mL (milliliter)	0.0002642	gallon
mm (millimeter)	0.03937	inch
pound (lb)	0.4536	kilogram

Vertical Datum

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Acronyms, Abbreviations, and Chemical Notation

(additional information given in parentheses)

CRV, certified reference value
CVAAS, cold vapor atomic-absorption spectroscopy
CVAFS, cold vapor atomic-fluorescence spectrometry
FDA, Food and Drug Administration
FGS, Frontier Geosciences, Incorporated (Seattle, Washington)
MDL, method detection limit
NRCC, National Research Council of Canada
OEHHA, Office of Environmental Health Hazard Assessment
QA–QC, quality assurance–quality control
RPD, relative percent difference
SRM, standard reference material
SV, screening value
TERL, Trace Element Research Laboratory (College Station, Texas)
TSMP, Toxic Substances Monitoring Program
EPA, U.S. Environmental Protection Agency
USGS, U.S. Geological Survey

g, gram
lb, pound
mL, milliliter
mm, millimeter
ppm, part per million
sp., species (singular)
spp., species (plural)

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ABSTRACT

Mercury that was used historically for gold recovery in mining areas of the Sierra Nevada continues to enter local and downstream water bodies, including the Sacramento–San Joaquin Delta and the San Francisco Bay of northern California. Methylmercury is of particular concern because it is the most prevalent form of mercury in fish and is a potent neurotoxin that bioaccumulates at successive trophic levels within food webs. In April 1999, the U.S. Geological Survey, in cooperation with several other agencies—the Forest Service (U.S. Department of Agriculture), the Bureau of Land Management, the U.S. Environmental Protection Agency, the California State Water Resources Control Board, and the Nevada County Resource Conservation District—began a pilot investigation to characterize the occurrence and distribution of mercury in water, sediment, and biota in the South Yuba River, Deer Creek, and Bear River watersheds of California. Biological samples consisted of semi-aquatic and aquatic insects, amphibians, bird eggs, and fish.

Fish were collected from 5 reservoirs and 14 stream sites during August through October 1999 to assess the distribution of mercury in these watersheds. Fish that were collected from reservoirs included top trophic level predators (black basses, *Micropterus spp.*), intermediate trophic level predators [sunfish (blue gill, *Lepomis macrochirus*; green sunfish, *Lepomis cyanellus*; and black crappie, *Poxomis nigromaculatus*)], and benthic omnivores (channel catfish, *Ictularus punctatus*). At stream sites, the species collected were upper trophic level salmonids (brown trout, *Salmo trutta)* and upper-to-intermediate trophic level salmonids (rainbow trout, *Oncorhynchus mykiss)*.

Boneless and skinless fillet portions from 161 fish were analyzed for total mercury; 131 samples were individual fish, and the remaining 30 fish were combined into 10 composite samples of three fish each of the same species and size class. Mercury concentrations in samples of black basses (*Micropterus spp.)*, including largemouth, smallmouth, and spotted bass, ranged from 0.20 to 1.5 parts per million (ppm), wet basis. Mercury concentrations in sunfish ranged from less than 0.10 to 0.41 ppm (wet). Channel catfish had mercury concentrations from 0.16 to 0.75 ppm (wet). The range of mercury concentrations observed in rainbow trout was from 0.06 to 0.38 ppm (wet), and in brown trout was from 0.02 to 0.43 ppm (wet). Mercury concentrations in trout were greater than 0.3 ppm in samples from three of 14 stream sites. Mercury at elevated concentrations may pose a health risk to piscivorous wildlife and

to humans who eat fish on a regular basis. Data presented in this report may be useful to local, state, and federal agencies responsible for assessing the potential risks associated with elevated levels of mercury in fish in the South Yuba River, Deer Creek, and Bear River watersheds.

INTRODUCTION

Overview of Mercury Use in Historic Gold Mining

Mercury associated with historic gold mining has likely been contaminating water bodies of the Central Valley, the Sacramento–San Joaquin Delta, and the San Francisco Bay Estuary for the past 150 years. Liquid mercury (quicksilver) was used extensively to aid in the recovery of gold from placer and hard-rock ores (Alpers and Hunerlach, 2000). In California, mercury was mined and refined in the Coast Ranges and then transported to the Sierra Nevada and Klamath and Trinity mountains for use in gold extraction. Churchill (1999) estimated that 26 million lb of mercury were used for the processing of gold in the Sierra Nevada region, mostly during California's historic Gold Rush period (late 1840s to 1880s). A large portion of the mercury used in hydraulic mining of placer ores was lost to the environment; typically, 10 to 30 percent was lost per season of gold processing (Bowie, 1905). Moreover, it is common to find visible quantities of elemental mercury still present in many mining areas of the Sierra Nevada and Trinity Mountains (M.P. Hunerlach, U.S. Geological Survey, oral commun., 2000).

Study Background

Preliminary assessments of mercury bioaccumulation in the northwestern Sierra Nevada indicate that the South Yuba River, Deer Creek, and Bear River watersheds are among the areas most severely affected by hydraulic mining and mercury contamination. Investigations by Slotton and others (1997) of mercury concentrations primarily in stream macroinvertebrates and stream fish at 57 sites in five watersheds in the northwestern Sierra Nevada region indicate that most of the highest concentrations of mercury are in the South Yuba River, Deer Creek, and Bear River watersheds. More recent studies in these watersheds report elevated concentrations of mercury and methylmercury in streambed sediments and water samples (Domagalski, 1998; Hunerlach and others, 1999; U.S. Geological Survey, 2000). Additionally, these watersheds contain extensive federal lands with numerous historic gold mines (fig. 1). For this reason, the South Yuba River, Deer Creek, and Bear River watersheds were selected by the U.S. Geological Survey (USGS), the federal land management agencies (the Bureau of Land Management and the U.S. Department of Agriculture's Forest Service), and state and local agencies as high priority areas for detailed studies of the distribution of mercury contamination (Alpers and Hunerlach, 2000).

The primary objectives of the overall multiagency investigation of abandoned mine lands in the South Yuba, Deer Creek, and Bear River watersheds are to document the occurrence and distribution of mercury in these watersheds and to identify mercury "hot spots" on federal lands for potential remediation. In April 1999, a team of scientists from the USGS and the cooperating agencies began collecting water, sediment, and biological samples, either directly from historic mine sites or from water bodies proximal to the mine sites, as well as from downstream receiving waters. Although biological samples included predatory aquatic and semiaquatic insects, amphibians, bird eggs, and fish, only the data on total mercury concentrations in fish are presented in this report.

Human and Wildlife Health Concerns

Methylmercury (CH_3Hg^+) is a potent neurotoxin and is one of the most toxic forms of mercury. Human fetuses and young children, as well as wildlife, are most sensitive to methylmercury exposure (Davidson and others, 1998; Wolfe and others, 1998). Human exposure to methylmercury comes almost entirely from consumption of contaminated fish; methylmercury accounts for greater than 95 percent of the total mercury in fish tissue (Bloom, 1992). Because of the known ratio of methylmercury to total mercury in fish tissues, and the high costs associated with methylmercury analyses, the U.S. Environmental Protection Agency (EPA) recommends the analysis of total mercury concentration in fish for reconnaissance studies of water bodies potentially contaminated with mercury (U.S. Environmental Protection Agency, 1995).

Levels of mercury contamination in several water bodies in northern California, primarily in the Coast

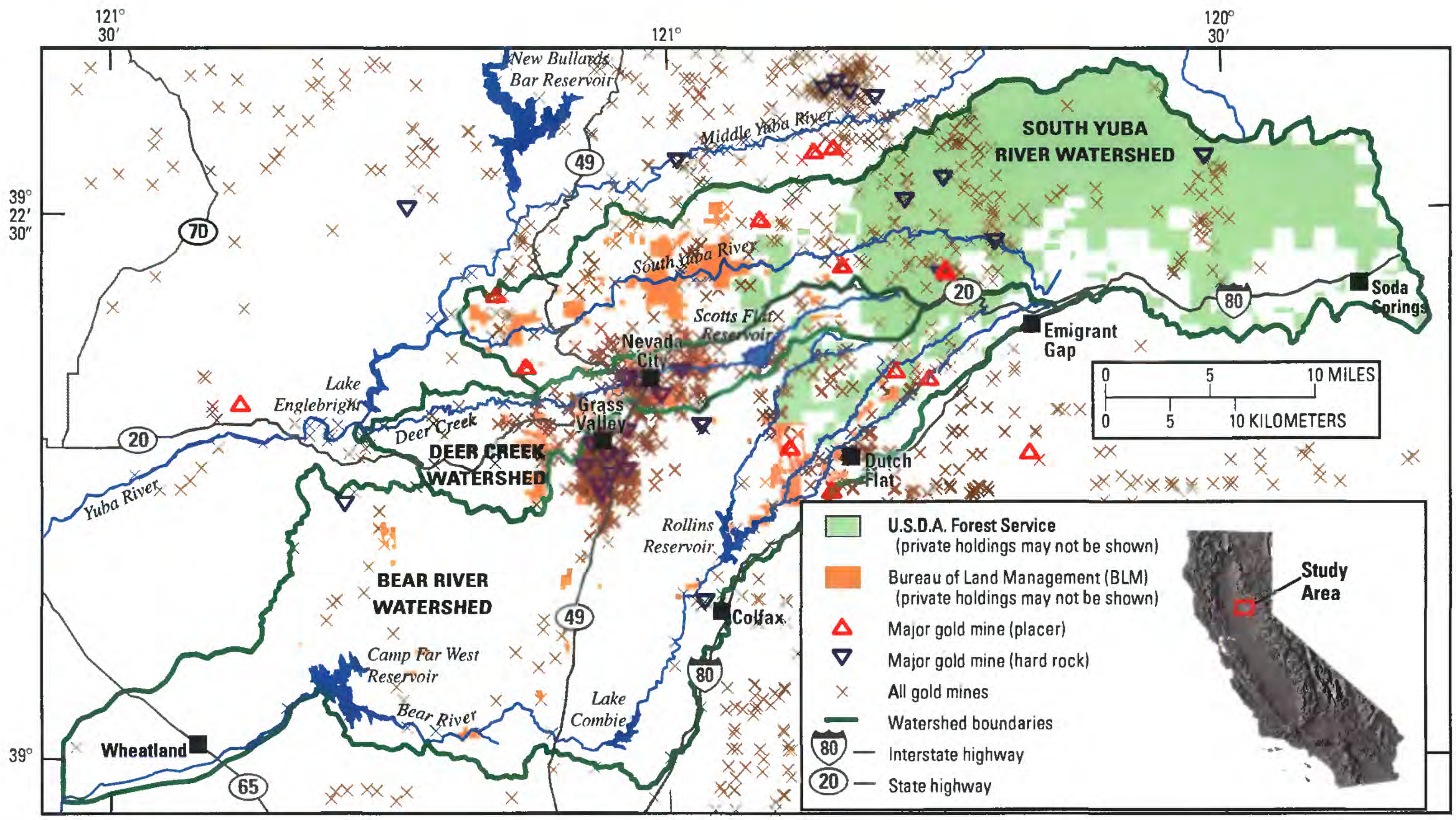

Figure 1. South Yuba River, Deer Creek, and Bear River watersheds, California, and locations of historic gold mines. Federal land ownership displayed only within the three watersheds. Locations for all known gold mines from Causey (1998); locations for major placer and hard-rock gold mines from Long and others (1998).

Ranges, the Sacramento–San Joaquin Delta, and the San Francisco Bay, are sufficiently high that public health advisories have been posted for fish consumption (Office of Environmental Health Hazard Assessment, 1999). In California, public health advisories for fish consumption are issued for individual water bodies by the Office of Environmental Health Hazard Assessment (OEHHA), which is part of the California Environmental Protection Agency. Guidance regarding consumption of mercury-contaminated fish is issued by several federal agencies, including the Food and Drug Administration (FDA), the Agency for Toxic Substances and Disease Registry, and the EPA. The FDA's action level for regulating mercury concentrations in commercial fish is 1.0 mg/kg, wet basis, which is equivalent to 1.0 part per million (ppm) (Foulke, 1994). Both EPA and OEHHA have health risk-assessment procedures with associated screening values (SV) for mercury concentrations in fish. An SV is defined as a contaminant concentration associated with the frequent consumption of contaminated fish that may be of human health concern. SVs are not intended to represent levels at which fish consumption advisories should be issued, but rather are levels at which recommendations may be made for more intensive sampling, analysis, or health evaluation efforts. OEHHA uses an SV of 300 parts per billion or 0.30 ppm for mercury concentrations in fish tissue (Brodberg and Pollock, 1999).

Critical levels of mercury concentrations in fish for wildlife health are somewhat uncertain, because of differences in the sensitivity of specific species. To date, no official mercury SVs are established for the health of piscivorous wildlife. However, mercury concentrations in fish of 0.30 ppm, and lower, have been commonly associated with adverse wildlife health effects (U.S. Environmental Protection Agency, 1997; Wolfe and others, 1998).

Purpose and Scope

The goals of this project are to investigate and identify "hot spots" for mercury contamination and to evaluate bioaccumulation pathways for mercury in the South Yuba River, Deer Creek, and Bear River watersheds, California. This report describes the data from a reconnaissance survey of mercury concentrations in edible fish tissues, from selected species in these watersheds. Predatory sport fish were targeted for collection from reservoirs and streams. In most reservoirs, largemouth bass (*Micropterus salmoides*) was the primary target species. Additional sport fish collected from reservoirs included smallmouth bass (*Micropterus dolomieu*), spotted bass (*Micropterus punctulatus*), channel catfish (*Ictalurus punctatus*), bluegill (*Lepomis macrochirus*), green sunfish (*Lepomis cyanellus*), and black crappie (*Poxomis nigromaculatus*). A small number of brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) were taken from some reservoirs; at stream sites, brown trout and rainbow trout were the only species collected.

The collection of a variety of species provides a qualitative insight into processes of mercury bioaccumulation at different trophic positions within a given fish community. The three black bass species (*Micropterus spp.*) collected in this study are top level predators, but in slightly distinct ecological niches, with diets that include other fish, amphibians, and invertebrates (Moyle, 1976). The bluegill, green sunfish, and black crappie are intermediate predators feeding on invertebrates and small fish. Channel catfish is the only benthic omnivore that was collected in this study. Although both rainbow and brown trout are mostly insectivores in early life stages, brown trout show a greater tendency for piscivory as they mature (Moyle, 1976). Therefore, brown trout are expected to bioaccumulate higher levels of mercury than rainbow trout.

Published data for mercury concentrations in fish tissues for the study area report the presence of elevated levels of mercury in fish from some water bodies of the South Yuba River, Deer Creek, and Bear River watersheds (Slotton and others, 1997; State Water Resources Control Board, accessed July 3, 2000). The available data for Lake Englebright in the South Yuba watershed are taken from nine fish samples representing five different species (Slotton and others, 1997). For Rollins Reservoir in the Bear River watershed, available mercury data from the State of California's Toxic Substance Monitoring Program (TSMP) database consist of four fish samples of three different species, and for Camp Far West Reservoir, also in the Bear River watershed, there are existing data for two samples of largemouth bass (State Water Resources Control Board, accessed July 3, 2000). In addition, Hunerlach and others (1999) reported mercury concentrations for five samples of rainbow trout from the Dutch Flat Afterbay in the Bear River watershed. No data on mercury concentrations in fish had previously been available for Scotts Flat Reservoir in the Deer

Creek watershed or Lake Combie in the Bear River watershed.

Boneless and skinless fillet portions from 161 fish were analyzed for total mercury; 131 samples were individual fish, and the remaining 10 samples were composites of three fish, each of the same species and size class. Total mercury concentrations are presented in this report for 141 samples, both on a dry and wet basis; tissue moisture, the sizes (total length and total mass) of individual fish sampled, and average fish size data for composite samples also are reported. The data included in this report may be helpful to local, state, and federal agencies that are responsible for assessing the potential risks from mercury bioaccumulation to public health and ecosystem integrity in these watersheds.

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STUDY DESIGN AND METHODS

Sample Collection and Processing

During August through October 1999, the USGS collected fish from 5 reservoirs and 14 stream locations in the watersheds of the South Yuba River, Deer Creek, and the Bear River. Fish were collected from Lake Englebright, Scotts Flat Reservoir, Rollins Reservoir, Lake Combie, and Camp Far West Reservoir (fig. 2). The stream sampling sites (fig. 2, table 1) included areas near the reservoirs, historic mine sites, and two "reference" sites upstream of known historic gold-mining activity. Complete site names are given in the Appendix and abbreviated versions are given in table 1.

Most fish were collected from reservoirs and streams using electrofishing equipment; two fish were collected by hook and line, and one fish by dip-netting. Rainbow trout stocked for fishing purposes were not collected during this study; stocked rainbow trout were differentiated from native trout by the presence of fused and bent fin rays. Fish were held in clean buckets or tubs with ambient water until they were weighed, to the nearest gram, and measured for standard and total length, in millimeters. The standard length is the distance from the upper lip to the posterior end of the vertebral column, excluding the caudal fin rays. After recording the length and weight, spines were removed from the channel catfish for age determination (to be published separately). Each fish was then wrapped in clean, heavy-duty aluminum foil, labeled, and placed in a plastic bag on wet ice for less than 8 hours. They were then taken to the laboratory where they were stored frozen until processing.

The processing of fish followed standard procedures (U.S. Environmental Protection Agency, 1995). Fish were handled with powder-free vinyl gloves, and dissections were performed on a new sheet of heavy-duty aluminum foil for each fish. High-quality stainless steel instruments and disposable scalpel blades were used in the processing of fish samples, and instruments were cleaned thoroughly between samples. Cleaning of the instruments involved washing with polished water (deionized water, further refined with an additional step to remove organic compounds) and laboratory detergent, acid washing, and finally

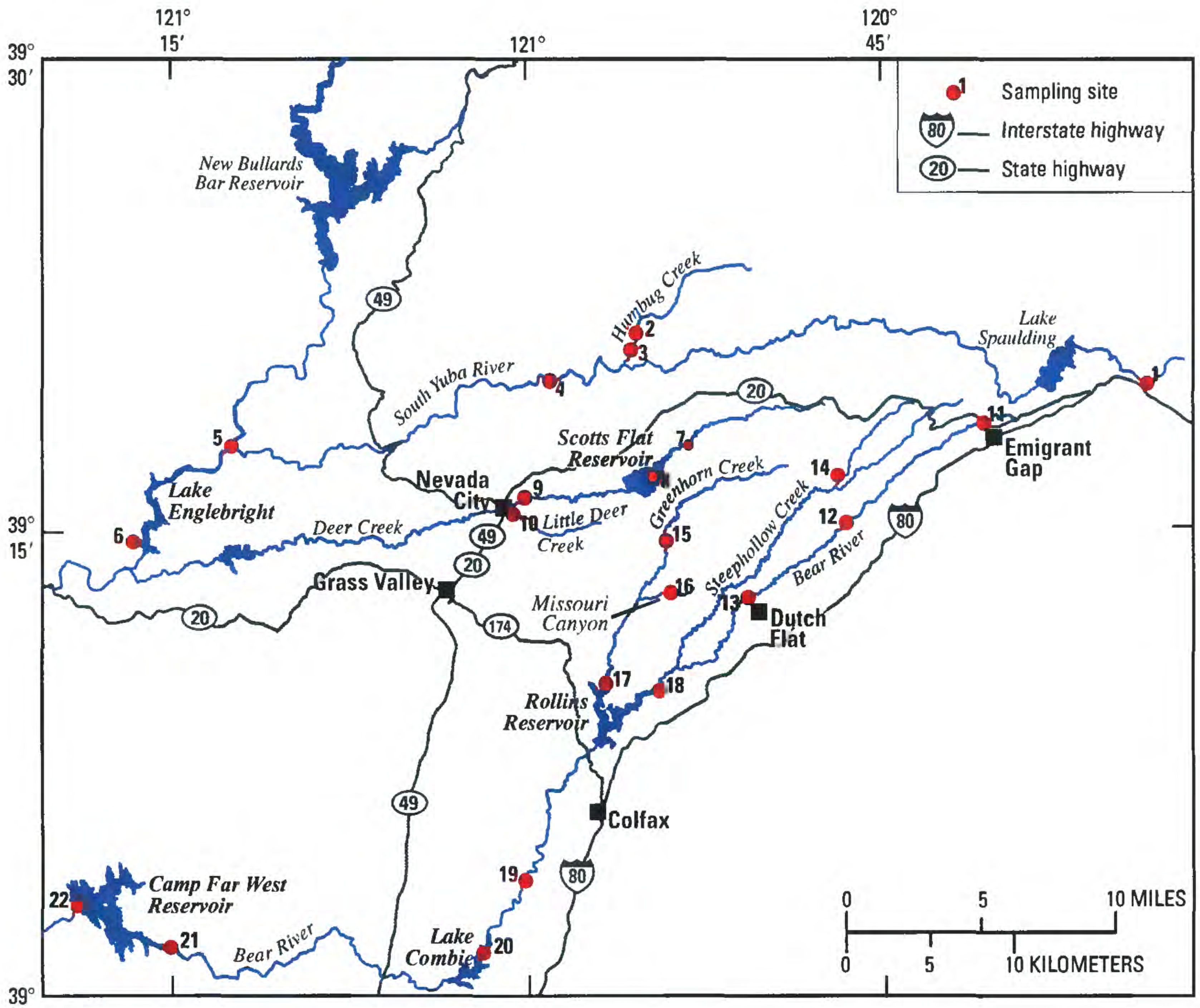

Figure 2. Fish sampling sites in the South Yuba River, Deer Creek, and Bear River watersheds, California, 1999.

rinsing the instruments with polished water before and after dissections of each fish specimen. Fish were thawed and scaled, or the skin was removed (on scaleless fish such as channel catfish) before dissection. Scales were removed for age determination (to be published separately). Boneless and skinless fillet portions were dissected from the upper medial-axial region of the fish in an approximately rectangular shape. Excised tissues were placed directly into labeled, chemically cleaned borosilicate glass jars on a pretared balance, the sample weight was recorded, and Teflon-lined lids were then screwed atop jars and sealed with Parafilm. Fish tissue samples were stored frozen in sealed sample jars until they were packed in coolers with dry ice and shipped to the analytical laboratory.

Muscle tissues were removed from both the left and right fillet of each fish processed during this study. Tissues dissected from the left fillet were labeled either with sample numbers beginning with "F" for individual samples or with "C" for composite samples. Composite samples were used for initial screening of mercury concentrations. The composite samples consisted of similarly sized tissue portions (within a tenth of a gram in most cases) from three fish of the same species that were within the same size class (that is, the smallest fish in the composite was at least 75 percent of the total weight and total length of the largest fish in the composite). Tissues removed from the right fillet were labeled with sample numbers beginning with "R." These samples served as archive samples that, in some cases, were later analyzed. Also, unless otherwise noted, "R" sample numbers that are listed in tables in this report indicate that a sample was initially analyzed as part of a composite and then later analyzed as an individual (from the archive tissue). In this situation, only the mercury concentrations for the individual samples are presented in this report.

Because multiple species of various sizes were collected in this study, there was a range in tissue sample weights collected. The ranges of sample weights submitted for analysis of each species were black crappie, 3 g; bluegill, 2–5 g; green sunfish, 3–5 g; rainbow trout, 2–10 g; brown trout, 5–15 g; smallmouth bass, 10 g; largemouth bass, 10–20 g; spotted bass, 10–20 g; and channel catfish 25–137 g. The actual sample weight excised from each fish fillet sample (or the average weight for composite samples) is listed in the data table for each sampling area, presented later in the report.

Fish samples were submitted to two analytical laboratories for total mercury analyses. The primary laboratory was the Trace Element Research Laboratory (TERL) at Texas A&M University in College Station, Texas. The U.S. Fish and Wildlife Service, through its Patuxent Analytical Control Facility in Patuxent, Maryland, has certified this laboratory for the analysis of trace elements in biological tissues. A second laboratory, Frontier Geosciences, Incorporated (FGS) in Seattle, Washington, was used for interlaboratory comparisons. The EPA, through their contractor Ecology & Environment, funded one group of analyses by FGS for this study; another group of analyses by FGS was contracted directly by the USGS.

Statistical Methods

Nonparametric statistical methods were used in this study because the data sets available for each collection area were relatively small, and a large portion of the data were not normally distributed. Nonparametric statistics, in general, are not sensitive to small sample sizes or to the potential bias of outlying values or nonnormally distributed data (Helsel and Hirsch, 1992). Geometric means were calculated for mercury concentrations because the geometric mean is less sensitive to nonnormally distributed data. The Wilcoxon paired-sample test was used to evaluate whether there were significant differences between the split sample values from the two independent laboratories. Spearman's rank correlation (Lehmann, 1975) was used to evaluate the correlations between mercury concentration and fish size (total length and total mass) within specific reservoirs. Statistical analyses were performed on mercury concentrations both on a wet and dry basis.

Laboratory Methods

Samples were packed in coolers on dry ice and shipped to the designated laboratories, with chain of custody documentation. All sample materials were received in good condition and recorded according to standard protocols by the receiving laboratories.

Trace Element Research Laboratory

Mercury concentrations were determined at TERL by cold-vapor atomic absorption spectroscopy (CVAAS) using EPA methods 245.5 and 245.6 (U.S.

Environmental Protection Agency, 1991). Prior to analysis by CVAAS, whole tissue samples were homogenized with a tissumizer in the original sample containers. After freeze-drying, samples were digested with nitric acid, sulfuric acid, potassium permanganate, and potassium persulfate in polypropylene tubes in a water bath at 90–95°C. Before analysis, hydroxylamine hydrochloride was added to reduce excess permanganate, and the samples were brought to volume with distilled, deionized water.

Tissue moisture content was determined by the weight loss upon freeze-drying and is expressed as weight percent of the original wet sample. Depending on sample size, either the whole sample or a representative aliquot was frozen, then dried under vacuum until a constant weight was attained. Sample size prior to freeze-drying was typically 5 g. Samples were prepared and dried using plastic materials to minimize potential contamination artifacts that might affect subsequent mercury analysis.

Frontier Geosciences Laboratory

Mercury analyses at FGS were performed using cold vapor atomic-fluorescence spectroscopy (CVAFS) using a modification of EPA method 1631 (U.S. Environmental Protection Agency, 1991). Prior to analysis by CVAFS, whole tissue samples were homogenized; for larger fish tissue samples, a food processor was used. For smaller fish tissue samples, homogenization was performed by chopping the fillet with a clean razor blade. Before and after homogenization, blanks were collected to confirm the absence of contamination. After homogenization, a subsample consisting of approximately 0.5 g of wet tissue was digested in a 40-mL borosilicate glass vial. Digestion was accomplished using a hot mixture of 70 percent nitric acid and 30 percent sulfuric acid for a period of approximately 2 hours, after which samples were diluted up to a final volume of 40 mL with a solution of 10 percent bromine chloride. Aliquots of each digestate were analyzed by tin-chloride reduction and dual gold-amalgamation CVAFS.

Quality Assurance and Quality Control

Both laboratories (TERL and FGS) performed internal quality assurance–quality control (QA–QC) measures. In addition, interlaboratory comparisons were made for numerous fish samples. Both laboratories conducted duplicate, blank, standard reference material (SRM), and spike recovery analyses.

Trace Element Research Laboratory

The analyses performed at TERL on samples from individual fish for this study were done in groups of 23, 42, and 66, for a total of 131. In addition, composite analyses were done with the first two groups of samples. Considering all three groups of analyses, 10 of each type of the QA–QC analyses were performed on duplicates, blanks, SRMs, and spike recoveries.

The variability of duplicate analyses was compared using the following formula for relative percent difference (RPD):

$$RPD = 100 \times \{(m_1 - m_2)/[(m_1 + m_2)/2]\} \quad (1)$$

where m_1 and m_2 are the two measurements being compared. The 10 duplicates had RPD values ranging from 0.27 to 15 percent, with 8 of the 10 values being less than 6 percent.

Procedural blanks were analyzed to assure that no analyte was added during the processing of the samples. All blanks analyzed by TERL were within an acceptable range.

The SRM used by TERL was dogfish (*Squalus sp.*) muscle, certified by the National Research Council of Canada (NRCC) as DORM-2, which has a certified reference value (CRV) of 4.64 ppm mercury (dry basis). Analyses of the SRM by TERL ranged from 4.17 to 4.88 ppm with an average value of 4.59 ppm mercury (dry basis), about 99 percent of the CRV.

Spike recoveries were done by adding mercury in the amount of about 4.00 to 5.40 ppm (dry basis) to samples in each group of analyses. The spike recoveries for ten such analyses ranged from 90.2 to 110 percent, all within acceptable limits.

Frontier Geosciences Laboratory

The analyses at the FGS laboratory were done in two groups, consisting of 31 and 11 individual fish samples. For each group, method blanks were analyzed to estimate the method detection limit (MDL). For the group of 31 samples, six method blanks were analyzed, from which an estimated MDL of 0.00051 ppm (wet basis) was determined. For the group of 11 samples, three method blanks were used to obtain an estimated MDL of 0.00025 ppm (wet basis).

A total of three replicate analyses of total mercury in fish tissue were done for the two groups of samples. The RPD values for these replicates ranged from 3.1 to 19.3 percent. Two analytical replicates also were done by FGS on moisture content analyses, giving RPD values of 0.5 and 1.4 percent. Additionally, three blind replicate samples were submitted to FGS as part of the first group of 31 analyses. The RPD values for the blind replicates ranged from 0 to 22 percent.

The SRM used by FGS was the same dogfish muscle standard (NRCC DORM-2) used by TERL, with a CRV of 4.64 ppm (dry basis). Three analyses by FGS ranged from 4.07 to 4.62 ppm (dry basis), with an average value of 4.31 ppm (dry basis), which is 92.8 percent of the CRV. The relatively low value for the SRM suggests that FGS results might have been biased toward the low side. Concerns regarding this possible bias, however, were mitigated on the basis of results of the interlaboratory comparisons, described later in this section.

FGS conducted spike recoveries on a total of six samples in the two groups of analyses. The spike levels ranged from 1.08 to 1.89 ppm (wet basis). The final reported recovery rates ranged from 98.3 to 111 percent. The initial analysis of one spiked sample gave a recovery of 128 percent, which exceeded the QC acceptance limit of FGS (125 percent). However, this sample was redone, and the rerun gave a spike recovery of 108 percent, which was within the acceptable range.

Interlaboratory Comparisons for Quality Control

Interlaboratory comparisons between TERL and FGS were performed on a total of 34 fish tissue samples (table 2). In some of the interlaboratory comparisons, one laboratory analyzed fish muscle tissue from the left fillet and the other laboratory analyzed tissue from the right fillet. Other comparisons were made in which both laboratories analyzed subsamples of tissue from the right fillet.

The Wilcoxon sign-rank test, used to compare mercury concentrations (wet basis) reported from the two laboratories, indicated no significant difference ($p = 0.34$, alpha = 0.001) in values reported between TERL and FGS. Statistical analysis also was performed on the dry basis analyses. There was no difference in the outcome of the statistical analysis, so the comparisons are reported on a wet basis only. In addition, RPD values were calculated as a second quality-control check on interlaboratory comparisons. RPD values of less than 30 percent were considered acceptable for these comparisons. Most interlaboratory comparisons yielded acceptable results; only 8 of 34 of the comparisons have RPD values greater than ±30 percent and 6 of 34 comparisons have RPD values greater than 20 percent (table 2). The arithmetic mean of RPD absolute values for the 34 comparisons is 15 percent, and the median absolute value is 11.6 percent. A correlation plot of the interlaboratory comparison data (fig. 3) indicates that there is no apparent bias toward higher mercury concentrations from one laboratory in relation to the other.

Results of both the individual laboratory QA–QC efforts and the interlaboratory comparisons (fig. 3, table 2) indicate that a high level of confidence is warranted in the accuracy of the data reported in this study for total mercury concentrations in fish tissue.

MERCURY CONCENTRATIONS IN FISH

Samples of 161 fish from 5 reservoirs and 14 stream sites in the South Yuba River, Deer Creek, and Bear River watersheds (fig. 2) were analyzed for total mercury in boneless and skinless upper-medial-axial muscle tissue. Analyses on 141 samples were done, with 131 as individual samples, and 10 as composite samples of three fish each. All results for total mercury concentrations in fish tissue are reported from the primary analytical laboratory, TERL, in parts per

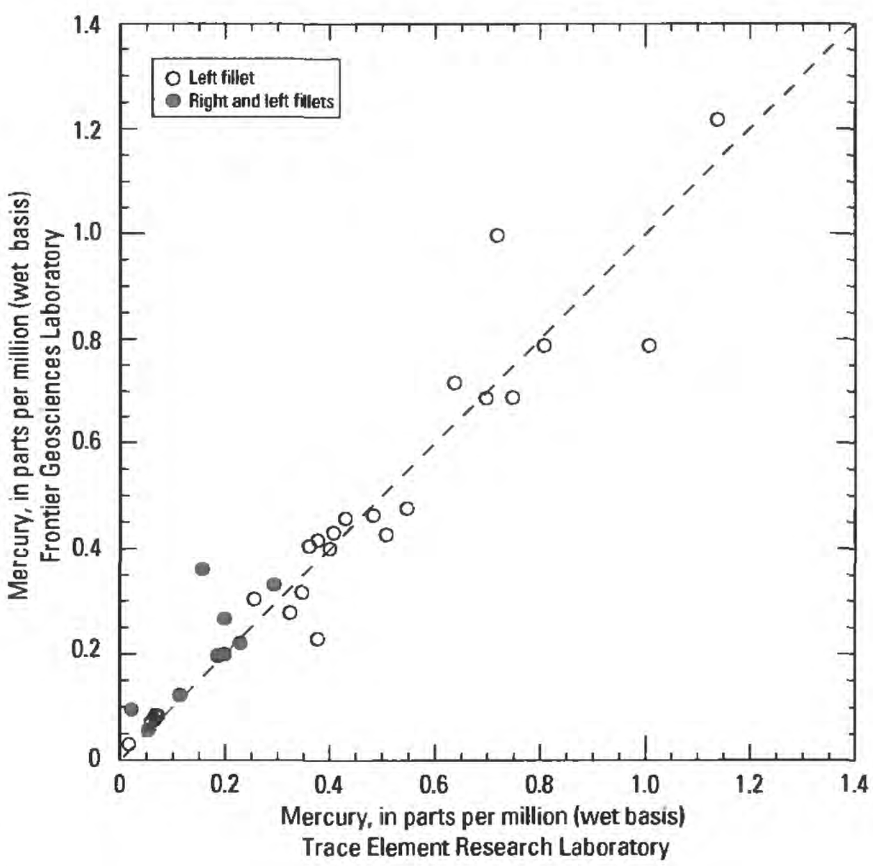

Figure 3. Correlation plot of interlaboratory comparisons for mercury concentrations in fish tissue. Orange circles represent comparison of right and left fillets, whereas white circles indicate analysis of right fillets. Dashed line represents theoretical line of perfect agreement. See table 2 for data.

million (ppm), wet basis, with two significant figures, unless noted otherwise.

Reservoirs

Lake Englebright

Twenty-one fish were collected for this study from Lake Englebright (table 3). Most samples (14) were collected from the South Yuba River arm of the reservoir near the Point Defiance campground (site 5, fig. 2), and the others were taken from the vicinity of Hogsback Ravine, a cove in the lower part of the lake near Englebright Dam (site 6, fig. 2). There were not enough data to test for differences of specific within-lake locations. Fourteen smallmouth bass were collected, including twelve from the South Yuba River arm. The smallmouth bass show a trend of increasing mercury concentration with increasing length and mass (fig. 4). Spearman's rank correlations for the 14 smallmouth bass samples (table 3) indicate significant (alpha = 0.05) relations between mercury concentration and total length ($p < 0.001$, rho = 0.88) and between mercury concentration and total mass ($p < 0.001$, rho = 0.94). Mercury concentrations in all 14 smallmouth bass, as well as the 3 spotted bass from Lake Englebright, were higher than OEHHA's screening value (SV) of 0.30 ppm. The geometric mean mercury concentration for the 14 smallmouth bass samples is 0.63 ppm. Mercury concentrations in the two largemouth bass collected for this study from Lake Englebright, however, were less than 0.30 ppm (fig. 4).

Slotton and others (1997) reported a smallmouth bass from Lake Englebright with a mercury concentration of 0.53 ppm, which fits the trend established by data from this study (fig. 4). The largemouth bass reported by Slotton and others (1997) had a mercury concentration of 0.64 ppm (fig. 4). Mercury concentrations reported by Slotton and others (1997) for species not sampled in the current study include 0.47 ppm in one sample of hardhead (*Mylopharodon conocephalus*), 0.88 ppm in one sample of common carp (*Cyprinus carpio*), and from 0.41 to 0.89 ppm in five samples of Sacramento sucker (*Catostomus occidentalis*).

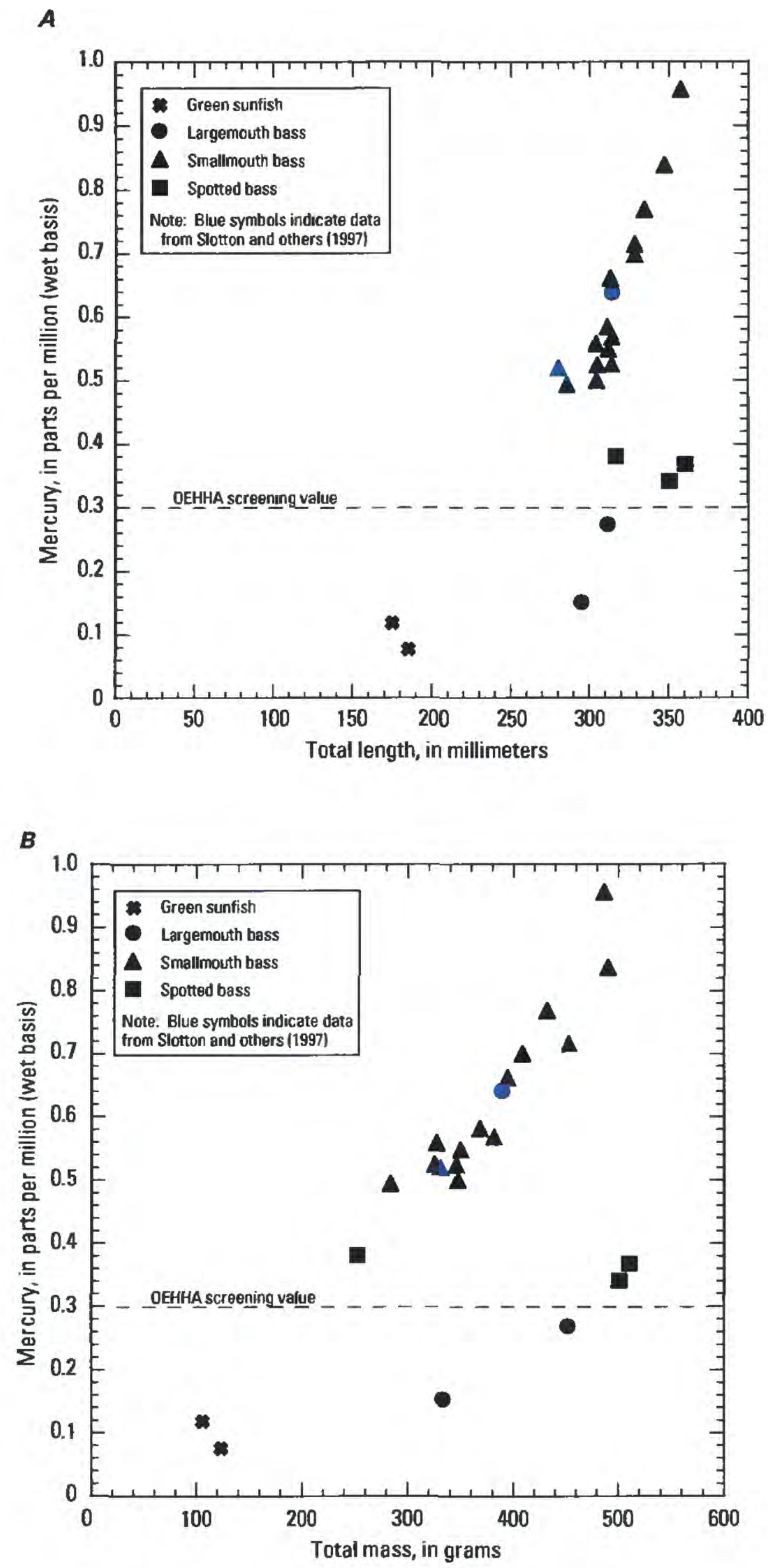

Figure 4. Mercury concentration for fish collected from Lake Englebright, California, 1999. *A*, In relation to total length. *B*, In relation to total mass. Dashed horizontal line at mercury concentration of 0.3 ppm represents a screening value provided by the Office of Environmental Health Hazard Assessment (Brodberg and Pollock, 1999. Blue symbols indicate data from Slotton and others (1997).

Scotts Flat Reservoir

Twelve fish analyses were determined for Scotts Flat Reservoir (site 8, fig. 2; table 4). Although none of these samples had mercury concentrations greater than 0.50 ppm, six of the seven largemouth bass had concentrations greater than 0.30 ppm. The geometric mean concentration for the seven largemouth bass samples is 0.36 ppm. There is no observable relation between mercury concentration and length or mass of these fish (fig. 5). In addition, Spearman's rank correlation of the seven largemouth bass samples indicate nonsignificant (alpha = 0.05) relations between mercury concentration and total length (p = 0.67, rho = –0.20) and mercury concentration and total mass (p = 1.00, rho = 0.00). Mercury concentrations in bluegill (two individual samples), green sunfish (one composite sample), and brown trout (two individual samples) from Scotts Flat Reservoir were all less than 0.20 ppm.

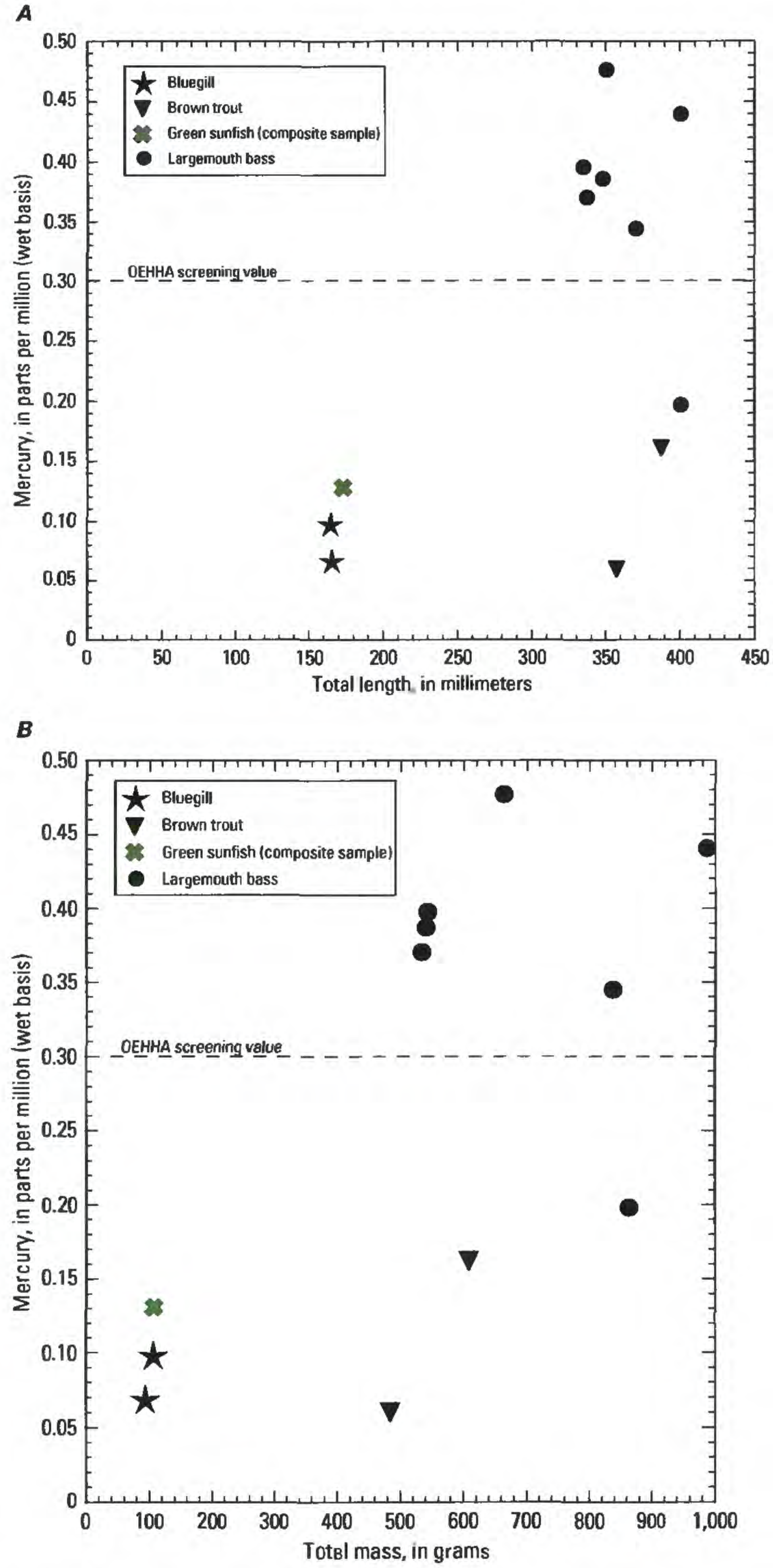

Figure 5. Mercury concentration for fish collected from Scotts Flat Reservoir, California, 1999. *A*, In relation to total length. *B*, In relation to total mass. Dashed horizontal line at mercury concentration of 0.3 ppm represents a screening value provided by the Office of Environmental Health Hazard Assessment (Brodberg and Pollock, 1999. Green symbol indicates composite sample from this study.

Rollins Reservoir

Twenty-eight fish analyses are reported for Rollins Reservoir; 18 samples were collected from the Bear River arm and 10 from the Greenhorn Creek arm (sites 18 and 17 respectively, fig. 2; table 5). There are not enough data to test for within-lake differences between these sampling sites. Fifteen of the 28 samples from Rollins Reservoir contained mercury concentrations greater than 0.30 ppm. Of the Rollins Reservoir samples analyzed for this study, channel catfish had the highest concentrations of mercury; the geometric mean for 13 catfish samples is 0.35 ppm. No clear relation is evident between fish length or mass and mercury concentration in the channel catfish (fig. 6). Spearman's rank correlations indicate nonsignificant (alpha = 0.05) relations between mercury concentration and total length (p = 0.94, rho = – 0.02) and between mercury concentration and total mass (p = 0.80, rho = 0.07). In contrast, the seven largemouth bass collected from Rollins Reservoir show a trend of increasing mercury concentration with increasing length and mass (fig. 6). Spearman's rank correlations of these seven bass samples indicate a significant (alpha = 0.05) relation between mercury concentration and total length (p = 0.04, rho = 0.79) and between mercury concentration and total mass (p = 0.01, rho = 0.86). Mercury concentrations in the seven largemouth bass samples ranged from 0.20 to 0.45 ppm with a geometric mean concentration of 0.33 ppm. Seven bluegill samples were analyzed as two composite samples of three fish each, plus one individual sample. The two composite samples of bluegill had mercury concentrations of 0.16 and 0.21 ppm, whereas the individual sample had an anomalously high concentration of 0.41 ppm. A composite sample of three black crappie had a mercury concentration of 0.31 ppm, and four individual brown trout samples had mercury concentrations less than 0.10 ppm.

Mercury data for four fish from Rollins Reservoir are reported in the California Toxic Substances Monitoring Program (TSMP) database (State Water Resources Control Board, accessed July 3, 2000). A largemouth bass collected in 1985, somewhat larger in size than the bass collected in this study from Rollins Reservoir, had 0.56 ppm mercury; this concentration is higher than all of the fish analyses for Rollins Reservoir from the current study, including bass and

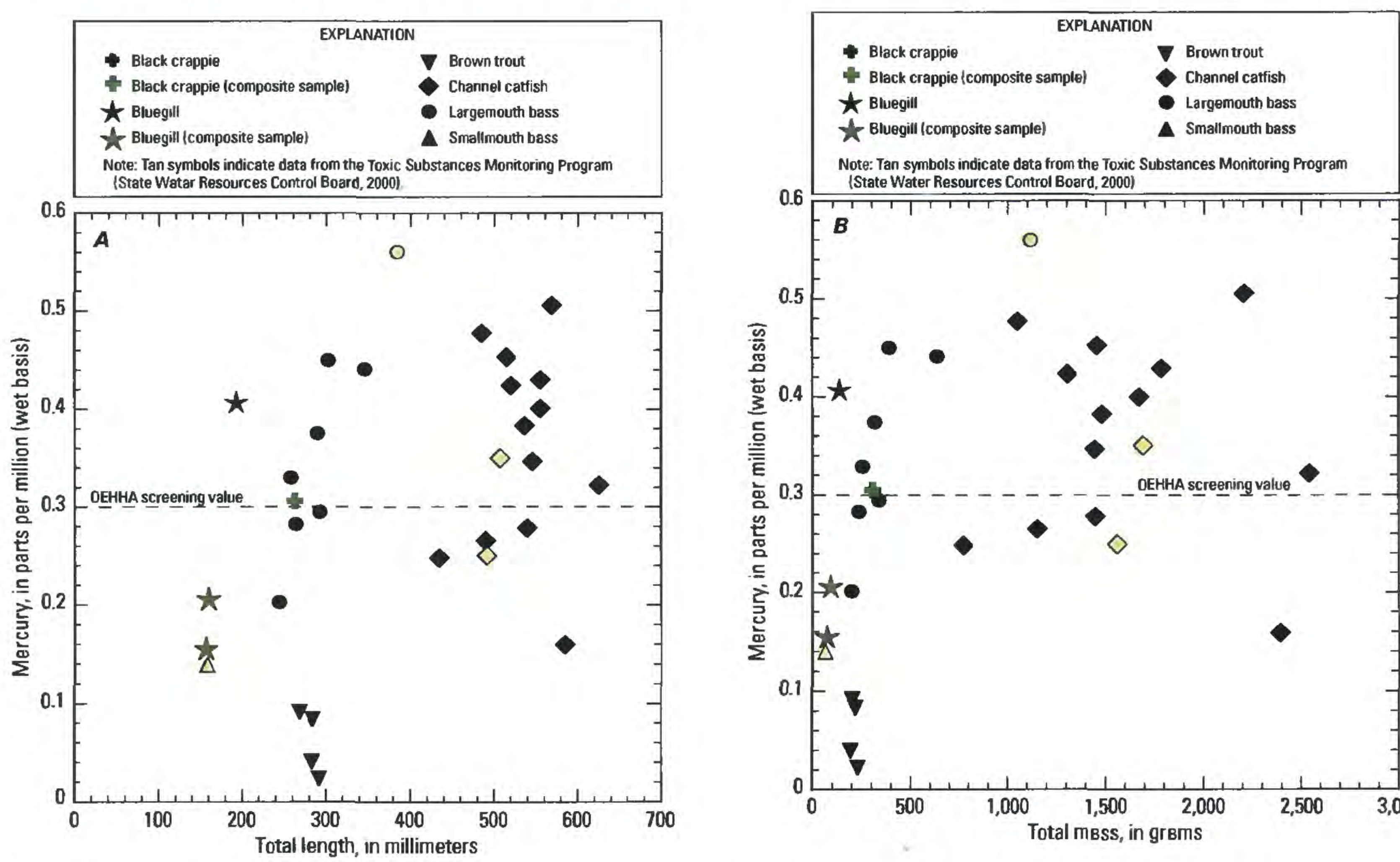

Figure 6. Mercury concentration for fish collected from Rollins Reservoir, California, 1999. *A*, In relation to total length. *B*, In relation to total mass. Dashed horizontal line at mercury concentration of 0.3 ppm represents a screening value provided by the Office of Environmental Health Hazard Assessment (Brodberg and Pollock, 1999). Tan symbols indicate data from the State of California's Toxic Substances Monitoring Program (State Water Resources Control Board, 2000); green symbols indicate composite samples from this study.

catfish. The TSMP database also includes a small-mouth bass from Rollins Reservoir, with a mercury concentration of 0.14 ppm. Two channel catfish samples reported in the TSMP database, collected during 1984 and 1985, had concentrations of 0.25 and 0.35 ppm, both within the range of the concentrations in catfish samples analyzed for this study (fig. 6, table 5).

Lake Combie

Thirteen fish were collected from Lake Combie, all from the northeastern part of the lake (site 20, fig. 2; table 6). The total mercury concentrations in largemouth bass (nine individual samples) range from 0.74 to 1.2 ppm. Five of the nine largemouth bass samples had mercury concentrations greater than 0.90 ppm; the geometric mean mercury concentration for the nine largemouth bass samples is 0.90 ppm. There is no significant trend for increasing mercury concentrations associated with length or mass in largemouth bass from Lake Combie (fig. 7). Spearman's rank correlations of the nine largemouth bass samples indicate nonsignificant (alpha = 0.05) relations between mercury concentration and total length (p = 0.73, rho = 0.13) and between mercury concentration and total mass (p = 0.46, rho = 0.28). Two individual rainbow trout samples and two individual bluegill samples from Lake Combie had mercury concentrations less than or equal to 0.20 ppm.

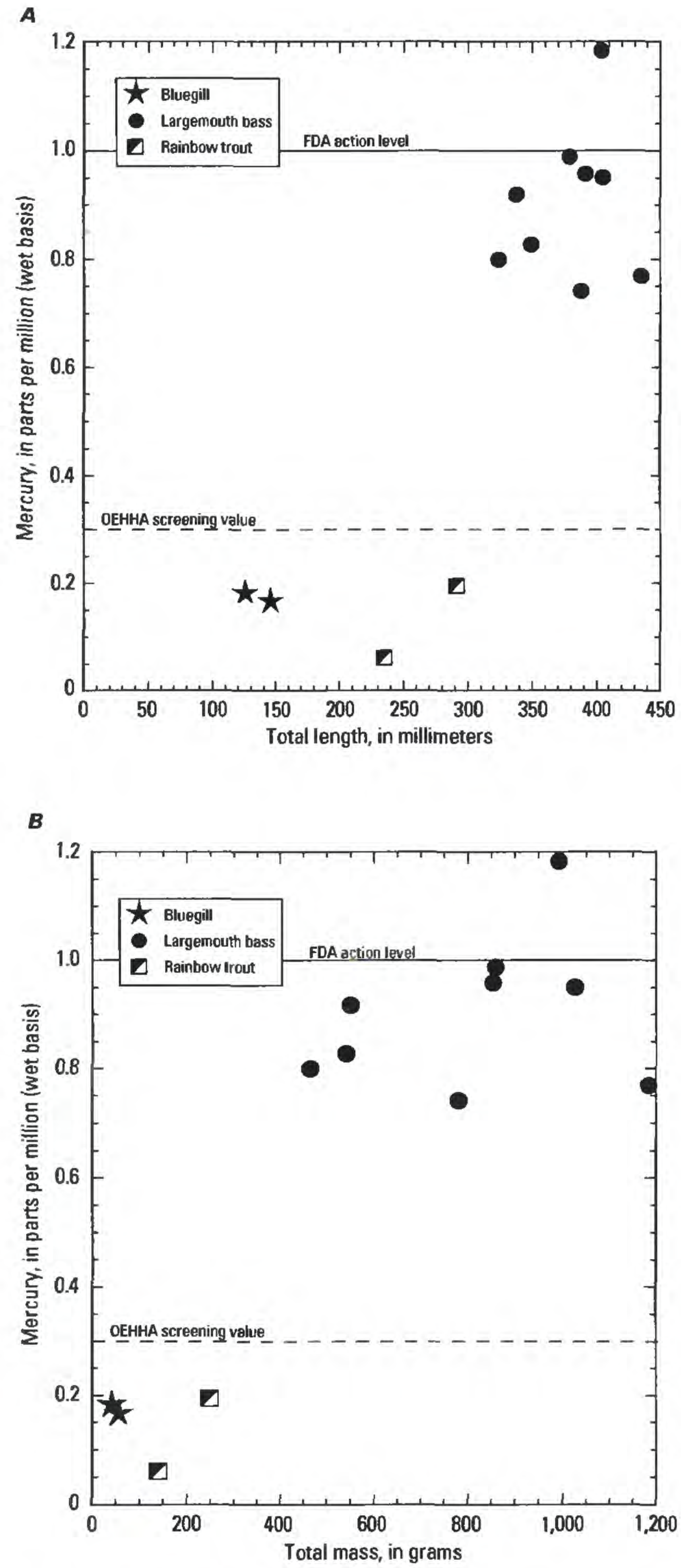

Figure 7. Mercury concentration for fish collected from Lake Combie, California, 1999. *A*, In relation to total length. *B*, In relation to total mass. Dashed horizontal line at mercury concentration of 0.3 ppm represents a screening value provided by the Office of Environmental Health Hazard Assessment (Brodberg and Pollock, 1999). Solid horizontal line at mercury concentration of 1.0 ppm indicates the Food and Drug Administration (FDA) action level for commercial fish.

Camp Far West Reservoir

Twenty-one fish analyses are reported from Camp Far West Reservoir; 14 samples were taken from the Bear River arm of the reservoir, and the remaining samples from near the dam (sites 21 and 22 respectively, fig. 2; table 7). There are not enough data to test for within-lake differences. Nineteen of the 21 samples collected from Camp Far West Reservoir had mercury concentrations greater than 0.30 ppm. Mercury concentrations for the 14 spotted bass samples range from 0.58 to 1.5 ppm, and the geometric mean concentration was calculated as 0.92 ppm; 7 of the 14 spotted bass had mercury concentrations greater than or equal to 1.0 ppm. The 14 spotted bass samples from Camp Far West Reservoir show weak, apparent positive relations for mercury concentration in relation to length and mass (fig. 8); however, Spearman's rank correlations for these samples indicate nonsignificant (alpha = 0.05) relations between mercury concentration and total length (p = 0.09, rho = 0.46) and between mercury concentration and total mass (p = 0.17, rho = 0.39). In addition, the three channel catfish collected from Camp Far West Reservoir had mercury concentrations between 0.51 and 0.75 ppm.

Data on two largemouth bass samples, one collected in 1987 and the other in 1990, are reported in the TSMP database (State Water Resources Control Board, accessed July 3, 2000). These samples had mercury concentrations of 0.40 and 0.65 ppm, respectively, and they were generally smaller than the largemouth and spotted bass samples collected for this study (fig. 8).

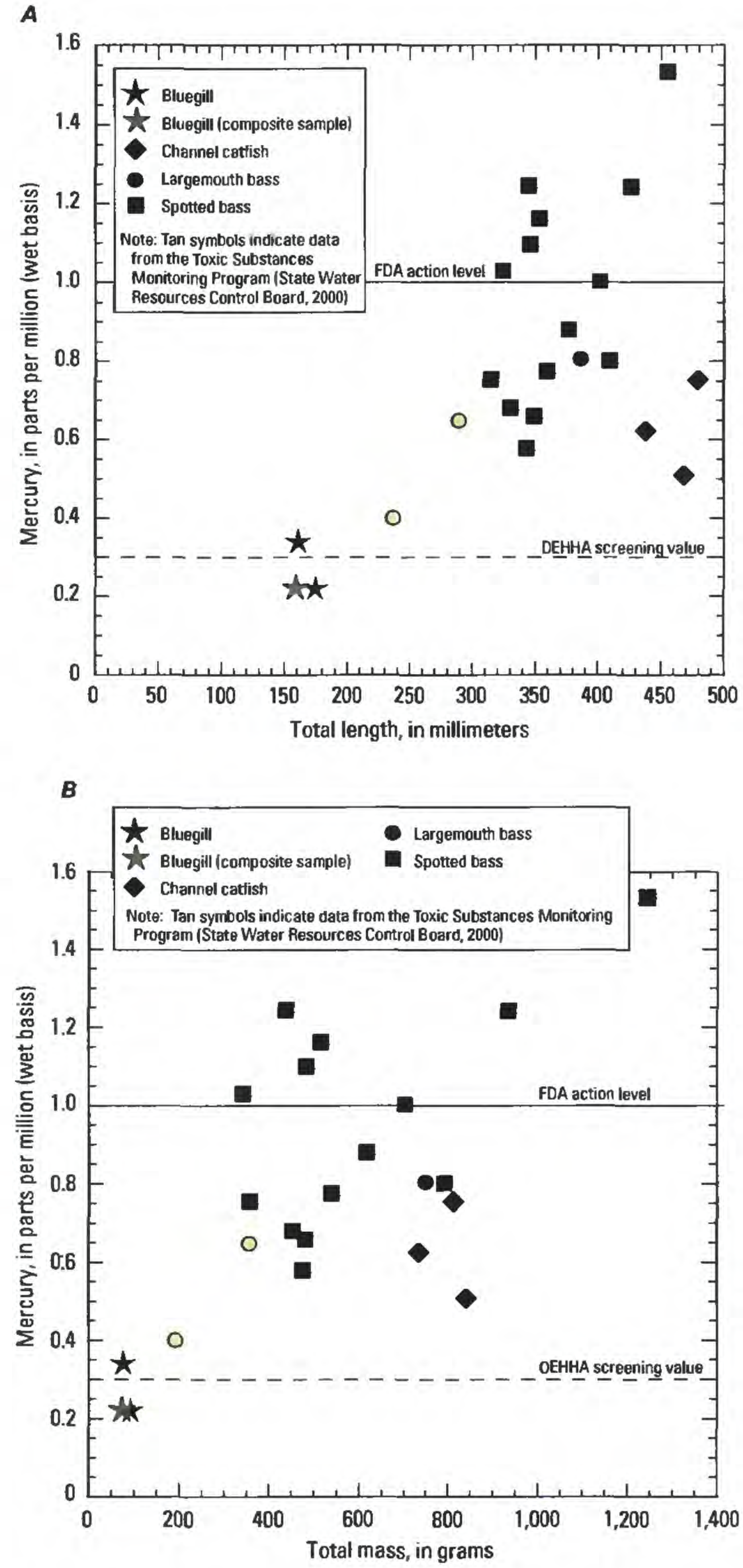

Figure 8. Mercury concentration for fish collected from Camp Far West Reservoir, California, 1999. *A*, In relation to total length. *B*, In relation to total mass. Dashed horizontal line at mercury concentration of 0.3 ppm represents a screening value provided by the Office of Environmental Health Hazard Assessment (Brodberg and Pollock, 1999). Solid horizontal line at mercury concentration of 1.0 ppm indicates the Food and Drug Administration (FDA) action level for commercial fish. Tan symbol indicates data from the State of California's Toxic Substances Monitoring Program (State Water Resources Control Board, 2000); green symbol indicates composite sample from this study.

Stream Habitats

Forty-six analyses are reported for brown and rainbow trout collected from stream habitats of the South Yuba River, Deer Creek, and Bear River watersheds (table 8). Mercury concentrations in trout samples from 14 of 14 sampling sites were less than 0.30 ppm (fig. 9; table 8). Two sites—South Yuba River near Emigrant Gap (site 1, fig. 2) and Bear River at Highway 20 (site 11, fig. 2)—were reference sites, relatively unaffected by historic gold mining activities. Ten of 11 trout samples from these two reference sites had mercury concentrations less than 0.10 ppm (fig. 9).

Three sampling sites—Bear River at Dog Bar Road (site 19, fig. 2), Little Deer Creek at Pioneer Park (site 10, fig. 2), and Deer Creek at Willow Valley Road (site 9, fig. 2)— had one or more individual trout samples with concentrations greater than 0.30 ppm (table 8). The Bear River at Dog Bar Road site had trout (two brown and one rainbow) with mercury concentrations that ranged from 0.38 to 0.43 ppm (fig. 9). The six brown trout collected from Little Deer Creek at Pioneer Park had mercury concentrations that ranged from 0.23 to 0.39 ppm with a geometric mean of 0.32 ppm (fig 9). Four brown trout taken from Deer Creek at Willow Valley Road had mercury concentrations that ranged from 0.11 to 0.32 ppm; a rainbow trout from this location had a concentration of 0.22 ppm (table 8).

Slotton and others (1997) presented data for 22 rainbow trout and 2 brown trout from stream habitats in the South Fork Yuba watershed, 9 rainbow trout collected below Englebright Dam in the lower Yuba River, and a single rainbow trout from the Bear River below Rollins Reservoir. Fourteen rainbow trout samples from the South Yuba River at Washington were used by Slotton and others (1997) to compute a normalized mercury concentration of 0.21 ppm, corresponding to a hypothetical rainbow trout with a mass of 250 g. The overall range in mercury concentration for the 32 rainbow trout from these watersheds reported by Slotton and others (1997) was 0.04 to 0.30 ppm, which is similar to the overall range for concentrations in rainbow trout in the present study (0.06 to 0.38 ppm). The number of brown trout analyzed by Slotton and others (1997) were too low for meaningful comparisons to be made with the present study.

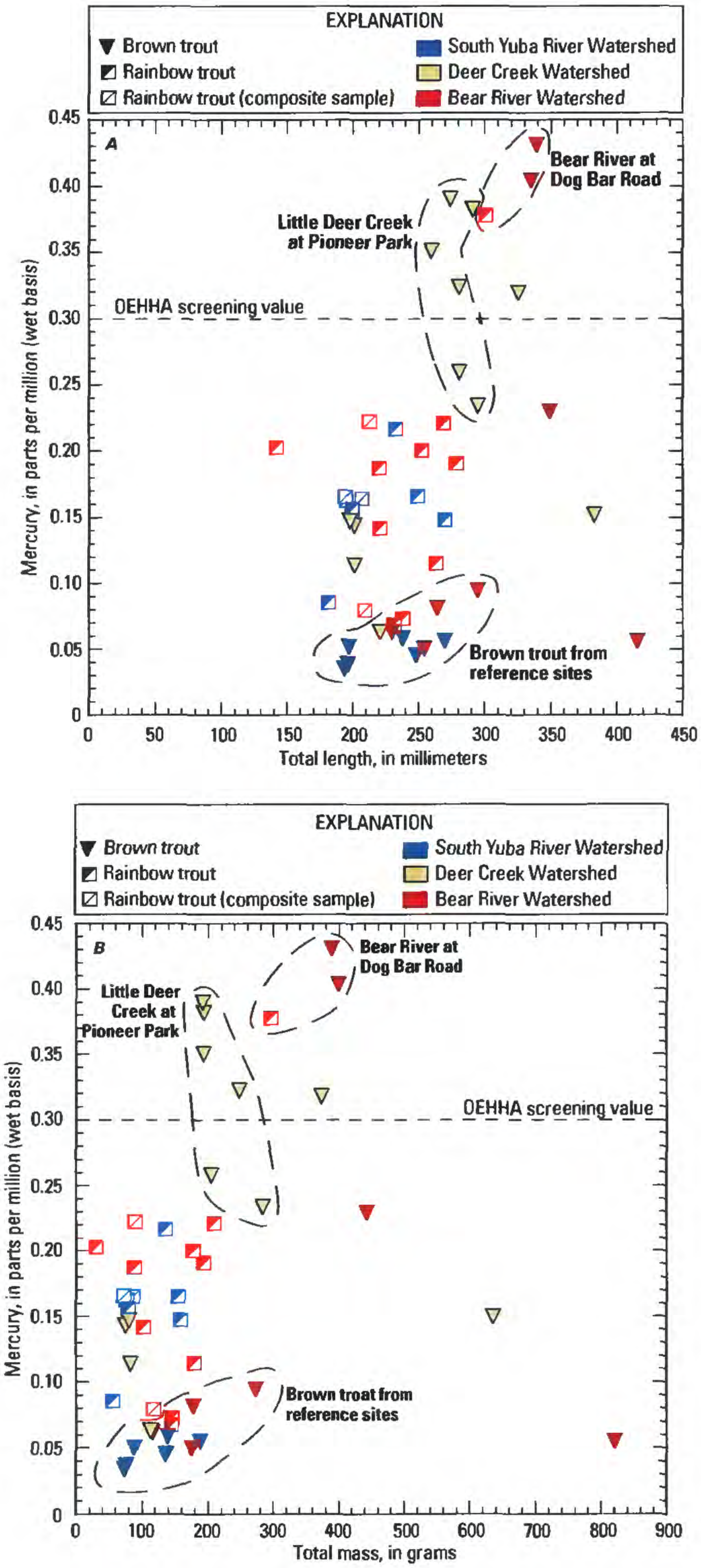

Figure 9. *Mercury concentration for stream fish samples collected from the South Yuba River, Deer Creek, and Bear River watersheds, California, 1999. A,* In relation to total length. *B,* In relation to total mass. Dashed horizontal line at mercury concentration of 0.3 ppm represents a screening value provided by the Office of Environmental Health Hazard Assessment (Brodberg and Pollock, 1999).

DISCUSSION

Numerous studies indicate that mercury bioaccumulates in fish muscle tissue and that mercury concentrations typically increase with increasing fish size and age (Phillips and others, 1980; Lange and others, 1993; Driscoll and others, 1994; Munn and Short, 1997; Neumann and others, 1997; Stafford and Hayes, 1997; Neumann and Ward, 1999). Considering all reservoir fish collected in this study, the best correlation between increasing size and mercury concentration for an individual species from a specific waterbody was found in smallmouth bass from Lake Englebright (fig. 4). Rollins Reservoir (fig. 6) and Camp Far West Reservoir (fig. 8) were the other reservoirs with positive correlations for mercury concentration in relation to increasing size for specific species of bass (*Micropterus spp.*).

It is difficult to compare mercury concentrations among the three bass species from the different reservoirs sampled in this study because the total number of samples from each reservoir was relatively small, each species of bass was not represented in each reservoir, and the size range of bass was different in each reservoir. Nevertheless, some general characteristics are apparent when the mercury data for all bass (*Micropterus spp.*) are plotted as a function of fish length and mass (fig. 10). The highest mercury concentrations were found in spotted bass collected from Camp Far West Reservoir and in largemouth bass collected from Lake Combie (fig. 10; table 9). Considering all of the bass data together, Scotts Flat Reservoir is the only reservoir site for which the data do not follow a general trend of increasing mercury concentration with increasing size.

Slotton and others (1997) investigated many of the streams of the northwestern Sierra Nevada region and identified the Yuba River and Bear River watersheds as problematic areas for mercury bioaccumulation in the food chain. Their study primarily focused on invertebrates and fish from stream habitats, with relatively few fish samples collected from the reservoirs in these watersheds. The data from the present study adds to the knowledge of the distribution of mercury concentrations in fish in these watersheds, and supports the conclusions of Slotton and others (1997) that the South Yuba River, Deer Creek, and Bear River watersheds have elevated concentrations of bioavailable mercury.

The data presented in this report contribute to a better understanding of the occurrence and distribution of mercury and methylmercury in the South Yuba River, Deer Creek, and Bear River watersheds. Results from the current study suggest the need for investigations of reservoirs in other Sierra Nevada foothill watersheds that have had similar historic gold mining activities.

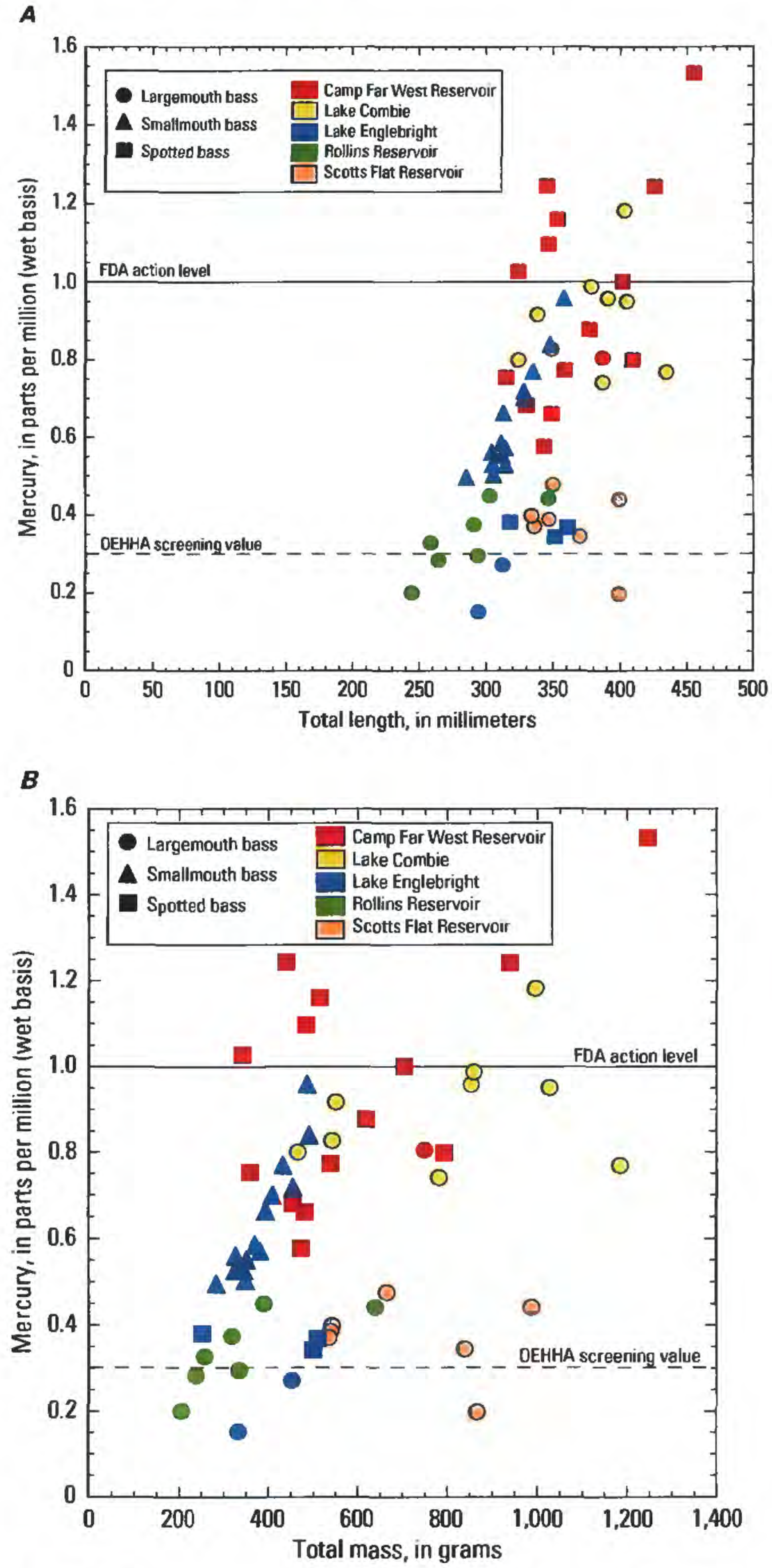

Figure 10. Mercury concentration for all bass (*Micropterus spp.*) samples collected from reservoirs in the South Yuba River, Deer Creek, and Bear River watersheds, California, 1999. *A*, In relation to total length. *B*, In relation to total mass. Dashed horizontal line at mercury concentration of 0.3 ppm represents a screening value provided by the Office of Environmental Health Hazard Assessment (Brodberg and Pollock, 1999). Solid horizontal line at mercury concentration of 1.0 ppm indicates the Food and Drug Administration (FDA) action level for commercial fish.

SUMMARY AND CONCLUSIONS

Mercury concentrations in fish collected from the South Yuba River, Deer Creek, and Bear River watersheds are summarized in table 9. The highest mercury concentrations were found in the upper-trophic-level predators—the largemouth, smallmouth, and spotted bass—from Camp Far West Reservoir and Lake Combie in the Bear River watershed, and Lake Englebright in the South Yuba River watershed.

Mercury concentrations exceeded 1.0 ppm, the FDA's action level for regulating mercury concentrations in commercial fish, in 14 percent (8 of 57) of the samples of bass (*Micropterus spp.*) analyzed for this study. Sixty-five percent of the black bass (*Micropterus spp.*) samples (37 of 57) had mercury concentrations greater than 0.50 ppm, and 88 percent (50 of 57) had mercury concentrations greater than 0.30 ppm, the level used by OEHHA as a screening value.

Mercury concentrations in benthic omnivores (channel catfish) and intermediate-trophic-level predators [sunfish (bluegill, green sunfish, and black crappie)] were generally lower than in black bass samples. Upper-level predators that feed on prey with more elevated mercury concentrations likely bioaccumulate mercury to a greater extent than the lower-trophic-level taxa.

Brown trout and rainbow trout collected from stream environments were found to have generally much lower mercury concentrations than the bass and catfish collected from the reservoirs. Trout are primarily insectivorous species and they were collected mostly from streams that are less likely to be mercury methylation sites than the reservoirs. Nevertheless, trout from three stream sites sampled in this study—Little Deer Creek at Pioneer Park (site10, fig. 2), Bear River at Dog Bar Road (site19, fig. 2), and Deer Creek at Willow Valley Road (site 9, fig. 2)—showed relatively elevated mercury concentrations greater than 0.30 ppm.

The data provided in this report may be useful to local, state, and federal agencies responsible for assessing potential risks associated with elevated concentrations of mercury in fish tissues in the South Yuba River, Deer Creek, and Bear River watersheds. Results from the present study suggest the need for investigation of mercury levels in fish from reservoirs and stream habitats in other watersheds that have been affected by historic gold-mining activities, especially hydraulic mining.

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TABLES AND APPENDIX

Table 1. Fish sampling sites in the South Yuba River, Deer Creek, and Bear River watersheds, California, 1999, including report site number and collection dates

[Report site number refers to figure 2. Site name, abbreviated version of official USGS station name listed in the Appendix. mm/dd/yy, month/day/year]

Report site number	Site name	Collection date(s) (mm/dd/yy)
	South Yuba River Watershed	
1	South Yuba River near Emigrant Gap[1]	10/1/99
2	Humbug Creek above Falls	9/4/99
3	Humbug Creek below Falls	9/4/99
4	South Yuba River near Edwards Crossing	9/29/99
5	Lake Englebright (South Yuba arm)	9/16/99
6	Lake Englebright (Hogsback Ravine)	9/17/99
	Deer Creek Watershed	
7	Deer Creek above Scotts Flat Reservoir	10/6/99
8	Scotts Flat Reservoir	9/7–8/99
9	Deer Creek near Willow Valley Road	10/6/99
10	Little Deer Creek at Pioneer Park	10/6/99
	Bear River Watershed	
11	Bear River at Hwy 20[1]	8/26/99
12	Bear River above Dutch Flat	10/8/99
13	Bear River below Dutch Flat	10/8/99
14	North Fork of Steephollow Creek	8/26/99
15	Greenhorn Creek above Buckeye Drain	9/30/99
16	Missouri Canyon	9/1/99
17	Rollins Reservoir (Greenhorn Creek arm)	9/14/99
18	Rollins Reservoir (Bear River arm)	9/15/99
19	Bear River at Dog Bar Road	9/23/99
20	Lake Combie	9/10–11/99
21	Camp Far West Reservoir (Bear River arm)	9/22/99
22	Camp Far West Reservoir (at dam)	9/21/99

[1]Sampling sites upstream of known gold mining effects.

Table 2. Summary of interlaboratory comparison data for mercury concentration in fish fillet samples from the South Yuba River, Deer Creek, and Bear River watersheds, California, 1999

[ID, identification code: F , tissue sample from left fillet; R, tissue sample from right fillet; ppm, parts per million; Hg, mercury; TERL, Trace Element Research Laboratory, College Station, Texas; FGS, Frontier Geosciences, Incorporated, Seattle, Washington; RPD, relative percent difference, computed from the formula RPD = $100 \times \{(m_1 - m_2 / [(m_1 + m_2)/2]\}$, where m_1 is the value from TERL and m_2 is the value from FGS; %, percent]

Sample ID[1]	TERL, total Hg in fish tissue (ppm wet)	FGS, total Hg in fish tissue (ppm wet)	RPD (%)
F-001/R-001[2]	0.02	0.09	–127
F-002/R-005[2]	0.30	0.33	–9.5
F-003/R-006[2]	0.20	0.27	–29.8
F-004/R-007[2]	0.16	0.36	–76.9
F-007/R-022[2]	0.06	0.06	0.0
F-008/R-023[2]	0.12	0.12	0.0
F-009/R-024[2]	0.20	0.20	0.0
F-010/R-025[2]	0.19	0.20	–5.1
F-011/R-026[2]	0.23	0.22	4.4
F-012/R-028[2]	0.07	0.08	–13.3
F-013/R-029[2]	0.07	0.08	–13.3
R-002	0.04	0.05	–22.2
R-003	0.08	0.10	–22.2
R-004	0.09	0.11	–20.0
R-008	0.43	0.45	–4.6
R-013	0.51	0.49	4.0
R-014	0.40	0.25	46.2
R-015	0.28	0.33	–16.4
R-016	0.35	0.30	15.4
R-017	0.38	0.43	–12.4
R-018	0.45	0.48	–6.5
R-019	0.42	0.42	0.0
R-020	0.27	0.24	11.8
R-086	0.40	0.44	–9.5
R-100	0.74	1.02	–31.8
R-105	0.83	0.81	2.4
R-114	0.37	0.34	8.5
R-123	0.53	0.45	16.3
R-127	0.57	0.50	13.1
R-129	0.72	0.71	1.4
R-131	0.77	0.71	8.1
R-144	1.03	0.81	23.9
R-148	1.16	1.24	–6.7
R-163	0.66	0.74	–11.4

[1]Multiple sample IDs indicate a comparison between samples of the left and right fillet, single sample IDs indicate a comparison between subsamples of the right fillet.

[2]Right fillet sample analysis (by FGS laboratory) provided by the U.S. Environmental Protection Agency.

Table 3. Data for fish collected from Lake Englebright, California, 1999, including common name, mercury concentrations, moisture content of fillet tissue, gender, total length, and total mass

[ID, identification code; Hg, mercury; ppm, parts per million; %, percent; Gender: F, female; M, male; mm, millimeter; g, gram]

Sampling location	Sample ID[1]	Common name	Tissue sample mass (g)	Total Hg (ppm dry)	Moisture (%)	Total Hg (ppm wet)	Gender	Total length (mm)	Total mass (g)
Lake Englebright (South Yuba River arm)	F-052	Green sunfish	5.10	0.36	79.0	0.08	M	185	123
Lake Englebright (South Yuba River arm)	F-053	Green sunfish	4.16	0.55	78.9	0.12	M	175	106
Lake Englebright (South Yuba River arm)	R-122	Smallmouth bass	10.70	2.3	75.5	0.56	F	304	327
Lake Englebright (South Yuba River arm)	R-123	Smallmouth bass	10.29	2.4	78.1	0.53	F	305	326
Lake Englebright (South Yuba River arm)	R-124	Smallmouth bass	10.41	3.1	81.0	0.58	M	311	369
Lake Englebright (South Yuba River arm)	R-125	Smallmouth bass	10.29	2.7	79.5	0.55	M	312	350
Lake Englebright (South Yuba River arm)	R-126	Smallmouth bass	10.16	3.2	79.5	0.66	F	313	394
Lake Englebright (South Yuba River arm)	R-127	Smallmouth bass	10.29	2.5	77.3	0.57	F	314	381
Lake Englebright (South Yuba River arm)	R-128	Smallmouth bass	10.47	2.3	77.1	0.53	F	314	345
Lake Englebright (South Yuba River arm)	R-129	Smallmouth bass	10.66	3.2	77.4	0.72	M	328	453
Lake Englebright (South Yuba River arm)	R-130	Smallmouth bass	10.70	3.3	78.5	0.70	M	328	408
Lake Englebright (South Yuba River arm)	R-131	Smallmouth bass	10.54	3.3	76.5	0.77	M	335	432
Lake Englebright (South Yuba River arm)	R-132	Smallmouth bass	10.67	3.9	78.4	0.84	M	347	490
Lake Englebright (South Yuba River arm)	R-133	Smallmouth bass	10.66	4.0	76.3	0.96	F	358	487
Lake Englebright (Hogsback Ravine)	F-059	Smallmouth bass	10.29	2.3	78.2	0.50	M	285	283
Lake Englebright (Hogsback Ravine)	F-060	Smallmouth bass	16.43	2.4	79.1	0.50	M	305	347
Lake Englebright (Hogsback Ravine)	F-054	Largemouth bass	15.41	0.74	79.4	0.15	M	295	334
Lake Englebright (Hogsback Ravine)	F-055	Largemouth bass	15.30	1.3	78.7	0.27	F	312	453
Lake Englebright (Hogsback Ravine)	F-056	Spotted bass	10.01	1.7	78.6	0.37	F	360	510
Lake Englebright (Hogsback Ravine)	F-057	Spotted bass	10.07	1.5	77.8	0.34	F	351	500
Lake Englebright (Hogsback Ravine)	F 061	Spotted bass	10.16	1.8	78.6	0.38	F	317	252

[1]Sample IDs beginning with "F" represent individual samples from the left fillet of the fish; IDs with "R" represent individual samples from right fillet of the fish.

Table 4. Data for fish collected from Scotts Flat Reservoir, California, 1999, including common name, mercury concentrations, moisture content in fish tissue, gender, total length, and total mass

[ID, identification code; Hg, mercury; ppm, parts per million; %, percent; Gender: F, female; M, male; —, undetermined; mm, millimeter; g, gram]

Sampling location	Sample ID[1]	Common name	Tissue sample mass (g)	Total Hg (ppm dry)	Moisture (%)	Total Hg (ppm wet)	Gender	Total length (mm)	Total mass (g)
Scotts Flat Reservoir	C-017	Green sunfish	3.34	0.67	80.5	0.13	—	171	106
Scotts Flat Reservoir	F-030	Brown trout	15.79	0.26	76.3	0.06	F	357	484
Scotts Flat Reservoir	F-031	Brown trout	15.74	0.69	76.2	0.16	M	387	608
Scotts Flat Reservoir	F-032	Bluegill	4.43	0.33	79.3	0.07	M	165	93
Scotts Flat Reservoir	F-033	Bluegill	4.56	0.51	80.9	0.10	M	164	107
Scotts Flat Reservoir	F-034	Largemouth bass	20.82	1.6	78.7	0.35	F	370	839
Scotts Flat Reservoir	F-035	Largemouth bass	20.83	0.93	78.7	0.20	F	400	867
Scotts Flat Reservoir	F-036	Largemouth bass	20.85	2.1	78.6	0.44	M	400	988
Scotts Flat Reservoir	F-039	Largemouth bass	20.81	2.2	78.5	0.48	F	350	666
Scotts Flat Reservoir	R-086	Largemouth bass	20.04	1.9	78.5	0.40	M	334	544
Scotts Flat Reservoir	R-087	Largemouth bass	20.22	1.8	79.4	0.37	M	336	537
Scotts Flat Reservoir	R-088	Largemouth bass	20.06	1.9	79.4	0.39	M	347	541

[1]Sample IDs beginning with "C" represent composite samples of three fish; corresponding tissue sample mass, total length, and weight values for composites represent arithmetic means; IDs with "F" represent individual samples from the left fillet of the fish; IDs with "R" represents individual samples from right fillet of the fish.

Table 5. Data for fish collected from Rollins Reservoir, California, 1999, including common name, mercury concentrations, moisture content in fish tissue, gender, total length, and total mass

[ID, identification code; Hg, mercury; ppm, parts per million; %, percent; Gender: F, female; M, male; —, undetermined; mm, millimeters; g, grams]

Sampling location	Sample ID[1]	Common name	Tissue sample mass (g)	Total Hg (ppm dry)	Moisture (%)	Total Hg (ppm wet)	Gender	Total length (mm)	Total mass (g)
Rollins Reservoir (Bear River arm)	R-002	Brown trout	25.29	0.19	78.7	0.04	—	284	191
Rollins Reservoir (Bear River arm)	R-003	Brown trout	23.80	0.42	80.5	0.08	—	284	221
Rollins Reservoir (Bear River arm)	R-004	Brown trout	25.55	0.43	78.8	0.09	—	269	203
Rollins Reservoir (Bear River arm)	F-001	Brown trout	15.57	0.11	79.2	0.02	—	292	239
Rollins Reservoir (Bear River arm)	R-008	Channel catfish	137.04	1.6	73.3	0.43	—	555	1,786
Rollins Reservoir (Bear River arm)	R-013	Channel catfish	113.93	2.2	77.4	0.51	—	569	2,202
Rollins Reservoir (Bear River arm)	R-014	Channel catfish	115.27	1.7	76.6	0.40	—	555	1,673
Rollins Reservoir (Bear River arm)	R-015	Channel catfish	103.58	1.1	74.4	0.28	—	540	1,446
Rollins Reservoir (Bear River arm)	R-016	Channel catfish	82.71	1.3	74.1	0.35	F	545	1,446
Rollins Reservoir (Bear River arm)	R-017	Channel catfish	102.16	1.7	76.9	0.38	M	535	1,485
Rollins Reservoir (Bear River arm)	R-018	Channel catfish	81.75	2.3	80.3	0.45	—	515	1,456
Rollins Reservoir (Bear River arm)	R-019	Channel catfish	90.53	1.4	70.6	0.42	M	521	1,304
Rollins Reservoir (Bear River arm)	R-020	Channel catfish	87.75	1.1	75.9	0.27	M	490	1,153
Rollins Reservoir (Bear River arm)	F-004	Channel catfish	40.02	0.56	71.3	0.16	—	585	2,389
Rollins Reservoir (Bear River arm)	F-005	Bluegill	5.14	2.0	79.7	0.41	—	193	138
Rollins Reservoir (Bear River arm)	C-003	Bluegill	5.04	0.99	79.1	0.21	—	161	94
Rollins Reservoir (Bear River arm)	F-002	Largemouth bass	20.07	1.4	78.5	0.30	M	294	336
Rollins Reservoir (Bear River arm)	F-003	Largemouth bass	20.16	0.93	78.4	0.20	F	245	206
Rollins Reservoir (Greenhorn Creek arm)	C-021	Black crappie	10.46	1.4	78.6	0.31	—	263	304
Rollins Reservoir (Greenhorn Creek arm)	C-022	Bluegill	3.05	0.77	79.9	0.16	—	157	75
Rollins Reservoir (Greenhorn Creek arm)	F-047	Largemouth bass	12.80	2.2	79.1	0.45	F	303	391
Rollins Reservoir (Greenhorn Creek arm)	F-048	Largemouth bass	20.13	2.1	78.5	0.44	F	347	640
Rollins Reservoir (Greenhorn Creek arm)	R-112	Largemouth bass	10.23	1.6	79.8	0.33	F	259	259
Rollins Reservoir (Greenhorn Creek arm)	R-113	Largemouth bass	10.08	1.3	78.9	0.28	M	265	239
Rollins Reservoir (Greenhorn Creek arm)	R-114	Largemouth bass	10.08	1.7	78.1	0.37	M	291	321
Rollins Reservoir (Greenhorn Creek arm)	F-049	Channel catfish	28.39	1.2	78.6	0.25	M	434	772
Rollins Reservoir (Greenhorn Creek arm)	F-050	Channel catfish	35.12	1.8	73.6	0.48	M	485	1,047
Rollins Reservoir (Greenhorn Creek arm)	F-051	Channel catfish	40.37	1.2	74.0	0.32	M	625	2,544

[1]Sample IDs beginning with "C" represent composite samples of three fish; corresponding tissue sample weight, total length, and mass values for composites represent arithmetic-means; IDs with "F" represent individual samples from the left fillet of the fish; IDs with "R" represent individual samples from right fillet of the fish.

Table 6. Data for fish collected from Lake Combie, California, 1999, including common name, mercury concentrations, moisture content in fish tissue, gender, total length, and total mass

[ID, identification code; Hg, mercury; ppm, parts per million; %, percent; Gender: F, female; M, male; —, undetermined; mm, millimeter; g, gram]

Sampling location	Sample ID[1]	Common name	Tissue sample mass (g)	Total Hg (ppm dry)	Moisture (%)	Total Hg (ppm wet)	Gender	Total length (mm)	Total mass (g)
Lake Combie	F-040	Bluegill	2.49	0.84	80	0.17	F	145	57
Lake Combie	F-041	Bluegill	2.21	0.98	81.2	0.18	F	125	42
Lake Combie	F-042	Rainbow trout	8.69	0.75	74.1	0.20	F	291	250
Lake Combie	F-043	Rainbow trout	6.30	0.26	76.3	0.06	—	234	140
Lake Combie	F-044	Largemouth bass	20.79	3.6	78.5	0.77	F	435	1,186
Lake Combie	F-045	Largemouth bass	20.83	4.5	79	0.95	F	405	1,027
Lake Combie	F-046	Largemouth bass	20.89	5.3	77.6	1.2	F	404	994
Lake Combie	R-100	Largemouth bass	20.29	3.5	78.7	0.74	F	388	783
Lake Combie	R-101	Largemouth bass	20.40	4.8	79.9	0.96	F	391	854
Lake Combie	R-102	Largemouth bass	20.35	4.8	79.5	0.99	F	379	860
Lake Combie	R-103	Largemouth bass	15.26	3.8	79.1	0.80	M	324	467
Lake Combie	R-104	Largemouth bass	15.31	4.5	79.6	0.92	F	338	552
Lake Combie	R-105	Largemouth bass	15.29	3.6	77.5	0.83	F	349	543

[1]Sample IDs beginning with "F" represent individual samples from the left fillet of the fish; IDs with "R" represent individual samples from right fillet of the fish.

Table 7. Data for fish collected from Camp Far West, California, 1999, including common name, mercury concentrations, moisture content in fish tissue, gender, total length, and total mass

[ID, identification code; Hg, mercury; ppm, parts per million; %, percent; Gender: F, female; M, male; —, undetermined; mm, millimeter; g, gram]

Sampling location	Sample ID[1]	Common name	Tissue sample mass (g)	Total Hg (ppm dry)	Moisture (%)	Total Hg (ppm wet)	Gender	Total length (mm)	Total mass (g)
Camp Far West Reservoir (at dam)	C-031	Bluegill	3.23	1.2	80.8	0.22	—	175	92
Camp Far West Reservoir (at dam)	F-067	Largemouth bass	20.29	3.8	78.9	0.81	F	387	751
Camp Far West Reservoir (at dam)	F-068	Spotted bass	20.57	3.7	78.1	0.80	M	409	792
Camp Far West Reservoir (at dam)	F-069	Spotted bass	20.60	3.9	77.6	0.88	M	377	617
Camp Far West Reservoir (at dam)	R-161	Spotted bass	15.26	3.5	78.5	0.76	M	315	356
Camp Far West Reservoir (at dam)	R-162	Spotted bass	15.46	6.0	79.1	1.2	F	345	439
Camp Far West Reservoir (at dam)	R-163	Spotted bass	15.42	3.3	79.7	0.66	F	349	482
Camp Far West Reservoir (Bear River arm)	F-062	Spotted bass	20.75	4.5	77.6	1.0	M	401	702
Camp Far West Reservoir (Bear River arm)	F-063	Spotted bass	20.68	5.7	78.0	1.2	M	426	935
Camp Far West Reservoir (Bear River arm)	F-064	Spotted bass	20.79	6.5	76.3	1.5	M	455	1,244
Camp Far West Reservoir (Bear River arm)	R-144	Spotted bass	13.17	4.8	78.5	1.0	F	324	341
Camp Far West Reservoir (Bear River arm)	R-145	Spotted bass	13.13	3.2	78.7	0.68	F	330	453
Camp Far West Reservoir (Bear River arm)	R-146	Spotted bass	13.13	2.8	79.7	0.58	F	343	472
Camp Far West Reservoir (Bear River arm)	R-147	Spotted bass	15.50	5.0	78.1	1.1	F	346	483
Camp Far West Reservoir (Bear River arm)	R-148	Spotted bass	15.60	5.4	78.3	1.2	—	353	516
Camp Far West Reservoir (Bear River arm)	R-149	Spotted bass	15.63	4.2	81.5	0.77	F	359	536
Camp Far West Reservoir (Bear River arm)	F-065	Bluegill	2.73	1.1	79.2	0.23	M	159	72
Camp Far West Reservoir (Bear River arm)	F-066	Bluegill	2.83	1.8	80.8	0.34	M	161	76
Camp Far West Reservoir (Bear River arm)	R-141	Channel catfish	25.20	3.2	80.5	0.62	M	437	737
Camp Far West Reservoir (Bear River arm)	R-142	Channel catfish	25.21	2.7	81.2	0.51	M	468	840
Camp Far West Reservoir (Bear River arm)	R-143	Channel catfish	25.22	3.6	79.2	0.75	M	479	812

[1]Sample IDs beginning with "C" represent composite samples of three fish; corresponding tissue sample mass, total length, and mass values for composites represent arithmetic means; IDs with "F" represents individual samples from the left fillet of the fish; IDs with "R" represents individual samples from right fillet of the fish.

Table 8. Data for stream fish collected from South Yuba River, Deer Creek, and Bear River watersheds, California, 1999, including common name, mercury concentration, moisture content in fish tissue, gender, total length, and total mass

[ID, identification code; Hg, mercury; ppm, parts per million; %, percent; Gender: F, female; M, male; —, undetermined; mm, millimeter; g, gram; NF, North Fork]

Sampling location	Sample ID[1]	Common name	Tissue sample mass (g)	Total Hg (ppm dry)	Moisture (%)	Total Hg (ppm wet)	Gender	Total length (mm)	Total mass (g)
South Yuba River Watershed									
South Yuba River near Emigrant Gap[2]	R-041	Brown trout	5.33	0.28	78.9	0.06	F	238	141
South Yuba River near Emigrant Gap[2]	R-042	Brown trout	5.36	0.21	78.0	0.05	F	247	138
South Yuba River near Emigrant Gap[2]	R-043	Brown trout	5.32	0.29	80.5	0.06	F	270	189
South Yuba River near Emigrant Gap[2]	R-044	Brown trout	4.12	0.19	80.2	0.04	M	195	77
South Yuba River near Emigrant Gap[2]	R-045	Brown trout	4.25	0.18	72.4	0.05	M	196	89
South Yuba River near Emigrant Gap[2]	R-046	Brown trout	4.24	0.19	81.0	0.04	M	193	76
Humbug Creek above Falls	C-014	Rainbow trout	3.29	0.72	77.2	0.16	—	195	77
Humbug Creek above Falls	C-015	Rainbow trout	3.59	0.73	77.3	0.17	—	207	87
Humbug Creek above Falls	F-028	Rainbow trout	5.77	0.96	77.3	0.22	F	233	138
Humbug Creek below Falls	C-013	Rainbow trout	3.55	0.69	76.0	0.17	—	195	75
Humbug Creek below Falls	F-026	Rainbow trout	5.29	0.69	77.3	0.16	M	200	82
Humbug Creek below Falls	F-027	Rainbow trout	7.09	0.69	76.1	0.17	F	249	156
South Yuba River near Edwards Crossing	F-014	Rainbow trout	10.04	0.66	77.6	0.15	F	270	161
South Yuba River near Edwards Crossing	F-015	Rainbow trout	4.34	0.40	78.6	0.09	—	182	58
Deer Creek Watershed									
Deer Creek above Scotts Flat Reservoir	F-019	Brown trout	15.43	0.67	77.3	0.15	M	383	638
Deer Creek above Scotts Flat Reservoir	F-020	Brown trout	5.15	0.29	78.2	0.06	—	221	118
Deer Creek near Willow Valley Road	F-021	Brown trout	15.07	1.5	78.9	0.32	F	325	374
Deer Creek near Willow Valley Road	F-022	Rainbow trout	10.07	0.94	76.4	0.22	F	270	213
Deer Creek near Willow Valley Road	R-051	Brown trout	4.20	0.68	78.8	0.14	F	199	77
Deer Creek near Willow Valley Road	R-052	Brown trout	4.22	0.68	78.5	0.15	F	197	82
Deer Creek near Willow Valley Road	R-053	Brown trout	4.28	0.55	79.4	0.11	F	202	85
Little Deer Creek at Pioneer Park	R- 054	Brown trout	7.74	2.0	81.1	0.38	F	291	196
Little Deer Creek at Pioneer Park	R-055	Brown trout	7.73	1.7	81.1	0.32	F	280	248
Little Deer Creek at Pioneer Park	R-056	Brown trout	7.64	0.95	75.3	0.23	M	295	284
Little Deer Creek at Pioneer Park	R-057	Brown trout	5.50	2.0	80.9	0.39	M	274	194
Little Deer Creek at Pioneer Park	R-058	Brown trout	5.45	1.6	77.5	0.35	F	260	195
Little Deer Creek at Pioneer Park	R-059	Brown trout	5.33	1.4	81.1	0.26	F	280	207
Bear River Watershed									
Bear River at Hwy 20[2]	F-029	Brown trout	10.11	0.43	77.8	0.10	F	295	275
Bear River at Hwy 20[2]	R-075	Brown trout	5.26	0.32	80.2	0.06	F	230	118
Bear River at Hwy 20[2]	R-076	Brown trout	5.39	0.20	75.4	0.05	F	255	177

Table 8. Data for stream fish collected from South Yuba River, Deer Creek, and Bear River watersheds, California, 1999, including common name, mercury concentration, moisture content in fish tissue, gender, total length, and total mass—*Continued*

Sampling location	Sample ID[1]	Common name	Tissue sample mass (g)	Total Hg (ppm dry)	Moisture (%)	Total Hg (ppm wet)	Gender	Total length (mm)	Total mass (g)
Bear River at Hwy 20[2]	R-077	Brown trout	5.36	0.34	76.3	0.08	M	265	180
Bear River above Dutch Flat	F-007	Brown trout	15.35	0.26	78.2	0.06	M	416	821
Bear River above Dutch Flat	F-008	Rainbow trout	10.17	0.52	77.8	0.12	F	263	183
Bear River above Dutch Flat	F-009	Rainbow trout	9.20	0.99	79.8	0.20	M	253	180
Bear River above Dutch Flat	F-010	Rainbow trout	4.27	0.92	79.7	0.19	—	220	92
Bear River below Dutch Flat	C-006	Rainbow trout	5.10	0.36	77.9	0.08	—	210	119
Bear River below Dutch Flat	F-011	Brown trout	15.36	0.97	76.2	0.23	M	350	445
Bear River below Dutch Flat	F-012	Rainbow trout	5.10	0.30	77.2	0.07	M	231	148
Bear River below Dutch Flat	F-013	Rainbow trout	5.33	0.33	77.7	0.07	M	238	148
North Fork of Steephollow Creek	F-024	Rainbow trout	5.14	0.61	76.9	0.14	M	220	105
North Fork of Steephollow Creek	F-025	Rainbow trout	5.57	0.89	78.4	0.19	F	280	197
Greenhorn Creek above Buckeye Hill	C-007	Rainbow trout	4.25	1.1	78.9	0.22	—	213	92
Missouri Canyon	F-023	Rainbow trout	2.00	0.96	78.9	0.20	M	142	33
Bear River at Dog Bar Road	F-016	Rainbow trout	10.63	1.8	78.4	0.38	F	301	301
Bear River at Dog Bar Road	F-017	Brown trout	15.09	1.8	76.2	0.43	F	339	390
Bear River at Dog Bar Road	F-018	Brown trout	15.15	1.8	77.2	0.40	F	335	401

[1]Sample IDs beginning with "C" represent composite samples of three fish; corresponding tissue sample mass, total length, and mass values for composites represent arithmetic means; IDs with "F" represents individual samples from the left fillet of the fish: IDs with "R" represents individual samples from right fillet of the fish.

[2]Reference sites upstream from known historic gold mines.

Table 9. Range and mean values of mercury concentrations and length for selected fish species and locations within the South Yuba River, Deer Creek, and Bear River watersheds, California, 1999

[N, number of samples; Hg, mercury; ppm, parts per million; mean, geometric mean]

Common name	Sampling location	N	Total Hg (ppm wet) minimum	Total Hg (ppm wet) mean	Total Hg (ppm wet) maximum	Total length (mm) minimum	Total length (mm) mean	Total length (mm) maximum
Smallmouth bass	Lake Englebright	14	0.50	0.63	0.96	285	317	358
Largemouth bass	Scotts Flat Reservoir	7	0.20	0.36	0.48	334	361	400
Largemout bass	Rollins Reservoir	7	0.20	0.33	0.45	245	284	347
Largemouth bass	Lake Combie	9	0.74	0.90	1.2	324	377	435
Spotted bass	Camp Far West Reservoir	14	0.58	0.92	1.5	324	364	455
Channel catfish	Rollins Reservoir	13	0.16	0.35	0.51	434	532	625
Channel catfish	Camp Far West Reservoir	3	0.51	0.62	0.75	437	460	479
Brown trout	South Yuba River near Emigrant Gap[1]	6	0.04	0.05	0.06	193	221	270
Brown trout	Deer Creek near Willow Valley Road	4	0.11	0.17	0.32	197	225	325
Brown trout	Little Deer Creek at Pioneer Park	6	0.23	0.32	0.39	260	279	295
Brown trout	Rollins Reservoir	4	0.02	0.05	0.09	269	282	292

[1]Sampling site upsream of known gold mining effects.

Appendix. Sampling site numbers, station names, station numbers, and locations in the South Yuba River, Deer Creek, and Bear River watersheds, California, 1999

[Report site number refer numbers to figure 2 and table 1; deg, degrees; min, minutes; sec, seconds; latitude and longitude referenced to NAD 83; NAD 83, North American Datum1983; USGS, U. S. Geological Survey. All latitude values are north of the equator all longitude values are west of the central meridian]

Report site number	USGS station name	USGS station number	Site latitude (deg min sec)	Site longitude (deg min sec)
	South Yuba River Watershed			
1	South Yuba River at Eagle Lakes Road near Emigrant Gap, California	391948120342201	39°19′52″	120°33′54″
2	Humbug Creek above Falls near Nevada City, California	392057120552901	39°21′17″	120°55′24″
3	Humbug Creek below Falls near Nevada City, California	392040120553701	39°20′47″	120°55′37″
4	South Yuba River near Edwards Crossing near Nevada City, California	391949120585001	39°19′49″	120°59′02″
5	Lake Englebright, South Yuba Arm at Point Defiance Campground near Bridgeport, California	391743121122401	39°17′47″	121°12′27″
6	Lake Englebright at Hogsback Ravine near Smartville, California	391442121163001	39°14′43″	121°16′36″
	Deer Creek Watershed			
7	Deer Creek Upstream of Scotts Flat Reservoir at Sawmill near Nevada City, California	391745120531201	39°17′44″	120°53′11″
8	Scotts Flat Reservoir Inlet South Shore near Nevada City, California	391716120540701	39°17′24″	120°54′00″
9	Deer Creek near Willow Valley Road near Nevada City, California	391602121000901	39°16′04″	121°00′06″
10	Little Deer Creek at Pioneer Park near Nevada City, California	391534121003101	39°15′34″	121°00′37″
	Bear River Watershed			
11	Bear River at Highway 20 near Emigrant Gap, California	391823120404101	39°18′23″	120°40′46″
12	Bear River below Drum Afterbay near Dutch Flat, California	391513120463101	39°15′12″	120°46′33″
13	Bear River below Dutch Flat Afterbay near Dutch Flat, California	11421790	39°12′49″	120°50′45″
14	North Fork of Steephollow Creek near Blue Canyon, California	391642120464701	39°16′45″	120°46′54″
15	Greenhorn Creek above Buckeye Drain near Nevada City, California	391437120541201	39°14′40″	120°54′12″
16	Missouri Canyon near Dutch Flat, California	391259120535801	39°12′59″	120°53′59″
17	Rollins Reservoir First Cove Greenhorn Creek arm near Chicago Park, California	391000120564301	39°10′05″	120°56′43″
18	Rollins Reservoir Bear arm near Chicago Park, California	390956120542501	39°10′06″	120°54′30″
19	Bear River at Dog Bar Road near Weimar, California	390346121000701	39°03′46″	121°00′09″
20	Lake Combie upper cove by Gravel Mine near Higgins Corner, California	390148121014701	39°00′38″	121°03′31″
21	Camp Far West Reservoir upper Bear River arm near Wheatland, California	390203121162701	39°01′41″	121°15′05″
22	Camp Far West Reservoir at dam near Wheatland, California	390304121184801	39°03′03″	121°18′57″