DRAFT REPORT

CONTAMINANTS IN FISH FROM CALIFORNIA LAKES AND RESERVOIRS: TECHNICAL REPORT ON A TWO-YEAR SCREENING SURVEY

Prepared for the
Surface Water Ambient Monitoring Program

Authors
J.A. Davis, A.R. Melwani, S.N. Bezalel, J.A. Hunt,
G. Ichikawa, A. Bonnema, W.A. Heim, D. Crane,
S. Swenson, C. Lamerdin, M. Stephenson

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EXECUTIVE SUMMARY

XX

TO BE WRITTEN LATER

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The Bioaccumulation Oversight Group (BOG)

Terry Fleming, USEPA
Bob Brodberg OEHHA
Chris Foe, Region 5 Water Board
Mary Adams, Region 3 Water Board
Michael Lyons, Region 4 Water Board
Karen Taberski, Region 2 Water Board
Jennifer Doherty, State Water Board
Jay Davis, SFEI
Mark Stephenson, CDFG
Dave Crane, CDFG
Gary Ichikawa, CDFG
Autumn Bonnema, CDFG
Aroon Melwani, SFEI
Cassandra Lamerdin, MLML
Marco Sigala, MLML
Dorena Goding, State Water Board
Tom Maurer, USFWS
Terry Adelsbach, USFWS
Collin Eagles-Smith, USGS
Scott McReynolds, DWR
Jay Rowan, CDFG

SWAMP Bioaccumulation Peer Review Panel

Jim Wiener, Distinguished Professor, University of Wisconsin, La Crosse
Chris Schmitt, USGS, Columbia, Missouri
Ross Norstrom, Canadian Wildlife Service (retired); Carleton University, Ottawa, Canada

San Francisco Estuary Institute

Project Management Support: Lawrence Leung, Rainer Hoenicke, Frank Leung, Irene Poche, Linda Russio, and Stephanie Seto

Moss Landing Marine Laboratories

*Contract Management:*Rusty Fairey
Fish Collection: Gary Ichikawa, Billy Jakl, Dylan Service, Bryan Frueh, Sean Mundell, John Negrey
*Dissection:*Stephen Martenuk, Erik Adams, Kyle Skaff, LA Solano, Jason Whitney
Mercury and Selenium Analysis: April Sjoboen, Brent Hughes, Jon Goetzl.
SWAMP Data Management Team: Cassandra Lamerdin, Mark Pranger, Stacey Swenson, Susan Mason, Marco Sigala, George Radojevic, Brian Thompson, Kyle Reynolds

California Department of Fish and Game Water Pollution Control Laboratory

Fish Collection: Glenn Sibbald, Matt Rock

Sample prep: Laurie Smith, David Gilman, Rafia Mohammed

Sample analysis: Kathleen Regalado, Gary Munoz

Data entry and QA: Loc Nguyen

SWAMP Staff

Valerie Connor, Jennifer Doherty, Vera Williams, and Dawit Tadesse of the State Water Resources Control Board guided the project on behalf of SWAMP.

Statistical Consultant

Don Stevens, Oregon State University

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INTRODUCTION

This technical report presents results from a two-year screening survey of contaminants in sport fish in California lakes and reservoirs. This survey was performed as part of the State Water Resources Control Board's Surface Water Ambient Monitoring Program (SWAMP). This effort marks the beginning of a new long-term, statewide, comprehensive bioaccumulation monitoring program for California surface waters.

Oversight for this project is being provided by the SWAMP Roundtable. The Roundtable is composed of State and Regional Board staff and representatives from other agencies and organizations including US Environmental Protection Agency (USEPA), the California Department of Fish and Game, and the California Office of Environmental Health Hazard Assessment (OEHHA). Interested parties, including members of other agencies, consultants, or other stakeholders also participate.

The Roundtable has formed a subcommittee, the Bioaccumulation Oversight Group (BOG) that specifically guides SWAMP bioaccumulation monitoring. The BOG is composed of State and Regional Board staff and representatives from other agencies and organizations including USEPA, the Department of Fish and Game, OEHHA, and the San Francisco Estuary Institute. The members of the BOG possess extensive experience with bioaccumulation monitoring.

The BOG has also convened a Bioaccumulation Peer Review Panel that is providing evaluation and review of the bioaccumulation program. The members of the Panel are internationally-recognized authorities on bioaccumulation monitoring.

The BOG has developed and begun implementing a plan to evaluate bioaccumulation impacts on the fishing beneficial use in all California water bodies. Sampling of sport fish in lakes and reservoirs was conducted in the first two years of monitoring (2007 and 2008). In 2009 and 2010, sport fish from the California coast, including bays and estuaries are being sampled. Sport fish from rivers and streams will be sampled in 2011. In 2012 the plan is to again begin a two year effort on lakes and begin another five-year cycle of sampling these water body types.

The Lakes Survey

Management Questions for This Survey

Three management questions were articulated to guide the design of the Lakes Survey. These management questions are specific to this initial monitoring effort; different sets of management questions will be established to guide later efforts.

Management Question 1
What is the condition of California lakes with respect to bioaccumulation in sport fish?

Answering this question has been the goal of assessments related to Section 305(b) of the federal Clean Water Act (CWA). In the past, 305(b) reports have provided water quality information to the general public and served as the basis for USEPA's National Water Quality Inventory Report to Congress. The report provided a statewide, comprehensive assessment of the status of California water bodies with respect to support of designated beneficial uses (e.g., SWRCB [2003]). In the future, this information will be part of an "Integrated Report" formally known as the California CWA Section 305(b)/303(d) Integrated Report. This report will satisfy both the CWA Section 305(b) and Section 303(d) requirements (CWA Section 303(d) is discussed further below). Answering this question also provides the state and the public with information that helps describe the magnitude, spatial dimensions, and priority of the bioaccumulation problem relative to other environmental and societal problems.

The information needed to answer this question is the representative, average concentration of contaminants in sport fish indicator species in each lake for an adequately large sampling of lakes.

Management Question 2

Should a specific lake be considered for inclusion on the 303(d) List due to bioaccumulation of contaminants in sport fish?

Answering this question is critical to determining the need for 303(d) listing and cleanup actions to reduce contaminant exposure in specific water bodies. Total Maximum Daily Load evaluations (TMDLs) are required for water bodies placed on the 303(d) list. This is the principal regulatory mechanism being used by the State Water Board, the Regional Water Boards, and USEPA to establish priorities for management actions.

The State Board has established a Listing Policy for placing water bodies on the CWA Section 303(d) list. The Listing Policy establishes a standardized approach and includes California listing and de-listing factors. The fish tissue information needed to make a listing determination depends on the type of data and the pollutant. The more representative the samples are of the water body, the better. The goal in addressing Management Question 2 in this survey was to assist the Regional Boards and State Board by providing the data needed for listing decisions. Actual 303(d) listing determinations will be made by the Regional Boards using the data generated in the Lakes Survey.

Management Question 3

Should additional sampling of bioaccumulation in sport fish at a lake be conducted for the purpose of developing consumption guidelines?

Answering this question is essential as a first step in developing consumption guidelines. Consumption guidelines provide a mechanism for reducing human exposure to problematic contaminants in the near-term. The information requirements for consumption guidelines are more extensive than for 303(d) listing. OEHHA, the agency responsible for issuing consumption guidelines in California, needs samples representing at least nine or more fish from a variety of species abundant in a water body in order to issue guidance. It is useful to have information not only on the species with high concentrations, but also the species with low concentrations so anglers can be encouraged to target the low species.

Overall Approach

The overall approach taken to answer these three questions was to perform a statewide screening study of bioaccumulation in sport fish. The highest priority for SWAMP in the short term is to answer Management Questions 1 and 2. Answering these questions will provide a basis for decision-makers to understand the scope of the bioaccumulation problem and will provide regulators with information needed to establish priorities for cleanup actions. In the longer term, developing consumption guidelines that inform the public on ways to reduce their exposure is also a high priority, and this initial monitoring effort is cost-effectively establishing a foundation for this by identifying lakes that are candidates for additional sampling in support of guideline development.

This screening study is already leading to more detailed followup investigations of many water bodies that are candidates for the 303(d) List or where consumption guidelines are needed.

This Report

The purpose of this technical report is to provide agency staff, scientists, and peer reviewers with a summary of the findings of the survey and a basis for technical evaluation of the work. A nontechnical fact sheet summarizing this work for a general audience will be prepared separately.

METHODS

Sampling Design

The sampling plan was developed to address the three management questions for the project. In 2007 and 2008, sampling was conducted at 272 lakes and reservoirs across California (Figures 1a-d, Tables 1a,b). Targeted sampling of “popular” lakes comprised the bulk of the effort (222 of 272 lakes), with a random sampling of 50 lakes. A list of the most popular fishing lakes and reservoirs in California was compiled, as identified through a review of published fishing guides (Stienstra 2004), websites, and consultation with Regional Board staff. The targeted lakes were sampled in random order, using the generalized random tessellation-stratified (GRTS) approach developed for USEPA’s Environmental Monitoring and Assessment Program (Stevens and Olsen 2004). In the random selection of these lakes, each lake was assigned an equal probability of inclusion. The advantage of this approach is that if the entire population of 222 lakes was not sampled, inferences could still be drawn about the population as a whole, including the unsampled popular lakes. With this approach, a preliminary statewide assessment could be based on the first year results (Davis et al. 2009).

In addition to the statewide targeted sampling of popular lakes, this report also includes data obtained from a coordinated targeted sampling of lakes in Region 4 (Figures 1a,c,d). Region 4 augmented the statewide effort with funds to provide for sampling of 22 additional lakes, including a more thorough analysis of replicate samples than was feasible in the statewide effort.

The second major emphasis of the survey was to provide an evaluation of statewide lake condition. A randomized sampling of 50 lakes from the entire population of California lakes was conducted to provide an unbiased statewide assessment, and a valuable frame of reference for interpreting bias in the targeted sampling. However, many of the lakes and reservoirs in California are inaccessible or unfishable. To avoid wasting sampling resources on these lakes, the population of random lakes was restricted to lakes greater than 4 ha in size that could be accessed and sampled within a one day period. Furthermore, given the general focus of the survey on evaluating the impact of bioaccumulation on the fishing beneficial use, higher inclusion probabilities were assigned to larger lakes that are more popular for fishing. These restrictions resulted in the exclusion of many lakes from the sample population. As with the popular lakes, the 50 random lakes were selected using the GRTS approach. The Sampling Plan (Davis et al. 2007a) provides more details on the design.

Target Species

The overall goal of this screening study was to determine whether or not sport fish in California lakes have concentrations of contaminants that are above thresholds for protection of human health. Therefore, the study focused on sampling of indicator species that tend to accumulate the highest concentrations of the contaminants of concern. Primary target species were selected that are popular for human consumption (e.g., rainbow trout [*Oncorhynchus mykiss*]), and/or are effective at documenting spatial trends in methylmercury (e.g., largemouth bass [*Micropterus salmoides*]) or organics (e.g., common carp [*Cyprinus carpio*]). Methylmercury biomagnifies primarily through its accumulation in muscle tissue, so top predators such as largemouth bass tend to have the highest methylmercury concentrations. In contrast, organic contaminants are biomagnified through accumulation in lipid. Bottom-feeding species such as common carp and channel catfish (*Ictalurus punctatus*) tend to have the highest lipid concentrations in their muscle tissue, and therefore usually have the highest concentrations of organics. Consequently, this study targeted two indicator species in each lake – a top predator (e.g., black bass) as a methylmercury indicator and a high lipid, bottom-feeding species (e.g., common carp or channel catfish) as an organics and selenium indicator. Another advantage of this approach is that it provides a characterization of both the pelagic and benthic food chains. This approach is recommended by USEPA (2000) and was used in a recent national survey by USEPA (Stahl et al. 2009). Some high elevation lakes only had one abundant high trophic level species (i.e., a trout species). In these cases, the one species still represented a worst-case indicator for methylmercury and organics and was sampled and analyzed for all of the pollutants on the analyte list. The species sampled most frequently were the primary target species: largemouth bass, common carp, and rainbow trout (Table 2). Other species were collected where the primary targets could not be obtained.

Specific size ranges for each species were established (Davis et al. 2007a). Sizes collected for each species are listed in Table 2. Black bass (including largemouth, smallmouth [*Micropterus dolomieui*], and spotted bass [*Micropterus punctulatus*]) and Sacramento pikeminnow (*Ptychocheilus grandis*) were the key methylmercury indicators. These species have a high trophic position and a strong size:methylmercury relationship. For these species, fish were sampled across a wide range of lengths and analyzed as individuals, to facilitate an ANCOVA and estimation of size-standardized methylmercury concentrations (however ANCOVA results are only presented for largemouth bass in this report). Individuals were analyzed for methylmercury in a few other instances when too few fish were collected to form a composite sample. As mentioned above, in many high elevation lakes only trout species were available. Past sampling of rainbow trout in the Bay-Delta watershed found low concentrations and a weak size:methylmercury relationship in hatchery fish (Grenier et al. 2007, Melwani et al. 2007). Therefore, ANCOVA was not used for the trout species sampled in this survey (including rainbow, brown [*Salmo trutta*], brook [*Salvelinus fontinalis*], lake [*Salvelinus namaycush*], and Eagle Lake trout [*Oncorhynchus mykiss aquilarum*]). Methylmercury was analyzed in composites of 5 individuals. These trout composites were also analyzed for organic contaminants. The size ranges established for trout were based on a combination of sizes prevalent in past sampling (Melwani et al. 2007, 2009) and the 75% rule recommended by USEPA (2000) for composite samples.

Channel catfish and common carp were the primary targets for high lipid bottom-feeders. These species were analyzed for organics, selenium, and methylmercury. Organics were expected to be highest in these species based on past monitoring in the Toxic Substances Monitoring Program and other studies (Davis et al. 2007b). Selenium was expected to be highest in these species, although the difference was not expected to be as distinct as for the organics, based on data from the Grassland Bypass Project (SFEI 2008). Methylmercury was expected to be highest in the pelagic predators, but concentrations were also expected to be above thresholds for concern in the bottom-feeders, so methylmercury was analyzed in these samples as well. Samples for these species were analyzed as composites (Table 2). The size ranges established for bottom-feeders were based on a combination of sizes prevalent in past sampling (Melwani et al. 2007, 2009) and the 75% rule recommended by USEPA (2000) for composite samples. In some lakes only bass were collected. In these cases, composites of the bass samples were created for organics analysis following the same approach (specified size range and the 75% rule) used for the bottom-feeders.

Locations Targeted

Lakes and reservoirs in California vary tremendously in size, from hundreds of small ponds less than 10 ha to Lake Tahoe at 50,000 ha. For larger lakes it is necessary to sample more than one location to obtain a representative characterization of the water body. In addition, it was frequently necessary to sample over a linear course of 0.5 – 1 mile to obtain the desired number of fish. Therefore, sampling locations in this study can be thought of as a circle with a diameter of 1 mile. For small lakes less than 500 ha in size, one sampling location covered a significant fraction of the surface area of the lake and was considered adequate to characterize the lake. However, for larger lakes, sampling of additional locations was performed. For lakes of medium size (500 – 1000 ha), two locations were generally sampled. For lakes in the large category (1000 – 5000 ha) and extra large category (>5000 ha), two to four locations were sampled.

Archiving Strategy

Due to the large number of water bodies to be sampled, the relatively high cost of organics analysis, and an expectation that some of these would be below thresholds for concern, an archiving strategy was developed for composite samples of the bottom-feeder species. Individual samples of the predator species were analyzed for methylmercury only and an archiving strategy was not used. This decision was driven by the low cost of methylmercury analysis and the need for the largest dataset possible for statistical techniques, as described below.

The archiving strategy for composite samples varied somewhat by the size of lake. For small lakes, two composites from one location were collected to represent the entire lake area. Both composites were analyzed immediately for methylmercury, given the low cost of analysis. However, the second composite sample was only analyzed for organics and/or selenium if the first composite sample exceeded a threshold. The threshold for this follow-up analysis was designated as 75% of the threshold for concern (Table 3). These thresholds were based on a draft report by OEHHA that was published in 2006. [NOTE: In OEHHA's final report (Klasing and Brodberg 2008) the thresholds were modified (Table 4). These newer thresholds were used for actually assessing the data in this report.]

For lakes of larger size, composite samples were collected from each discrete location (the number of locations was based on lake size as described above). These composites were homogenized and analyzed immediately for methylmercury, but archived for organics and selenium. Aliquots of homogenate from each location composite were pooled to form a lake-wide composite. The lake-wide composite was analyzed initially for organics and selenium. If the lake-wide composite concentration of any of the organics or selenium exceeded the threshold for follow-up analysis, then all of the discrete location composites were analyzed. This approach avoided expenditure of funds on organics analysis where it was not needed. Aliquots from all composites were archived whether they were analyzed or not, in case of any analytical problems or other circumstances calling for analysis or re-analysis at a later time. In addition, aliquots of some samples were selected for long-term archiving (described further below).

Field Sampling

Sport fish were collected from lakes across the state from June through November in 2007 and 2008 (Figures 1a-d, Tables 1a,b). Fish were collected by Moss Landing Marine Laboratories (MLML) and the California Department of Fish and Game's Water Pollution Control Laboratory (WPCL) staff with electrofisher boats and gill nets. The crew remained on location until the desired number of target species was caught. Total length (longest length from tip of tail fin to tip of nose/mouth), fork length (longest length from fork to tip of nose/mouth), and weight were measured in the field when possible; otherwise these parameters were measured in the lab and this was noted in the database. Latitude and longitude were recorded for every fish collected to document the spatial resolution among locations within a lake. Fish samples were wrapped in aluminum foil and frozen on dry ice for transportation to the laboratory. Cruise reports with detailed information on locations are available atxx: xxhttp://www.swrcb.ca.gov/water_issues/programs/swamp/lakes_study.shtml/.

Sample Processing

Fish were stored at -20°C in their original bags until dissection and homogenization. Homogenates were also frozen until analysis was performed. Dissection and compositing of muscle tissue samples were performed following USEPA guidance (USEPA 2000). At the time of dissection, fish were placed in a clean lab in their original bags to thaw. After thawing, fish were cleaned by rinsing with de-ionized (DI) and ASTM Type II water, and were handled only by personnel wearing polyethylene or powder-free latex gloves (glove type is analyte dependent). All dissection materials were cleaned by scrubbing with Micro® detergent, rinsing with tap water, DI water, and finally ASTM Type II water. All fish were dissected skin-off, and only the fillet muscle tissue was used for analysis.

The labs analyzed the predator species as individuals for methylmercury and composites for organics, and trout and bottom species as composites. For composite samples, a subsample of equal mass was taken from each of 5 individual fish following the 75% size rule recommended by USEPA (2000). Tissue was homogenized with a Büchi B-400 mixer, to form a location composite with a target weight of 200g or greater. A subsequent lake-wide composite was created from equal portions of each contributing location composite within each lake. Post-homogenization aliquots were taken from the lake-wide composite for methylmercury, selenium, and organics analyses. Aliquots for methylmercury and selenium were transferred to pre-cleaned 30ml polypropylene jars. Organics aliquots were transferred to 60 ml borosilicate cleaned jars.

Scales were taken from all black bass individuals and analyzed for age by the counting of growth rings according to the methods found in Campana (2001). These results are in the database generated for this Survey, but not reported in this report. To obtain these data please contact Jay Davis (jay@sfei.org).

Archiving

Aliquots of homogenates of all composite samples analyzed were archived on a short-term basis to provide for reanalysis in case of any mishaps or confirmation. In addition, aliquots of the lakewide homogenates prepared for the bottom-feeder species were made and archived for long-term storage. This will provide a integrative, representative sample for each lake that can be reanalyzed in later years to confirm earlier analyses, look for new chemicals of concern, provide material for application of new analytical methods, provide material for other ecological research, and other purposes. Long-term archiving of the lakewide homogenates is the most cost-effective approach to addressing this need.

Black bass individuals were archived on a short-term basis wrapped in the original aluminum foil. Long-term archives, stored un-homogenized in glass, were created for the 5 individuals within the 75% size rule. The exception to this was when bass composites were created from the lake for organic analysis (when bottom-feeder species were not collected).

Furthermore, long-term archives were created for individuals of all species collected at lakes identified for potential future trend analysis. Each Regional Board identified lakes they were interested in sampling more often and establishing a baseline for trend analysis. A list of trend lakes can be found in Table 3 of the sampling plan for this survey (Davis et al. 2007a). Collections and analyses did not differ at these lakes from the other lakes, however the archiving was more extensive. For trend lakes individual archives were retained for all species and all locations, and where sufficient tissue was present, location and lakewide archives were also retained. Otoliths were extracted from all individuals collected from each of the trend lakes. Otoliths were preserved in alcohol and stored in cryovials for preparation and reading at a later date if funds become available.

Chemical Analysis

Methylmercury and Selenium

Nearly all (>95%) of the mercury present in fish is methylmercury (Wiener et al. 2007). Consequently, monitoring programs usually analyze total mercury as a proxy for methylmercury, as was done in this study. USEPA (2000) recommends this approach, and the conservative assumption be made that all mercury is present as methylmercury to be most protective of human health.

Total mercury and selenium in muscle tissue were measured by Moss Landing Marine Laboratory (Moss Landing, CA).

All samples, blanks, and standards were prepared using clean techniques. ASTM Type II water and analytical grade chemicals were used for all standard preparations. A continuing calibration verification (CCV) was performed after every 10 samples. Samples whose initial or continuing calibration verification values drifted by more than ±20% of the true value were reanalyzed. One to three blanks (depending on analyte), a certified reference material (DORM-2), as well as a method duplicate and matrix spike pairs were run with each analytical batch of samples.

Total mercury in composite samples and individuals were analyzed by Thermal Decomposition, Catalytic Conversion, Amalgamation and Atomic Absorption Spectrophotometry which is described in EPA 7473 (USEPA, 1998) using a Direct Mercury Analyzer (Milestone DMA-80). Approximately 0.1-0.2 g of tissue was removed from either the composite homogenate or individual fillet, weighed and placed into the DMA-80 sample boat. Each sample is ultimately decomposed at 1000°C and the mercury is detected by a single beam spectrophotometer with sequential flow through two measurement cells. Samples were divided into analytical batches of 20 samples plus analytical QA samples (CRM, matrix spike and spike duplicate, duplicate and method blanks). Detection limits for total mercury and all of the other analytes are presented in Table 5.

Approximately 1.25 g of tissue from each composite sample for selenium analysis was weighed and digested by Microwave Assisted Acid Digestion (EPA 3052m) with concentrated nitric acid under pressure at 195°C. Samples were divided into analytical batches of 20 samples plus analytical QA samples (CRM, matrix spike and spike duplicate, duplicate and method blanks) digested simultaneously. Digestates were subsequently analyzed according to EPA 200.8 (USEPA, 1994) by Inductively Coupled Plasma-Mass Spectrometry (Perkin-Elmer ELAN 9000 ICP-MS).

Organics

Trace organics in muscle tissue were measured by the California Department of Fish and Game Water Pollution Control Laboratory (Rancho Cordova, CA).

Pressurized fluid extraction (EPA 3545A) was used for the extraction of organochlorine (OCs) pesticides and polychlorinated biphenyls (PCBs) in fish tissue. Gel permeation chromatography (EPA 3640A) and Florisil column chromatography (EPA 3620C) were used to purify and fractionate the extracts prior to analysis. Gas chromatography with triple quadrupole mass spectrometry (GC-MSMS) was used to analyze OC pesticides and PCBs. Dual column gas chromatography with dual electron capture detectors (GC-ECD) is used to analyze a small list of the more polar target OC pesticides.

Tissue samples containing surrogate compounds were extracted twice using a Dionex Accelerated Solvent Extractor (ASE 200) extractor. A portion of the extract was removed for percent lipid determination. Initial sample cleanup was done by gel permeation (size exclusion) chromatography. Additional cleanup and fractionation were done using Florisil® column chromatography.

A Varian Model 3800/1200L gas chromatograph (GC)/triple quadrupole mass spectrometer equipped with a Model 1177 split-splitless injector with electronic pressure control (EPC) and CombiPal® autosampler was used for all GC-MSMS analyses. The GC is equipped with a J&W Scientific 60 meter, 0.25 mm ID, 0.25 µm (film thickness) XLB column. The injector is operated isothermal at 280 degrees C in splitless mode with pressure pulse (45 psi for 1.05 min). The mass spectrometer is operated in electron impact (EI) ionization MSMS mode using argon as the CID gas. Precursor and product ions were selected to optimize selectivity and sensitivity. Internal standard calibration using carbon 13 isotope labeled pesticides and PCB congeners were used.

An Agilent 6890plus gas chromatograph equipped with two 63Ni micro-electron capture detectors with EPC and autosampler was used to analyze a select list of the more polar pesticides. Two 60 meter, 0.25 mm ID, 0.25 µm (film thickness) fused silica columns (J&W) were used. The injector is operated in splitless mode isothermal at 240 degrees C. Helium is used as the carrier gas at a linear velocity of 35 cm/sec. Nitrogen is used for the detector makeup at 30 mL/min.

Each analysis sequence included a minimum of seven calibration standards. The calibration curve concentration for chlorinated hydrocarbons was 0.5 ppb to 500 ppb. The calibration curve concentration range for polychlorinated biphenyl congeners (PCBs) was 0.5 ppb to 100 ppb. Higher concentrations of PCB standards (50 ppb to 1000 ppb) were analyzed with samples containing higher concentrations of PCBs.

An initial calibration blank and initial calibration verification standard were analyzed after the calibration standards and prior to the first sample extract. Continuing calibration blanks (CCBs) and calibration verification standards (CCVs) were analyzed after ten sample extracts. The CCV analyte concentrations were at the mid-range of the calibration curve (5 – 10 ppb).

A procedural blank, blank spike, matrix spike, matrix spike duplicate, sample duplicate and standard reference material (SRM 1588b-cod liver oil) produced and distributed by the National Institute of Standards and Technology (NIST) was extracted and analyzed with each set of 18 samples. Results of the QC analyses (except the ICVs and CCVs) are evaluated and reported with the data.

PCBs are reported as the sum of 55 congeners (Table 5). Concentrations in many lakes were near or below limits of detection (Table 5). The most abundant congeners were detected in 65-69% of the 364 samples analyzed for PCBs. Frequencies of detection and reporting were lower for the less abundant PCB congeners. Reporting frequencies were lower for some congeners due to blank contamination and other QA issues. For some samples, the sum of congeners was significantly affected by the absence of reportable data for multiple congeners. Most of the censoring was due to blank contamination. If the congeners with censored results comprised more than 30% of the sum for a sample, and the concentration prior to censoring was above the Fish Contaminant Goal (FCG – the lowest threshold for PCBs [see Table 4]), then the sample was designated for reanalysis. Samples with censoring of more than 30% but with uncensored sums below the FCG were not submitted for reanalysis because the sum based on reanalyzed results would be expected to be even lower than the original sum and this would not affect the assessment relative to the FCG.

The relative abundances of the PCB congeners fell within expected ranges, with some samples showing greater influences of Aroclor 1248 (San Luis Reservoir, Silverwood Lake, O'Neill Forebay, Lake Elsinore, Castaic Lake, Brite Valley Lake, Lee Lake/Corona Lake, Perris Reservoir), Aroclor 1254 (Pyramid Lake, Peck Road Water Conservation Park, Alondra Park Lake, Rollins Reservoir, Calero Reservoir), Aroclor 1260 (Chesbro Reservoir, Thermalito Afterbay, Hollenbeck Park Lake, Lake Chabot-San Leandro, Yosemite Lake, Lake Vasona, Hell Hole Reservoir, Little Rock Reservoir), and Aroclor 1262 (Lake Chabot-Vallejo, Santa Fe Reservoir, Isabella Lake, Little Rock Reservoir).

As recommended by USEPA (2000), DDTs are reported as the sum of six isomers and metabolites: p,p'-DDE, o,p'-DDE, p,p'-DDD, o,p'-DDD, p,p'-DDT, and o,p'-DDT. p,p'-DDE, the most abundant DDT isomer, was detected and reported in 93% of the 360 samples analyzed (Table 5). p,p'-DDD was detected second most frequently (71%). The other isomers and metabolites were detected in 30% or less of the samples. None of the DDT results were censored due to QA issues. The relative concentrations of the DDTs fell within expected ranges. The largest contribution of p,p'-DDT to the sum of DDTs was 17% at Lake Piru.

As recommended by USEPA (2000), chlordanes are reported as the sum of five components of technical chlordane: *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor, and oxychlordane. Concentrations in many lakes were near or below limits of detection (Table 5). The most abundant chlordane (*trans*-nonachlor) was detected in 68% of the 360 samples analyzed for chlordanes. The relative abundances of the chlordanes fell within expected ranges.

In calculating sums of PCBs, DDTs, and chlordanes, results below detection limits were set to zero.

Quality Assurance

The samples were digested and analyzed in multiple batches. Batches consisted of up to 20 samples per batch. QAQC samples for the SWAMP Data Quality Objectives (DQOs) (precision, accuracy, recovery, completeness, and sensitivity) were performed for each batch as required by the SWAMP BOG QAPP (Bonnema 2007). DQOs were reviewed and appropriate batch qualifiers assigned by the SWAMP Data Management Team. Measurement Quality Objectives were assessed according to the SWAMP BOG QAPP (see Table 12a and 12b in Bonnema [2007]).

A brief summary of the QA results is provided below. A more detailed summary is presented in Appendix 4. Data were classified as compliant, estimated, and rejected. Rejected data were not included in this report; compliant and estimated data were included. All data are uploaded to the California Environmental Data Exchange Network (CEDEN) but the rejected results will not be made available to the public.

A total of 22 samples did not pass QA review for all pollutants and were rejected. These samples were reanalyzed, new data were re-evaluated and included in this report. Blank contamination issues for PCBs and chlordanes caused these rejections. These results were rejected when the affected samples had a summed value (either sum of PCBs or sum of chlordanes) higher than the FCG and where the final sum was reduced by 30% due to rejection of individual analytes (e.g., PCB congeners).

Blank Contamination

Blank matrices are run with each analytical batch to measure potential contamination of field samples from collection and sample handling. Acceptable blank results are those with values less than the method detection limit (MDL) for a particular analyte. All 579 laboratory method blanks met the MQO with the exception of 14 results in 5 blanks where concentrations of target analytes were detected above the RL in the method blanks (Appendix 4 - Table 2). Target analyte concentrations detected above the MDL in the field samples were compared to the associated method blank concentrations. Results for target analyte concentrations in batches with blank contamination that were less than 3X the blank contamination were classified as “rejected”. Congeners or isomers that make up a significant percentage of the sum of PCBs, sum of chlordanes, or sum of DDTs (PCBs 66, 87, 101, 110, 118, *trans*-chlordane, p,p’-DDE) had rejections for some samples. There were 819 rejections in the dataset. All other results were classified as “compliant”.

Surrogate Spikes

Surrogate spikes are used to assess analyte losses during sample extraction and clean-up procedures, and must be added to every composite and quality control sample prior to extraction. Whenever possible, isotopically-labeled analogs of the analytes should be used.

All surrogate percent recoveries were within the acceptance criteria listed in Appendix 4, Table 1, with the exception of 15 out of 1607 (1%) surrogate percent recoveries spiked in 444 field and laboratory QA/QC samples analyzed for Polychlorinated Biphenyls and Organochlorine Pesticides (Appendix 4, Table 3). The associated analytes in these samples were classified as “estimated” with regard to the BOG MQO for surrogates. No data was rejected.

Accuracy

Certified Reference Materials (CRM), Matrix Spike/ Matrix Spike Duplicates (MS/D), and Laboratory Control Standards (LCS) are the QC elements used to assess the accuracy of an analytical method. Following SWAMP Management Quality Objectives, one QC accuracy element is allowed to fail in a batch and still be compliant. When more than one QC element fails, the analyte, for all batches, was classified as estimated. When the % Recovery was above 200 for more than 1 QC element, the analyte was rejected. In the case where there is only one QC element reported in the batch and the % Recovery was above 200 then the analyte would also be rejected.

According to the BOG QAPP for metal and organic analyses, at least one MS/MSD pair should be performed per 20 samples or one per batch, whichever is more frequent. One percent (2 out of 244) of total batches did not include MS/MSDs performed at the required frequency. These two batches were classified as "estimated".

As required by the BOG QAPP, one CRM or LCS was analyzed per 20 samples or per batch, whichever is more frequent. The required frequency was met for all 244 batches. Laboratory batches with CRM or LCS %R values outside of acceptance criteria were either classified as "compliant" or "estimated" based on the number of QC elements outside criteria. Batches containing CRM or LCS outside of acceptance criteria are presented in Appendix 4 - Table 6. Significant analytes that had some accuracy failures included PCBs 66, 87, 95, 101, 118, cis and *trans*-chlordane, p,p'-DDE, dieldrin, and selenium. All other CRM and LCS %Rs were within acceptance criteria. No analytes were rejected due to accuracy measures.

Precision

Matrix Spike Duplicates (MSD) and Laboratory Duplicates (DUPs) were analyzed to assess laboratory precision. As required by the SWAMP BOG QAPP a duplicate of at least one field sample per batch was processed and analyzed. One percent (2 out of 244) total batches did not include DUPs at the required frequency. These two batches were classified as "estimated".

The duplicate results reported above the RL were compared and the Relative Percent Difference (RPD) was calculated. RPDs, for either the MSD or DUPs, <25% were considered acceptable as specified in the QAPP. RPDs >25% but <50% were classified as estimated. RPDs >50% were classified as rejected. Rejections were applied to the entire batch for an analyte that failed precision. Only two analytes had RPDs above 50% (PCBs 101 and 141, one batch each) (Appendix 4 - Table 8).

Holding Times

Fourteen percent of the results (7,759 out of 55,598 total results) in 6,845 tissue composites were classified as estimated due to holding time exceedances. These results consisted of organochlorine pesticides, PCBs, selenium, and mercury analyses. Tissue samples analyzed for organochlorine pesticides and PCBs, exceeded either the 12 month holding time criterion between collection and extraction or the 40 day holding time criterion from extraction to analysis. Tissue samples analyzed for selenium and mercury exceeded the 12 month holding time criteria between collection and analysis.

QA Summary

There were 55,598 sample results, including tissue composites, composite blind duplicates and laboratory QA/QC samples. Of these:

- 40,003 (72%) were classified as “compliant”;
- 11,998 (21.6%) were classified as “estimated”
- 865 (1.6%) were classified as “rejected”.

Classification of this dataset is summarized as follows:

- 819 results (1.6%) were classified as “rejected” due to blank contamination;
- 108 results were classified as “estimated” due to surrogate recovery exceedances;
- 2900 results were classified as “estimated” due to insufficient QC samples;
- 488 results were classified as “estimated” and 8 results were classified as “rejected” due to percent recovery exceedances;
- 739 results were classified as “estimated” and 38 results were classified as “rejected” due to RPD exceedances; and
- 7,759 results were classified as “estimated” due to holding time exceedances.

Data that met all BOG MQOs as specified in the QAPP were classified as “compliant” and considered usable without further evaluation. Data that failed to meet all program MQOs specified in the BOG QAPP were classified as estimated. Data that were >2X MQO requirements or the result of blank contamination were classified as “rejected”. All data with the exception of the 865 rejected results were considered usable for the intended purpose. A 98% completeness level was attained which met the 90% project completeness goal specified in the BOG QAPP.

Assessment Thresholds

This report compared fish tissue concentrations to two types of thresholds for concern for pollutants in sport fish that were developed by OEHHA (Klasing and Brodberg 2008): Fish Contaminant Goals (FCGs) and Advisory Tissue Levels (ATLs) (Table 4).

FCGs, as described by Klasing and Brodberg (2008), are “estimates of contaminant levels in fish that pose no significant health risk to humans consuming sport fish at a standard consumption rate of one serving per week (or eight ounces [before cooking] per week, or 32 g/day), prior to cooking, over a lifetime and can provide a starting point for OEHHA to assist other agencies that wish to develop fish tissue-based criteria with a goal toward pollution mitigation or elimination. FCGs prevent consumers from being exposed to more than the daily reference dose for non-carcinogens or to a risk level greater than $1x10^{-6}$ for carcinogens (not more than one additional cancer case in a population of 1,000,000 people consuming fish at the given consumption rate over a lifetime). FCGs are based solely on public health considerations without regard to economic considerations, technical feasibility, or the counterbalancing benefits of fish consumption.” For organic pollutants, FCGs are lower than ATLs.

ATLs, as described by Klasing and Brodberg (2008), “while still conferring no significant health risk to individuals consuming sport fish in the quantities shown over a lifetime, were developed with the recognition that there are unique health benefits associated with fish consumption and that the advisory process should be expanded beyond a simple risk paradigm in order to best promote the overall health of the fish consumer. ATLs provide numbers of recommended fish servings that correspond to the range of contaminant concentrations found in fish and are used to provide consumption advice to prevent consumers from being exposed to more than the average daily reference dose for non-carcinogens or to a risk level greater than $1x10^{-4}$ for carcinogens (not more than one additional cancer case in a population of 10,000 people consuming fish at the given consumption rate over a lifetime). ATLs are designed to encourage consumption of fish that can be eaten in quantities likely to provide significant health benefits, while discouraging consumption of fish that, because of contaminant concentrations, should not be eaten or cannot be eaten in amounts recommended for improving overall health (eight ounces total, prior to cooking, per week). ATLs are but one component of a complex process of data evaluation and interpretation used by OEHHA in the assessment and communication of fish consumption risks. The nature of the contaminant data or omega-3 fatty acid concentrations in a given species in a water body, as well as risk communication needs, may alter strict application of ATLs when developing site-specific advisories. For example, OEHHA may recommend that consumers eat fish containing low levels of omega-3 fatty acids less often than the ATL table would suggest based solely on contaminant concentrations. OEHHA uses ATLs as a framework, along with best professional judgment, to provide fish consumption guidance on an ad hoc basis that best combines the needs for health protection and ease of communication for each site.” For methylmercury and selenium, the 3 serving and 2 serving ATLs are lower than the FCGs.

Consistent with the description of ATLs above, the assessments presented in this report are not intended to represent consumption advice.

The OEHHA thresholds do not take into consideration effects of contaminants on wildlife. Exposures and risks to wildlife, such as fish-eating birds, at the concentrations observed in California lakes, are likely to be higher than for humans in some instances. Due to the limits of the funding for this survey of bioaccumulation in California lakes, assessment of risks to wildlife was beyond the scope of this study. A different sampling design, focusing on different indicators (e.g., different fish species – either wildlife prey or fish that are themselves sensitive to pollutant effects – or avian eggs) would be needed to accurately evaluate exposure and risks in sensitive wildlife species. Assessment of the impact of bioaccumulation on aquatic life, though not feasible with the current level of funding, is considered a significant concern and would be evaluated if funding of this program increases sufficiently in the future.

Data Analysis

In comparing results to methylmercury thresholds, concentrations in individuals and location composites were used in a combined assessment. For individual largemouth bass, sufficient data were collected to estimate length-standardized methylmercury concentrations using analysis of covariance with a general linear mixed model. For other species, arithmetic mean concentrations of results for individuals were calculated. Geometric means were not used because the small numbers of concentrations being averaged (usually of composite samples) spanned a narrow range (Costa 2009), and because average data for individual fish were compared to equal-weight composite pooled samples.

In previous studies, largemouth bass have exhibited a strong size:methylmercury relationship when collected over a wide (spanning 150 mm or more) size range (Melwani et al. 2007, 2009; Davis et al. 2008), and have provided reasonable estimations of size-standardized methylmercury concentrations. The general linear model employed here (PROC MIXED in SAS v. 9.1; Littell et al. 1996) used a maximum likelihood approach (Burnham and Anderson 2002) to evaluate the "best" regression model from which to estimate methylmercury concentrations. Once the "best" model was selected, the relationship between fish length and methylmercury concentrations among lakes was tested to obtain the appropriate parameter estimates. The method employed dummy variables to determine differences in means, slopes, and curve shapes. The resulting regression equations were used to calculate predicted methylmercury concentrations (mean and 95% confidence interval) for each lake in a 350 mm (total length) largemouth bass. The 350 mm value was selected to represent the middle of the typical size distribution above the legal limit of 305 mm (12 in) for largemouth bass in California.

Next, average methylmercury concentrations (whether standardized for length or not) were combined with methylmercury concentrations based on composites, by taking the maximum average concentration among species. If multiple composites were analyzed for a given lake and species, the average of these data were calculated prior to taking the maximum among species. These concentrations were then compared to the thresholds selected for methylmercury (Table 4).

To compare concentrations for organic contaminants and selenium to thresholds, the concentrations in bottom species from lake-wide composites, as well as any location composites, were used. Organics and selenium were not measured in individual fish. As with methylmercury, these composite results were compared with the OEHHA thresholds.

To assess statewide condition, the same approach described above was taken. Only the randomly selected lakes provide an unbiased assessment of statewide condition. These lakes were selected using the GRTS approach, and are most appropriate for performing a CDF analysis of lake condition across the state. For methylmercury, the composites and individuals from random lakes were used. For organic contaminants and selenium, the average of composites from small lakes and lake-wide or location composites from medium to large lakes were used. For all contaminants, where multiple species were sampled at a given lake, the maximum average concentration among species was selected.

Candidates for 303(d) Listing

One of the objectives of this survey was to provide information that could be used in evaluating whether a given lake should be included on the 303(d) List for each pollutant. The sampling design was developed specifically to address this objective. To meet listing requirements in a cost-effective manner, additional samples were analyzed for lakes where an initial analysis of a lakewide composite sample showed that concentrations approached a threshold.

This report does not, however, present an assessment for the purposes of 303(d) listing determinations. There are several reasons for this. First, other data and other considerations will factor in to decisions made by the Regional Boards on listing. Second, with the availability of new thresholds recently developed by OEHHA, it is unclear which thresholds will be used by the State and Regional Boards for 303(d) evaluation. Third, the State and Regional Boards will have to decide whether to modify the requirement for replicate samples to possibly include replicates from this study that were collected from the same date and location.

Mapping and GIS Methods

The map figures were designed using ESRI ArcInfo 9.1 software and are in a California Teale Albers NAD 83 Projection. A connection to the GIS from the SWAMP Tissue Database 2.5 (Microsoft Access 2003) was established to display the results of queries that calculated concentrations.

Methods used to delineate the boundaries of watershed of selected individual lakes are described in Melwani et al. (2010).

RESULTS AND DISCUSSION

In this screening study, 4905 fish from 23 species were collected from 272 lakes and reservoirs in California (Figure 1a-c, Tables 1a,b). A concise summary of the data for each lake is provided in Appendix A. More detailed summaries are provided in Appendices B (average and composite concentrations for all samples) and C (results for methylmercury analyses on individual fish). Excel files containing these tables are available from SFEI (contact Jay Davis, jay@sfei.org). All data collected for this study are maintained in the SWAMP database which is managed by the data management team at Moss Landing Marine Laboratories (http://swamp.mpsl.mlml.calstate.edu/). The complete dataset, which may be of use for 303(d) listing determinations, includes QA data (quality control samples and blind duplicates) and additional ancillary information (specific location information, fish sex, weights, etc). It is anticipated that by the fall of 2010, the complete dataset from this study will also be available on the web at http://www.ceden.org/. Finally, data from this study are available on the web through the California Water Quality Monitoring Council's "My Water Quality" portal (http://www.waterboards.ca.gov/mywaterquality/). This site is designed to present data from the Lakes Survey and other studies in a nontechnical manner to the public, and allows mapping and viewing of summary data from each lake.

Methylmercury

Comparison to Thresholds

Methylmercury is the pollutant that poses the most widespread potential health risks to consumers of fish caught from California lakes.

Methylmercury was the only pollutant that frequently reached concentrations high enough that OEHHA would consider recommending no consumption of the contaminated species (0.44 ppm). This degree of contamination was quite prevalent across the state. Overall, 56 of the 272 lakes surveyed (21%) had a species with an average concentration exceeding 0.44 ppm (Table 6, Figure 2). For the random lakes, 23% were above 0.44 ppm (Figure 3a). The 95% confidence interval for this estimate was ±11%. Expressed on an areal basis, an estimated 18% of California lake area was above 0.44 ppm (Figure 3a). For the targeted lakes, 20% were above the 0.44 ppm threshold (Figure 3b). The occurrence of these high mercury lakes showed distinct regional variation. Only 2% of the northern California trout lakes were above 0.44 ppm (Table 6). In contrast, 48% of the lower elevation lakes in northern California were above 0.44 ppm. In southern California, the overall degree of contamination was less severe than in the low elevation lakes of northern California, but the fraction of lakes above 0.44 ppm was still substantial (16%).

Most of the lakes surveyed had some degree of methylmercury contamination. Methylmercury concentrations measured in this study were also very frequently higher than the lowest OEHHA threshold for methylmercury – 0.07 ppm – a concentration at which OEHHA would consider recommending consumption of less than three servings per week. Overall, 68% of the 272 lakes sampled had a methylmercury concentration above the lowest threshold for methylmercury (the 0.07 ppm three serving ATL) (Table 6, Figure 2). In the random sample of 50 lakes, 80% of the lakes had a species with an average methylmercury concentration higher than 0.07 ppm (Figure 3a). The 95% confidence interval for this estimate was 68 – 91%. For the random sample, the percentage was similar expressed on an areal basis (78%). For targeted lakes (n=222), 65% had a species average higher than 0.07 ppm (Figure 3b). Most (71%) of the northern California trout lakes were below 0.07 ppm (Table 6). This was in sharp contrast to lower elevation lakes (below 2000 ft) in northern California, which had only 2% below 0.07 ppm. Concentrations in Southern California were intermediate, with 27% below 0.07 ppm.

Interspecific and Intraspecific Variation

As in past studies (e.g., Davis et al. [2008], Melwani et al. [2009]), clear differences were observed in mercury accumulation among species. As expected, relatively high concentrations were observed in species that are high trophic position predators, including largemouth, smallmouth, and spotted bass and Sacramento pikeminnow (Table 7). For some of these species, however, the averages are based on small sample sizes and therefore are imprecise estimates. Statewide average concentrations in smallmouth and largemouth bass (0.42 and 0.41 ppm, respectively) approached OEHHA's no consumption ATL of 0.44 ppm. Other warmwater species such as common carp, channel catfish, black crappie, and bluegill had moderate methylmercury contamination. Rainbow trout generally had low concentrations of methylmercury, with a statewide average (0.05 ppm) below the lowest OEHHA threshold (the 0.07 ppm three serving ATL).

Trout generally occupy a lower trophic position and accumulate lower concentrations of methylmercury and other pollutants, though exceptions to this pattern occur and were observed in this study (discussed further below). Another factor that probably contributes to lower observed concentrations in trout is that, in many lakes, recently planted hatchery fish are part of the catch. A previous study found that hatchery trout consistently had very low concentrations of methylmercury (rainbow trout from four hatcheries all had less than 0.023 ppm – Grenier et al. 2007).

It is important to note that resident, self-sustaining trout populations in these lakes are likely to have higher concentrations than the hatchery fish that are most readily collected. The results from Hetch Hetchy Reservoir illustrate this point. Hetch Hetchy Reservoir was anomalous among the trout lakes with methylmercury concentrations of 0.96 and 0.54 ppm in composites of brown trout from two distinct locations (Figure 4). One other lake (Loon Lake) also had relatively high concentrations in two composites of brown trout (0.50 and 0.30 ppm). Brown trout from the other nine lakes where they were collected generally had low concentrations (all around 0.10 ppm or less, except for one composite from Hell Hole Reservoir at 0.28 ppm).

While the high concentrations in Hetch Hetchy indicate that the food web in this reservoir is relatively contaminated with methylmercury, two other factors also probably contribute to the anomalous results. First, the brown trout population in Hetch Hetchy is self-sustaining. Hetch Hetchy has not been stocked in many years (Jay Rowan, California Department of Fish and Game, personal communication). As mentioned above, many trout lakes are stocked with fish from hatcheries that past work (Grenier et al. 2007) has indicated are probably low in methylmercury. Hetch Hetchy may be anomalous because the brown trout collected were lifelong residents that had more time to accumulate methylmercury concentrations that are representative of the Hetchy Hetchy food web. Boles (2007) also observed relatively high methylmercury concentrations (0.35 ppm in a composite of five fish) in brown trout from another reservoir (Sly Creek Reservoir in Butte County) with a self-sustaining population. These findings suggest that although the results obtained in this screening study do probably accurately portray concentrations in the predominant catch taken by anglers, they may not be accurate indicators of the degree of contamination of the food webs or self-sustaining fish populations in lakes where extensive planting of hatchery fish occurs. A second factor that could contribute to the high concentrations in brown trout from Hetchy Hetchy Reservoir and Loon Lake is that brown trout are known to switch to piscivory as they get older (Moyle 2002). The brown trout samples with high methylmercury were all above 400 mm in average length, while the samples with lower methylmercury were all below 400 mm (Figure 4).

Rainbow trout showed less variation than brown trout. The highest concentrations of methylmercury in rainbow trout were observed in two composites from Pilarcitos Lake in Region 2 (0.26 and 0.27 ppm). Other lakes with relatively high concentrations in rainbow trout were Jameson Lake in Region 3 (0.19 and 0.27 ppm in two composites) and Mammoth Pool Reservoir in Region 5(0.10 and 0.22 in two composites).

Sacramento sucker had a surprisingly high statewide average (0.27 ppm – Table 7) for a species that primarily consumes algae and detritus, along with lesser amounts of benthic invertebrates (Moyle 2002). Similar concentrations for Sacramento sucker were observed in past sampling (Davis et al. 2008, Melwani et al. 2009). Perhaps their benthic foraging occurs in zones with relatively high rates of net methylmercury production.

Very few California lakes contain predatory fish, such as largemouth bass, with low concentrations of methylmercury (Figure 5). Only 8 of the 143 lakes where largemouth bass were sampled (6%) had average largemouth concentrations of 0.07 ppm or lower. The average (size-adjusted) concentrations observed in lakes with largemouth bass that were below the lowest OEHHA threshold were 0.07 ppm in Lake of the Pines (Region 5), 0.03 ppm in Lake Calabassas and 0.01 ppm in Toluca Lake (Region 4), 0.07 ppm in Prado Lake and 0.03 ppm in Lake Evans (Region 8), and 0.05 ppm in each of three Region 9 lakes (Dixon Lake, Lake Poway, and Lake Wohlford). These lakes stand out as having exceptionally low methylmercury contamination. These low concentrations may be due to variation in ecosystem factors such as water chemistry, productivity, trophic dynamics, wetland presence, or others; or due to variation in sources, such as an absence of mining influence. The influence of these factors was explored and is discussed in further detail below and in a companion paper (Melwani et al. 2010). The low concentrations observed at these lakes indicate that it is indeed possible for lakes in the California landscape, even those with self-sustaining populations of predators, to not have excessive bioaccumulation of methylmercury, and that a management goal for at least some lakes may be to attain concentrations of this magnitude.

A much higher percentage of the low elevation lakes where predators (black bass, Sacramento pikeminnow, striped bass) were not collected had methylmercury concentrations below the 0.07 ppm threshold: 16 of 23 (70%). The species sampled at these lakes (e.g., common carp, channel catfish, black crappie, and bluegill) tend to accumulate lower concentrations of methylmercury.

Limited evaluation of correlations among species could be evaluated with this dataset (Figure 6). The largest sample size was available for largemouth bass and common carp. A fairly strong correlation was observed between these species (R^2=0.59), with bass averaging 1.6 times higher concentrations than carp. Considerable variation around the regression line was observed, especially toward the higher end of the distribution of concentrations. Interestingly, in two locations carp even had higher average concentrations than bass (Lake Isabella: carp 0.40 ppm, bass 0.19 ppm; and Turlock Lake: carp 0.41 ppm, bass 0.23 ppm). Although sample sizes were small, concentrations in largemouth bass also appeared to have consistent relationships with Sacramento sucker, brown bullhead, and channel catfish. Sucker actually tended to have slightly higher concentrations than bass at lakes where the two species were sampled. As discussed above, this is surprising given the presumed lower trophic position of Sacramento sucker. Melwani et al. (2009) also found consistent relationships between largemouth bass and several other species in the Sacramento-San Joaquin Delta region, with Sacramento sucker the only species that did not correlate.

Spatial Patterns

Methylmercury concentrations across the state varied at a regional scale (Table 6, Figure 2). In northern California, low concentrations were commonly observed in high elevation lakes in the Sierra Nevada and Trinity Alps. The highest species averages observed in most of these lakes were below the three-serving ATL (0.07 ppm). Trout (mostly rainbow trout, but a few lakes had brown trout, brook trout, lake trout, or Eagle Lake trout) were the most commonly caught species in these lakes, and, as discussed above, tend to accumulate lower methylmercury concentrations than largemouth bass. For the 87 northern California trout lakes sampled, 71% had a maximum species average below 0.07 ppm, another 16% were between 0.07 and 0.15 ppm, and only of these lakes (1%) had a species average above 0.44 ppm – Hetch Hetchy Reservoir with brown trout at 0.75 ppm (Table 8).

In contrast to the northern California trout lakes, methylmercury concentrations in lower elevation (below 2000 ft) lakes in northern California (Table 6, Figure 2) were almost always higher than the three-serving per week ATL (0.07 ppm), and frequently higher than the no consumption ATL (0.44 ppm). Of the 82 lower elevation lakes sampled in northern California, 48% had a maximum species average above 0.44 ppm, another 34% were between 0.22 and 0.44 ppm, and only two (2%) lakes in this region had a species average below 0.07 ppm. The two lakes that had a methylmercury concentration at or below 0.07 ppm were Lago Los Osos in Region 2 and Lake of the Pines in Region 5. Largemouth bass were not caught at Lago Los Osos – only channel catfish were collected. Lake of the Pines was the only lake in northern California where largemouth bass were collected that had an average concentration at a standard size of 350 mm of 0.07 ppm or lower. Interestingly, the concentration measured at this lake was in sharp contrast to concentrations in 350 mm largemouth at two adjacent lakes: Lake Combie immediately to the south at 0.78 ppm and Zayak/Swan Lake to the north at 0.98 ppm.

Although methylmercury concentrations were generally not as high in southern California, the methylmercury problem is not confined to northern California and its well-known mining regions. Most of the 83 lakes in southern California were between 0.07 and 0.44 ppm (57%), but 16% had a maximum species average above 0.44 ppm

(Table 6). Average concentrations above 0.90 ppm were observed for two lakes in close proximity to each other: Crystal Lake (0.95 ppm in largemouth) and Little Rock Reservoir (0.92 ppm in largemouth). The remaining lakes (27%) in this region had a species average below 0.07 ppm (Table 6, Figure 2). Largemouth bass were collected at only seven of the 22 lakes that were below 0.07 ppm in southern California.

Implications Regarding Sources

Although identifying sources of contamination was not a primary goal of the study, this is one of the broader goals of the SWAMP. With an extensive statewide dataset, an attempt was made to determine whether the results from this study may shed some light on the relative importance of sources of methylmercury uptake such as historic mining activity and atmospheric deposition. Understanding the relative importance of these and other sources has significant implications for management of the methylmercury problem in California.

Two approaches were taken to attempt to discern the importance of different sources. The first approach was quantitative – the development of a statistical model to evaluate the relative importance of many potentially important factors influencing methylmercury bioaccumulation (Melwani et al. 2010). This assessment examined watershed attributes relating to contaminant sources (mercury and gold mining, soil mercury, point sources) and other factors (e.g., watershed area, forested area, wetland area), as well as detailed information on lake attributes, making use of information generated in companion study to develop bioaccumulation factors for lakes (Negrey et al. 2010). This quantitative assessment focused on the 17 lakes where detailed information was available. Melwani et al. (2010) presents this quantitative analysis.

The second approach, presented here, was a qualitative evaluation of the fish methylmercury data in comparison to broad scale datasets on mining and geology. This qualitative effort focused on assessing the potential influence of atmospheric deposition of mercury. Considerable uncertainty surrounds this topic.

It seems certain that atmospheric deposition contributes to food web uptake to some degree. Global atmospheric transport brings a significant quantity of mercury across the Pacific Ocean. Local terrestrial sources of atmospheric mercury then add to this global background. Mercury deposited to surface waters from the atmosphere is considered to have relatively high bioavailability (refxx).

However, the extent of the atmospheric deposition contribution to food web mercury is unclear. At one end of the spectrum is the hypothesis that atmospheric deposition alone could be sufficient to cause the degree of methylmercury bioaccumulation that is observed across California. One major body of evidence in support of this hypothesis is extensive data from other regions in North America where atmospheric deposition is clearly the driver of bioaccumulation (refsxx). In spite of the extensive mining legacy in California, the degree of food web contamination in this state is not much different from that seen across the rest of the continent (discussed further below). An alternative hypothesis is that atmospheric deposition constitutes a lower level background that contributes to, but does not dominate, food web contamination, and that mining legacy or geologic mercury is the primary source of methylmercury in the food web.

The approach taken here to evaluate these hypotheses was to compare patterns in some of the key watershed attributes identified by Melwani et al. (2010) to fish methylmercury at a selected subset of the 272 lake dataset (Table 9). GIS layers developed for the quantitative evaluation were used to generate watershed attribute data for this analysis. A small subset was chosen because even this qualitative evaluation required one labor-intensive step: mapping the watershed boundary of each lake. Accurately delineating the boundaries often involved reconciling conflicting information from different layers and a significant amount of fine scale groundtruthing. The subset of lakes selected for this analysis all had largemouth bass, and included the 14 lakes with the highest bass methylmercury concentrations, the 14 lakes with the lowest concentrations, and the 17 lakes included in the quantitative analysis. It was hoped that any obvious patterns would readily emerge from a comparison of the most contaminated and the cleanest lakes.

As is apparent in Table 9, none of the parameters exhibited a clear association with bass methylmercury. The parameter quantifying the amount of mining activity in a watershed that could be readily estimated was the number of gold and mercury mines in each watershed. This parameter is discussed further below. Few lakes had POTWs in the watershed, making it difficult to discern a compelling pattern, but those that did tended to have low concentrations in fish. Some information was available on average mercury in watershed soils, but the limited scope of this dataset was a constraint. The limited data available suggested that high concentrations of mercury in soil were equally associated with either high or low fish methylmercury, as were the low concentrations of soil mercury. Similarly, there was no clear association of bass methylmercury with either watershed area or forested area. Wetland area in watersheds has been correlated with higher fish methylmercury in other studies, but this pattern was not evident in this dataset (see Melwani et al. [2010] for further discussion of the limitations of the dataset in this regard).

It was hoped that the GIS information on the presence of mercury and/or gold mines in the watersheds might provide definitive information for evaluating the linkage between atmospheric deposition and food web uptake of methylmercury. One form of support for this linkage would be lower concentrations of food web methylmercury in lakes without the influence of mining or other sources aside from atmospheric deposition. Based on available GIS layers, some lakes appeared to have no gold or mercury mines in their watersheds (Table 9). Given the prevalence of mining throughout the state, however, some of these were in regions with significant amounts of mining activity, so they were examined further. On closer inspection, it was found that one lake that was not listed as having mines in the GIS layer did actually have mining influence, specifically Calero Reservoir in Santa Clara County, which probably had some prospecting in its watershed and has a canal that brings in mining-contaminated sediments and water from

Almaden Reservoir (Carrie Austin, SFBRWQCB, personal communication; Tetra Tech [2005]). Other lakes listed as not having mines were very close to mines (within a few miles) even though none were documented within the watershed boundaries. The close proximity to known mines raises uncertainty as to whether small scale mining may have actually occurred within the watershed, as suspected in the case of Calero Reservoir.

Another factor confounding the evaluation of the linkage between the absence of mining and bioaccumulation is the widespread occurrence of mercury-bearing geological formations in California. Many of the lakes without mines in the GIS layer are situated in areas with mercury rich geology. The California Coast Range includes a mercury mineral belt that extends through a large portion of the state (Rytuba 2000, Figure 7). There are two types of mercury deposits in the mercury mineral belt. Silica-carbonate mercury deposits are closely associated with serpentinite and occur along the contacts of serpentinite bodies, typically over a vertical interval of as much as 600 m. Serpentinite occurs widely in California – in the Coast Range, the Klamath Mountains, and in the Sierra Nevada foothills – and is the state rock of California. Hot-spring type mercury deposits are generally found within 100 m of the surface, and commonly occur in and adjacent to volcanic centers (Rytuba 2000). Some lakes that had no mines according to the GIS database were nevertheless in regions with serpentinite (e.g., Lower Crystal Springs) or past or present volcanic or hot spring activity (e.g., San Luis Reservoir) (Figures 8 and 9).

Given the difficulties of conclusively identifying extremely high or low lakes with watersheds free from mining activity or geologic mercury sources based on the GIS database, a broader evaluation was made by identifying broader regions of the state where mining was less prevalent and examining bioaccumulation patterns from lakes in these regions (Figures 10a,b). The reasoning behind this was that a regional absence of mines would be a stronger indication that mining and mercury, gold, or silver deposits were indeed minimal or absent from watersheds in those regions.

One apparently promising region in southern California in the Santa Monica Mountains (see rectangle in Figure 10a, and enlarged map in Figure 10b) appears to have had little mining activity and several lakes sampled in the survey. This region had a cluster of lakes with very low concentrations of methylmercury in largemouth bass (Figure 10b), but one lake in the region had a high concentration (Lake Sherwood at 0.54 ppm). However, according to Kim et al. (2005) this area has a type of geology (Neogene volcanic fields) associated with enriched mercury (Figure 7).

Reservoirs in the East Bay hills (Upper San Leandro Reservoir, San Pablo Reservoir, and Briones Reservoir) in the Bay Area appear to be in regions without volcanic geology in their watersheds based on geologic maps. However, the presence of some mining near these watersheds, some serpentine soils, and an extensive network of faults and the complex geology in this area raises some doubt as to whether soil mercury in these watersheds is indeed uniformly low. Methylmercury concentrations in largemouth from these reservoirs vary considerably: 1.01 ppm in Upper San Leandro Reservoir, 0.48 ppm in San Pablo Reservoir, and 0.16 ppm in Briones Reservoir. If atmospheric deposition truly is the dominant source of mercury to these watersheds, this would support the hypothesis that this source could dominate across the state.

Based on available information, perhaps the strongest candidates for lakes capturing a background atmospheric signal are two lakes with largemouth bass in areas with sedimentary geology (Figure 8) and very close to the coast: Pinto Lake (0.19 ppm) and Little Oso Flaco (0.16 ppm) (Figure 10a). These lakes are appealing in this regard because atmospheric emission and redeposition from mining-contaminated landscapes is significant and could be a major source to inland lakes, but this would not be a factor for these lakes.

Several lakes in the Sierra Nevada were in regions with apparently little mining activity (Figure 10a). Most of these were trout lakes with low concentrations. Due to their usually low trophic position and the common practice of planting, trout are generally not a useful indicator of spatial patterns. However, one trout lake in the Sierra that is quite interesting is Hetch Hetchy, which, as described above, had brown trout with unusually high methylmercury (0.75 ppm). Hetch Hetchy is in a region with little mining activity (Figure 10a), suggesting that atmospheric deposition (either from the global background or re-emission from the motherlode belt) may be the source of the observed contamination.

Further complicating interpretation of statewide patterns of food web contamination relative to sources is the understanding gained from many other studies (e.g., Wiener et al. 2006) that biogeochemistry and trophic dynamics can cause wide variation in food web methylmercury even for lakes with very similar sources.

On an even broader regional scale, the contrast between fish methylmercury in low elevation lakes in northern California and lakes in southern California (Figure 3, Table 6), especially when considering the largemouth bass data (Figure 5), which provide a more comparable dataset, seems to provide evidence of the importance of mining sediments and geological sources. The greater prevalence of high concentrations in northern California appears to be consistent with the presence of the mercury mineral belt and the larger amount of mercury and gold mining activity and the in that region (Figure 10a).

Overall, this analysis suggests that in the active and complex geology of California it is not possible to conclusively determine whether specific watersheds are free from the possible influence of historic mining activity or mercury-enriched geology based solely on available GIS layers. In order to resolve the question of the influence of atmospheric deposition it would be necessary to perform more detailed, site-specific field work to assess the contributions of mining sediment or geology. The simplest approach would be to measure the amount of total mercury in lake sediments and see how this correlates with mercury in the food web. This approach appears promising based on Negrey et al. (2010). To reduce potential variability related to food web structure, a more definitive study would ideally examine accumulation in young-of-the-year fish (Wiener et al. 2007). Another possible approach would be to assess mercury sources through the use of mercury isotopes, which have shown some promise in identifying sources of food web mercury in San Francisco Bay (unpublished data).

Available data appear to support a general conceptual model that includes a combination of atmospheric deposition, legacy contamination from mining, and geological sources as the drivers of methylmercury bioaccumulation in California lakes and reservoirs. Methylmercury concentrations in largemouth bass of approximately 0.2 ppm in two coastal lakes situated relatively far from geologic sources of mercury but very close to the coast may be a reasonable indication of the degree of contamination attributable to the atmospheric background coming across the Pacific Ocean. This background amount of atmospheric deposition can probably lead to significantly higher or lower concentrations in aquatic food webs depending on site-specific biogeochemistry. Emissions from urban areas, historic mining districts, and geological sources lead to increased atmospheric deposition in inland areas adding to the background oceanic input. Mining-contaminated sediments, mercury-rich soils, and other terrestrial sources are transported into aquatic ecosystems and can also contribute to severe food web contamination, with the Guadalupe Reservoir being the most extreme example. Lake biogeochemistry can also greatly dampen or increase the impact of the combined mix of sources. The end result of the interplay of these and other factors is the spatially heterogeneous patchwork of aquatic food web contamination observed in this survey.

Comparison to the National Lakes Survey

USEPA recently published results from a national probabilistic survey of contaminants in fish based on sampling conducted in 2000-2003 (Stahl et al. 2009). The results from this survey provide a national frame of reference for the present study. Unfortunately, the data from the two surveys are not directly comparable for two major reasons. First, the USEPA survey used a similar approach with a predator and a bottom-dweller targeted at each lake. However, USEPA analyzed fillets in the predator, but whole bodies in the bottom-dweller. USEPA consequently presented results for predators and bottom-dwellers separately. Second, USEPA did not make as great an effort to control for size. The sizes of fish collected were more variable and they did not use ANCOVA to estimate concentrations at a standard size. As an example of this, the USEPA data for California largemouth bass are shown in Figure 11. The national survey found that fillets of predators in 49% of the sampled population of lakes had methylmercury concentrations that exceeded the USEPA 0.3 ppm fish tissue criterion for mercury. In comparison, the species with the highest average (usually a predator species) in the 50 random lakes from this survey exceeded 0.3 ppm in 38% of the population. Overall, 35% of the 272 lakes sampled in this survey had a highest species average above 0.3 ppm. The relatively high proportion of trout lakes, the smaller size of predators targeted, and the use of species averages (rather than individual samples) in this survey probably explain the lower percentage of lakes above the threshold in California relative to the rest of the country. Nevertheless, it is noteworthy that the degree of contamination of California lakes documented in this survey is not unusual compared to the rest of the country.

The USEPA survey sampled 18 California lakes. Nine out of 18 (50%) of these lakes had a sample above the USEPA threshold of 0.3 ppm, similar to the national dataset as a whole. In general these data fell within the range of results from the present survey. One exception was Guadalupe Reservoir, which was sampled by USEPA but not in the California survey. The largemouth bass composite sample from Guadalupe Reservoir had a methylmercury concentration of 6.60 ppm, the highest concentration measured in the entire country. The carp composite from Guadalupe Reservoir measured 0.52 ppm, close to the national maximum for bottom dwellers of 0.60 ppm. Exceptionally high methylmercury contamination in Guadalupe Reservoir, downstream of the historic New Almaden mercury mining district, has previously been documented (e.g., Tetra Tech 2005).

Priorities for Further Assessment

Lakes with average methylmercury concentrations of one or more species above 0.44 ppm should be considered high priorities for further assessment to determine the need for consumption guidelines and management actions. Many lakes had concentrations well above the 0.44 ppm threshold (Table 8). Almaden Lake in Santa Clara County (also downstream of New Almaden) had the highest species average methylmercury concentration in this survey: 2.15 ppm in largemouth bass. Other lakes with a species average concentrations above 1 ppm included (all are in 350 mm largemouth bass unless otherwise noted): Lake Pillsbury in Region 1 (1.31 ppm); Upper San Leandro Reservoir (1.01 ppm) and Calero Reservoir (1.05 ppm) in Region 2; Cosumnes River (1.15 ppm), Lower Mokelumne River 7 (1.21 ppm in Sacramento pikeminnow), New Melones Lake (1.12 ppm), and Eastman Lake (1.04 ppm) in Region 5; and Chesbro Reservoir (1.04 ppm) and Lake Nacimiento (1.00 ppm in smallmouth bass [not size-adjusted]) in Region 3. All of these lakes above 1 ppm were in the mercury and gold mining regions in the northern part of the state. Table 8 shows the data for samples at the 61 lakes that had a species average above 0.44 ppm based on either composite samples or the ANCOVA results. Consumption guidelines have already been issued for xx (xx%) of these lakes, but xx (xx%) do not have guidelines.

PCBs

Comparison to Thresholds

PCBs (measured as the sum of 55 congeners) were second to methylmercury in reaching concentrations posing potential health risks to consumers of fish caught from California lakes. However, far fewer lakes had PCB concentrations exceeding OEHHA's higher risk thresholds (Table 10, Figure 12). Overall, only three of the 272 lakes assessed (1.1%) had a species with an average concentration high enough that OEHHA would consider recommending no consumption of the contaminated species (120 ppb). The vast majority of lakes in the survey (92%) were below the three serving ATL for PCBs (21 ppb).

The lowest threshold for PCBs was the FCG (3.6 ppb). For PCBs, 33% of the 272 lakes were above this threshold: 20% of the random lakes and 35% of the targeted lakes (Figures 13a,b). Southern California had a higher percentage of lakes with at least one sample above 3.6 ppb (60%) than lower elevation lakes in northern California (40%) and northern California trout lakes (8%) (Table 10).

The frequency distributions were different for random and targeted lakes (Figures 13a,b). This was due to the relatively extensive sampling of Region 4, the region with the highest PCB concentrations. For the random lakes, the percentages expressed on an areal basis were very similar to those expressed on a per lake basis.

Spatial Patterns

PCB concentrations across the state varied at a regional scale (Table 10, Figure 12). As for methylmercury, in northern California, low concentrations were commonly observed in high elevation lakes in the Sierra Nevada and Trinity Alps. The vast majority of species averages observed in these lakes were below the FCG (3.6 ppb). For the 87 northern California lakes where trout were collected, 92% had a maximum species average below 3.6 ppb, 7% were between 3.6 and 21 ppb (the 3 serving ATL), one lake (1%) was between 21 and 42 ppb (the 2 serving ATL), and none were above 42 ppb. The highest species average measured in this region was 28 ppb in a brown trout sample from Silver Lake in Region 6.

PCB concentrations in low elevation (below 2000 ft) lakes in northern California were greater than those in the trout lakes (Table 10, Figure 12). Of the 82 low elevation lakes sampled in northern California, 60% had a maximum species average below 3.6 ppb, 29% were between 3.6 and 21 ppb, 2% were between 21 and 42 ppb, 7% were between 42 and 120 ppb, and one was above 120 ppb. The one lake with a species average above 120 ppb was Lake Vasona in Region 2, where two common carp composites had an average of 147 ppb (Table 11). The two composites measured 204 and 89 ppb. Average concentrations at two other low elevation lakes from northern California were among the highest concentrations measured in the state (Table 11): Lake Chabot in San Leandro in Region 2 (98 ppb) and San Luis Reservoir in Region 5 (85 ppb).

Southern California was the region with the highest PCB concentrations. Of the 83 lakes in southern California sampled, 40% had a maximum species average below 3.6 ppb, 46% were between 3.6 and 21 ppb, 5% were between 21 and 42 ppb, 7% were between 42 and 120 ppb, and two lakes (2%) were above 120 ppb (Table 10). Average concentrations at four lakes from southern California were among the highest concentrations measured in the state (Table 11): Pyramid Lake (238 ppb in brown bullhead), Elderberry Forebay (131 ppb in channel catfish), and Echo Lake (101 ppb in common carp) in Region 4; and Silverwood Lake (93 ppb in largemouth bass) in Region 6. Pyramid Lake and Elderberry Forebay were the two lakes in southern California exceeding the 120 ppb no consumption ATL. The PCB concentrations observed in largemouth bass in Silverwood Lake are exceptionally high for this species, and much higher than those measured largemouth bass from Pyramid Lake where the higher lipid, bottom-feeding species (brown bullhead) reached the maximum concentrations observed in the entire dataset.

Implications Regarding Sources

The geographic distribution of PCBs measured in California sport fish provides an indication of the location and nature of the principal sources of these chemicals. A review of historic bioaccumulation monitoring of PCBs in California (Davis et al. 2007) found that high concentrations of PCBs tended to occur in areas of historic use or maintenance of electrical equipment. These areas tend to be concentrated in urban centers with high amounts of industrial activity, but also occur in scattered areas across the landscape where electrical equipment or other PCB-containing equipment was used. The many hydroelectric facilities in the state are potential sites of past or present PCB contamination. Similar to methylmercury, significant variation exists among species in their tendency to accumulate PCBs, with high-lipid bottom-feeders like common carp, channel catfish, and brown bullhead accumulating the highest concentrations. Because of this interspecific variation, a map of concentrations in common carp and channel catfish provides a clearer picture of spatial variation (Figure 14). The patchy distribution of PCBs across the state, with lakes with low concentrations observed in most areas and scattered lakes with much higher concentrations, is consistent with contamination by local sources. The Los Angeles and San Francisco Bay regions appear to be exceptions to this general pattern, with a very high prevalence of lakes above the FCG (Figure 14) that may suggest an elevated signal of regional atmospheric deposition. Other urban sources, such as urban runoff and landfill leachates may also contribute to this regional pattern.

Comparison to the National Lakes Survey

USEPA's national lakes survey found that predator fillets in 16.8% of the sampled population of lakes had total PCB tissue concentrations that exceeded a 12 ppb human health risk-based threshold (Stahl et al. 2009). In comparison, the species with the highest average (usually a bottom-feeder species) in the 50 random lakes from this survey exceeded 12 ppb in 13% of the population. Overall, 17% of the 272 lakes sampled in this survey had a highest species average above 12 ppb. The data for this study are not directly comparable to the national data due to the inclusion of high lipid bottom-feeders in these statistics, while the USEPA statistics are only for predators. The disproportionately large sample of lakes from Region 4 in this survey also inflated the number of lakes in this study above the 12 ppb threshold. The median concentration for bottom dwellers (whole body) in the national survey was 13.9 ppb. Median concentrations based on highest species averages in this study were 1.4 ppb for the random lakes and 0.7 ppb for the targeted lakes. Overall, the degree of PCB contamination of California lakes documented in this survey is relatively low compared to the rest of the country.

The USEPA survey sampled bottom dwellers in 11 California lakes. Seven out of 11 (64%) of these lakes had a sample above 12 ppb. In general these samples had higher PCB concentrations than observed in the present study. Particularly high concentrations were measured in Lake Oroville (252 ppb in common carp), Guadalupe Reservoir (103 ppb in common carp), and San Luis Reservoir (102 ppb in Sacramento sucker). This result for San Luis Reservoir was very consistent with results from the present study (average of 85 ppb in common carp - Table 11).

Priorities for Further Assessment

Using the same criterion that was employed for methylmercury (i.e., exceedance of the no consumption ATL - 120 ppb for PCBs) only three lakes (in contrast to 61 for methylmercury) stand out as high priorities for further assessment to determine the need for consumption guidelines and management actions. Pyramid Lake in Region 4 had the highest species average by far for PCBs in the state (224 ppb in brown bullhead), and the highest concentration in a sample (416 ppb in a composite sample) (Table 11). Elderberry Forebay, a lake just 10 miles away from Pyramid Lake, was another lake with an average concentration exceeding 120 ppb (131 ppb in channel catfish) (Table 11). The third lake with an average above 120 ppb was Lake Vasona in Region 2 (146 ppb in common carp) (Table 11).

Other lakes with relatively high PCB concentrations included Echo Lake (average of 101 ppb in common carp), Lake Chabot (San Leandro) (average of 98 ppb in common carp), Silverwood Lake (average of 93 ppb in largemouth bass), and San Luis Reservoir (average of 85 ppb in common carp). The high concentrations in largemouth bass at Silverwood Lake suggest that this water body may warrant further investigation. Consumption guidelines have not been issuedxx for these lakes.

Other Pollutants With Thresholds

OEHHA (Klasing and Brodberg 2008) developed thresholds for four other pollutants that were analyzed in this survey: dieldrin, DDT, chlordane, and selenium. Concentrations of these pollutants infrequently exceeded any threshold, and only one highly unusual lake exceeded any no consumption ATLs (Tables 12-15). Results for these pollutants are briefly summarized below.

Dieldrin

The maximum species averages for dieldrin were below the lowest threshold (the 0.46 ppb FCG) in 80% of all the lakes sampled, including 89% of the northern California trout lakes, 72% of the northern California low elevation lakes, and 73% of the southern California lakes (Table 12, Figure 15). Only one lake out of the 272 lakes sampled exceeded an ATL threshold – Little Oso Flaco Lake, which had an exceptionally high average concentration of 276 ppb based on two goldfish composites. This lake will be discussed further below. The next highest species average measured was 6.6 ppb in common carp from San Luis Reservoir. Only Little Oso Flaco Lake appears to be a high priority for further assessment or action based on dieldrin concentrations.

Little Oso Flaco Lake is a small lake in the midst of agricultural fields and dunes 1.5 miles from the coast in San Luis Obispo County (Figure 16, also shown on Figure 10a). This lake was discussed in the methymercury section as a good candidate for capturing the oceanic atmospheric deposition signal. Probably due to its proximity to agricultural fields, this lake also is noteworthy for its extremely high concentrations of dieldrin, DDTs, and chlordanes. Little Oso Flaco Lake had the highest concentrations in the state for dieldrin and DDT, and one of the highest concentrations of chlordanes.

The USEPA survey (Stahl et al. 2009) appears to have had a low frequency of detection for dieldrin. For the California lakes, quantitative results were reported for only three of 33 samples. Stahl et al. (2009) did not report any national statistics for dieldrin. Two samples from San Luis Reservoir were among the three California samples with reported results. These measurements (7.4 ppb in xx and 3.5 ppb in xx) were consistent with data for this reservoir from the present study.

DDTs

The maximum species averages for DDTs were below the lowest threshold (the 21 ppb FCG) in 87% of all the lakes sampled, including 99% of the northern California trout lakes, 76% of the northern California lower elevation lakes, and 82% of the southern California lakes (Table 13, Figure 17). As for dieldrin, Little Oso Flaco Lake stood out as the only one of 272 lakes exceeding the no consumption ATL of 2100 ppb. DDTs in the two goldfish composites from Little Oso Flaco averaged 7490 ppb. Only one other lake had a sample exceeding the 3 serving ATL threshold for DDTs (520 ppb): Pinto Lake in Region 3, which had a concentration of 557 ppb in a common carp composite (and 290 ppb in a second carp composite). Only Little Oso Flaco Lake appears to be a high priority for further assessment of human health risks due to DDT contamination.

USEPA's national lakes survey found that predator fillets in 1.7% of the sampled population of lakes had concentrations that exceeded the 69 ppb human health risk-based threshold for DDT (Stahl et al. 2009). In comparison, in the present study the species with the highest average (usually a bottom-feeder species) in the 50 random lakes exceeded 12 ppb in 4% of the population. As discussed for PCBs, the data from this study are not directly comparable to the national data due to the inclusion of high lipid bottom-feeders in these statistics, while the USEPA statistics are only for predators. The median concentration for bottom dwellers (whole body) in the national survey was 12.7 ppb. Median concentrations based on highest species averages in this study were 4.1 ppb for the random lakes and 2.7 ppb for the targeted lakes. The maximum concentration observed in the national survey was 1761 ppb. The average concentration observed for Little Oso Flaco Lake in this study (7490 ppb) greatly exceeded all of the concentrations measured by USEPA. With the exception of Little Oso Flaco Lake, the degree of DDT contamination of California lakes documented in this survey is relatively low compared to the rest of the country.

The USEPA survey sampled bottom dwellers in 11 California lakes. Four out of 11 (36%) of these lakes had a sample above 69 ppb. In general these samples had higher DDT concentrations than observed in the present study. Particularly high concentrations were measured in Clear Lake (154 ppb in xx and 106 ppb in xx), San Luis Reservoir (97 ppb in Sacramento sucker), and Guadalupe Reservoir (85 ppb in common carp). The result for San Luis Reservoir was lower than the result from the present study (average of 196 ppb in common carp), but the present study found high variance among three composites at this reservoir (324, 175, and 90 ppb). The USEPA bottom dweller result for Clear Lake was very similar to the concentration observed in common carp at Clear Lake in the present study (134 ppb).

Risks to wildlife from DDT contamination in some lakes are likely to be significant. Based on the degree of contamination observed in this survey, DDT would be expected to exceed thresholds for effects on raptor reproduction in some lakes. In addition to Little Oso Flaco Lake, Pinto Lake, San Luis Reservoir, and Clear Lake, other lakes with relatively high concentrations included Sepulveda Lake (275 ppb in common carp), Perris Reservoir (193 ppb in largemouth bass), Lake del Valle (104 ppb in channel catfish), and Almaden Lake (99 ppb in common carp).

Chlordanes

The maximum species averages for chlordanes were below the lowest threshold (the 5.6 ppb FCG) in 91% of all the lakes sampled, including 99% of the northern California trout lakes, 87% of the northern California lower elevation lakes, and 86% of the southern California lakes (Table 14, Figure 18). None of the ATL thresholds were exceeded in any part of the state. The highest species average measured was 68 ppb in common carp from Almaden Lake in Region 2. The highest concentration measured in any sample was 78 ppb in a common carp composite from Lake Lindero (a second sample in Lake Lindero measured 43 ppb). Other lakes with relatively high concentrations were Lake Chabot (San Leandro) (42 ppb) and Little Oso Flaco Lake (36 ppb).

USEPA compared their predator results to a threshold of 67 ppb for chlordanes. Predator fillets in 0.3% of the national sampled population of lakes had concentrations that exceeded this threshold. Bottom-dweller concentrations in the national survey had a median concentration of 1.65 ppb. Only one lake in the present study had a concentration above 67 ppb (Almaden Lake). Relative to methylmercury and PCBs, none of the lakes sampled appear to be a high priority for further assessment or action based on chlordane concentrations.

Selenium

The maximum species averages for selenium were below the lowest selenium threshold (the 3 serving ATL of 2500 ppb) in 98% of all lakes sampled, including 100% of the northern California trout lakes, 99% of the northern California lower elevation lakes, and 96% of the southern California lakes (Table 15, Figure 19). Only Lake Cunningham (3780 ppb) in Region 2 and Ramer Lake (3020 ppb) and Salton Sea (2580 ppb) in Region 7, and Lake Lindero (2790 ppb) in Region 4 exceeded the 2500 ppb threshold. The highest concentration measured in any sample was 4040 ppb in a common carp composite from Lake Cunningham. Relative to methylmercury and PCBs, none of the lakes sampled appear to be a high priority for further assessment or action based on selenium concentrations.

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Table 1a. **Lakes sampled, ordered by station number.** Note: These station numbers were assigned only for the purpose of identification on these maps. These are not related to the official station identification numbers in the database.

			Lake Size				Lake Selection	
Station Number	Station Name	Regional Board	Small	Medium	Large	Extra-large	Random	Targeted
1	Cave Lake	5	X					X
2	Lily Lake	5	X					X
3	Copco Lake	1	X					X
4	Iron Gate Reservoir	1	X					X
5	Dead Lake	1	X					X
6	Reservoir C	5	X					X
7	Medicine Lake	5	X					X
8	Reservoir F	1	X				X	
9	Lake Shastina	1	X					X
10	Duncan Reservoir	5	X					X
11	Kangaroo Lake	1	X					X
12	Siskiyou Lake	5	X					X
13	Castle Lake	5	X					X
14	Gumboot Lake	5	X					X
15	West Valley Reservoir	5	X				X	
16	Big Lake	5	X					X
17	Moon Lake	5			X		X	
18	Iron Canyon Reservoir	5	X					X
19	Lake Britton	5	X					X
20	Tunnel Reservoir	5	X				X	
21	Dodge Reservoir	6	X					X
22	Trinity Lake	1				X		X
23	Lewiston Lake	1	X					X
24	Shasta Lake	5				X		X
25	Crater Lake	6	X				X	
26	Whiskeytown Lake	5			X			X
27	Eagle Lake	6				X		X
28	North Battle Creek Reservoir	5	X					X
29	Butte Lake	5	X					X
30	McCumber Reservoir	5	X					X
31	Lake California	5	X				X	
32	Ruth Lake	1	X					X
33	Lake Almanor	5				X		X
34	Finger Lake	5	X				X	
35	Antelope Lake	5	X					X
36	Butt Valley Reservoir	5		X				X
37	Lake Davis	5			X			X
38	Frenchman Lake	5		X				X
39	Lower Bucks Lake	5	X				X	
40	Howard Lake	1	X					X
41	Bucks Lake	5		X				X
42	Paradise Lake	5	X					X
43	Black Butte Lake	5			X			X
44	Little Grass Valley Reservoir	5		X				X
45	Plaskett Lake	1	X					X
46	Gold Lake	5	X					X
47	Lake Oroville	5				X		X
48	Stony Gorge Reservoir	5		X				X
49	Jackson Meadow Reservoir	5	X					X
50	Cleone Lake	1	X					X
51	Stampede Reservoir	6			X			X
52	Thermalito Afterbay	5		X			X	
53	Bowman Lake	5	X					X
54	New Bullards Bar Reservoir	5			X			X
55	Faucherie Lake	5	X					X
56	Lake Pillsbury	1		X				X
57	Boca Reservoir	6	X					X
58	Feeley Lake	5	X				X	
59	Prosser Creek Reservoir	6	X					X
60	Fuller Lake	5	X				X	
61	Lake Spaulding	5	X					X
62	Collins Lake	5	X					X
63	East Park Reservoir	5		X				X

Table 1a. (continued) Lakes sampled, ordered by station number. Note: These station numbers were assigned only for the purpose of identification on these maps. These are not related to the official station identification numbers in the database.

			Lake Size				Lake Selection	
Station Number	Station Name	Regional Board	Small	Medium	Large	Extra-large	Random	Targeted
64	Donner Lake	6	X					X
66	Kidd Lake	5	X				X	
67	Harry L Englebright Lak	5	X					X
68	Scotts Flat Reservoir	5	X					X
69	Lake Mendocino	1		X				X
70	Blue Lakes	5	X					X
71	Lower Blue Lake	5	X				X	
72	Rollins Reservoir	5	X					X
73	Big Reservoir	5	X					X
74	Zayak/Swan Lake	5	X				X	
75	French Meadows Reservoir	5		X				X
76	Lake Tahoe	6				X		X
77	Hell Hole Reservoir	5		X				X
78	Lake of the Pines	5	X				X	
79	Camp Far West Reservoir	5		X				X
80	Lake Combie	5	X				X	
81	Loon Lake	5	X					X
82	Clear Lake	5				X		X
83	Fallen Leaf Lake	6		X				X
84	Stump Meadow Lake	5	X				X	
85	Union Valley Reservoir	5		X				X
86	Ice House Reservoir	5	X					X
87	Indian Creek Reservoir	6	X					X
88	Folsom Lake	5			X			X
89	Jenkinson Lake	5	X					X
90	Lake Sonoma	1		X				X
91	Caples Lake	5	X					X
92	Topaz Lake	6	X					X
93	Silver Lake	5	X					X
94	Lake Natomas	5	X					X
95	Upper Blue Lake	5	X					X
96	Lower Blue Lake (Alpine Count	5	X					X
97	Lake Berryessa	5				X		X
98	Lake Henne	2	X				X	
99	Lower Bear River Reservoir	5	X					X
100	Lake Alpine	5	X					X
101	Spring Lake	1	X					X
102	Spicer Meadow Reservoir	5	X					X
103	Lake Madigan	2	X				X	
104	Lake Amador	5	X					X
105	White Pines Lake	5	X				X	
106	Bridgeport Reservoir	6		X				X
107	Meadows Slough	5	X				X	
108	Cosumnes River	5	X				X	
109	Camanche Reservoir	5			X			X
110	Beardsley	5	X					X
111	Pinecrest	5	X					X
112	New Hogan Lake	5			X			X
113	Upper Twin Lake	6	X				X	
114	Soulejoule Lake	2	X					X
115	Lake Chabot (Vallejo)	2	X					X
116	Nicasio Lake	2	X					X
117	Unnamed Lake 2	5	X				X	
118	Virginia Lakes	6	X					X
119	Lundy Lake	6	X					X
120	Saddlebag Lake	6	X					X
121	Contra Loma Reservoir	5	X					X
122	Yosemite Lake	5	X					X
123	New Melones Lake	5		X				X
124	Bon Tempe Lake	2	X					X
125	Hetch Hetchy Reservoir	5		X			X	
126	Ellery Lake	6	X					X
127	Tioga Lake	6	X					X

Table 1a. (continued) Lakes sampled, ordered by station number. Note: These station numbers were assigned only for the purpose of identification on these maps. These are not related to the official station identification numbers in the database.

			Lake Size				Lake Selection	
Station Number	Station Name	Regional Board	Small	Medium	Large	Extra-large	Random	Targeted
128	Briones Reservoir	2	X				X	
129	San Pablo Reservoir	2	X					X
130	Discovery Bay	5	X				X	
131	Tulloch Reservoir	5	X					X
132	Lafayette Reservoir	2	X					X
133	Woodward Reservoir	5		X				X
134	Grant Lake	6	X					X
135	Los Vaqueros Reservoir	5		X				X
136	June Lake	6	X					X
137	Silver Lake (Region 6)	6	X					X
138	Upper San Leandro Reservoir	2	X				X	
139	Gull Lake	6	X					X
140	Lake Chabot (San Leandro)	2	X				X	
141	Don Pedro Reservoir	5			X			X
142	La Grange Reservoir	5	X				X	
143	Shadow Cliffs Reservoir	2	X					X
144	Modesto Reservoir	5		X				X
145	Lake McClure	5			X			X
146	Twin Lakes	6	X					X
147	Lake Mamie	6	X					X
148	Lake Mary	6	X					X
149	Lake George	6	X					X
150	Lake Crowley	6			X			X
151	Turlock Lake	5			X			X
152	Lake del Valle	2	X					X
153	Convict Lake	6	X					X
154	Lago Los Osos	2	X				X	
155	Pilarcitos Lake	2	X				X	
156	Lake Elizabeth	2	X					X
157	Lower Crystal Springs Reserv	2	X				X	
158	Lake McSwain	5	X					X
159	Calaveras Reservoir	2		X			X	
160	Rock Creek Lake	6	X					X
161	Pleasant Valley Reservoir	6	X					X
162	Mammoth Pool Reservoir	5	X					X
163	Lake Cunningham	2	X					X
164	Bass Lake	5	X					X
165	Stevens Creek Reservoir	2	X					X
166	Florence Lake	5	X					X
167	Lake Vasona	2	X					X
168	Almaden Lake	2	X					X
169	Huntington Lake	5		X				X
170	Eastman Lake	5		X				X
171	Lake Sabrina	6	X					X
172	Oiger Quarry Ponds	2	X				X	
173	Calero Reservoir	2	X					X
174	Anderson Lake	2	X					X
175	Hensley Lake	5		X				X
176	Chesbro Reservoir	3	X					X
177	Loch Lomond Reservoir	3	X					X
178	Coyote Lake	2	X					X
179	Courtright Reservoir	5		X				X
180	O'Neill Forebay	5		X				X
181	Uvas Reservoir	3	X					X
182	Millerton Lake	5			X			X
183	Wishon Reservoir	5	X					X
184	San Luis Reservoir	5				X		X
185	Los Banos Reservoir	5	X					X
186	Pinto Lake	3	X					X
187	Pine Flat Lake	5			X		X	
188	Unnamed Lake 1	5	X				X	
189	Hume Lake	5	X					X
190	Marsh in Fresno Slough	5	X				X	

Table 1a. (continued) Lakes sampled, ordered by station number. Note: These station numbers were assigned only for the purpose of identification on these maps. These are not related to the official station identification numbers in the database.

			Lake Size				Lake Selection	
Station Number	**Station Name**	**Regional Board**	**Small**	**Medium**	**Large**	**Extra-large**	**Random**	**Targeted**
191	Lake Kaweah	5		X				X
192	Hernandez Reservoir	3	X					X
193	Success Lake	5			X			X
194	Lake San Antonio	3			X			X
195	Lake Nacimiento	3			X			X
196	Isabella Lake	5			X			X
197	Santo Margarita Lake	3	X					X
198	Lake Webb	5	X					X
199	Lopez Lake	3	X					X
200	Brite Valley Lake	5	X					X
201	Little Oso Flaco Lake	3	X					X
202	Castac Lake	5	X				X	
203	Apollo Lake	6	X					X
204	Lake Hughes	4	X					X
205	Elizabeth Lake	4	X					X
206	Pyramid Lake	4		X				X
207	Elderberry Forebay	4	X				X	
208	Lake Cachuma	3			X			X
209	Palmdale Lake	6	X				X	
210	Castaic Lake	4		X				X
211	Castaic Lagoon	4	X					X
212	Spring Valley Lake	6	X				X	
213	Jameson Lake	3	X				X	
214	Little Rock Reservoir	6	X					X
215	Lake Piru	4	X					X
216	Lake Havasu	7				X		X
217	Lake Casitas	4		X				X
218	Crystal Lake	4	X					X
219	Gene Wash Reservoir	7	X				X	
220	Silverwood Lake	6	X					X
221	Hansen Lake	4	X					X
222	Lake Arrowhead	6	X					X
223	Big Bear Lake	8			X			X
224	Lake Gregory	6	X					X
225	Balboa Lake	4	X					X
226	Sepulveda Lake	4	X					X
227	Lake Calabasas	4	X					X
228	Lake Lindero	4	X					X
229	Toluca Lake	4	X					X
230	Westlake Lake	4	X					X
231	Lake Sherwood	4	X					X
232	Las Virgenes Reservoir	4	X				X	
233	Santa Fe Reservoir	4	X					X
234	Malibou Lake	4	X				X	
235	Peck Road Water Conservatior	4	X					X
236	Puddingstone Reservoir	4	X					X
237	Echo Lake (Reg 4)	4	X					X
238	Lincoln Park Lake	4	X					X
239	Hollenbeck Park Lake	4	X					X
240	Belvedere Park Lake	4	X					X
241	Legg Lake	4	X					X
242	Ken Hahn Park Lake	4	X					X
243	Lake Evans	8	X					X
244	John Ford Park Lake	4	X					X
245	Prado Lake	8	X					X
246	Alondra Park Lake	4	X					X
247	Perris Reservoir	8		X				X
248	Lake Mathews	8			X		X	
249	El Dorado Lakes	4	X					X
250	Harbor Lake (Lake Machado)	4	X					X
251	Irvine Lake	8	X					X
252	Lee Lake/Corona Lake	8	X					X
253	Lake Hemet	8	X					X

Table 1a. (continued) Lakes sampled, ordered by station number. Note: These station numbers were assigned only for the purpose of identification on these maps. These are not related to the official station identification numbers in the database.

Station Number	Station Name	Regional Board	Lake Size				Lake Selection	
			Small	Medium	Large	Extra-large	Random	Targeted
254	Lake Elsinore	8		X				X
255	Lake Cahuilla	7	X					X
256	Salton Sea	7				X		X
257	Lake Henshaw	9		X				X
258	Lake Wohlford	9	X					X
259	Dixon Lake	9	X					X
260	Lake Sutherland	9	X					X
261	Ramer Lake	7	X					X
262	Lake Hodges	9	X					X
263	Wiest Lake	7	X					X
264	Lake Poway	9	X					X
265	Ferguson Lake	7	X				X	
266	San Vicente Reservoir	9	X					X
267	Senator Wash Reservoir	7	X				X	
268	El Capitan Lake	9		X				X
269	Lake Jennings	9	X					X
270	Loveland Reservoir	9	X				X	
271	Sweetwater Reservoir	9	X					X
272	Morena Reservoir	9	X					X
273	Lower Otay Reservoir	9	X					X

Table 1b. **Lakes sampled, ordered by name.** Note: These station numbers were assigned only for the purpose of identification on these maps. These are not related to the official station identification numbers in the database.

Station Number	Station Name	Regional Board	Lake Size				Lake Selection	
			Small	Medium	Large	Extra-large	Random	Targeted
168	Almaden Lake	2	X					X
246	Alondra Park Lake	4	X					X
174	Anderson Lake	2	X					X
35	Antelope Lake	5	X					X
203	Apollo Lake	6	X					X
225	Balboa Lake	4	X					X
164	Bass Lake	5	X					X
110	Beardsley	5	X					X
240	Belvedere Park Lake	4	X					X
223	Big Bear Lake	8			X			X
16	Big Lake	5	X					X
73	Big Reservoir	5	X					X
43	Black Butte Lake	5			X			X
70	Blue Lakes	5	X					X
57	Boca Reservoir	6	X					X
124	Bon Tempe Lake	2	X					X
53	Bowman Lake	5	X					X
106	Bridgeport Reservoir	6		X				X
128	Briones Reservoir	2	X				X	
200	Brite Valley Lake	5	X					X
41	Bucks Lake	5		X				X
36	Butt Valley Reservoir	5		X				X
29	Butte Lake	5	X					X
159	Calaveras Reservoir	2		X			X	
173	Calero Reservoir	2	X					X
109	Camanche Reservoir	5			X			X
79	Camp Far West Reservoir	5		X				X
91	Caples Lake	5	X					X
202	Castac Lake	5	X				X	
211	Castaic Lagoon	4	X					X
210	Castaic Lake	4		X				X
13	Castle Lake	5	X					X
1	Cave Lake	5	X					X
176	Chesbro Reservoir	3	X					X
82	Clear Lake	5				X		X
50	Cleone Lake	1	X					X
62	Collins Lake	5	X					X
121	Contra Loma Reservoir	5	X					X
153	Convict Lake	6	X					X
3	Copco Lake	1	X					X
108	Cosumnes River	5	X				X	
179	Courtright Reservoir	5		X				X
178	Coyote Lake	2	X					X
25	Crater Lake	6	X				X	
218	Crystal Lake	4	X					X
5	Dead Lake	1	X					X
130	Discovery Bay	5	X				X	
259	Dixon Lake	9	X					X
21	Dodge Reservoir	6	X					X
141	Don Pedro Reservoir	5			X			X
64	Donner Lake	6	X					X
10	Duncan Reservoir	5	X					X
27	Eagle Lake	6				X		X
63	East Park Reservoir	5		X				X
170	Eastman Lake	5		X				X
237	Echo Lake (Reg 4)	4	X					X
268	El Capitan Lake	9		X				X
249	El Dorado Lakes	4	X					X
207	Elderberry Forebay	4	X				X	
205	Elizabeth Lake	4	X					X
126	Ellery Lake	6	X					X
83	Fallen Leaf Lake	6		X				X
55	Faucherie Lake	5	X					X
58	Feeley Lake	5	X				X	
265	Ferguson Lake	7	X				X	
34	Finger Lake	5	X				X	
166	Florence Lake	5	X					X

Table 1b. (continued) Lakes sampled, ordered by name. Note: These station numbers were assigned only for the purpose of identification on these maps. These are not related to the official station identification numbers in the database.

			Lake Size				Lake Selection	
Station Number	Station Name	Regional Board	Small	Medium	Large	Extra-large	Random	Targeted
88	Folsom Lake	5			X			X
75	French Meadows Reservoir	5		X				X
38	Frenchman Lake	5		X				X
60	Fuller Lake	5	X				X	
219	Gene Wash Reservoir	7	X				X	
46	Gold Lake	5	X					X
134	Grant Lake	6	X					X
139	Gull Lake	6	X					X
14	Gumboot Lake	5	X					X
221	Hansen Lake	4	X					X
250	Harbor Lake (Lake Machado)	4	X					X
67	Harry L Englebright Lak	5	X					X
77	Hell Hole Reservoir	5		X				X
175	Hensley Lake	5		X				X
192	Hernandez Reservoir	3	X					X
125	Hetch Hetchy Reservoir	5		X			X	
239	Hollenbeck Park Lake	4	X					X
40	Howard Lake	1	X					X
189	Hume Lake	5	X					X
169	Huntington Lake	5		X				X
86	Ice House Reservoir	5	X					X
87	Indian Creek Reservoir	6	X					X
18	Iron Canyon Reservoir	5	X					X
4	Iron Gate Reservoir	1	X					X
251	Irvine Lake	8	X					X
196	Isabella Lake	5			X			X
49	Jackson Meadow Reservoir	5	X					X
213	Jameson Lake	3	X				X	
89	Jenkinson Lake	5	X					X
244	John Ford Park Lake	4	X					X
136	June Lake	6	X					X
11	Kangaroo Lake	1	X					X
242	Ken Hahn Park Lake	4	X					X
66	Kidd Lake	5	X				X	
142	La Grange Reservoir	5	X				X	
132	Lafayette Reservoir	2	X					X
154	Lago Los Osos	2	X				X	
33	Lake Almanor	5				X		X
100	Lake Alpine	5	X					X
104	Lake Amador	5	X					X
222	Lake Arrowhead	6	X					X
97	Lake Berryessa	5				X		X
19	Lake Britton	5	X					X
208	Lake Cachuma	3			X			X
255	Lake Cahuilla	7	X					X
227	Lake Calabasas	4	X					X
31	Lake California	5	X				X	
217	Lake Casitas	4		X				X
140	Lake Chabot (San Leandro)	2	X				X	
115	Lake Chabot (Vallejo)	2	X					X
80	Lake Combie	5	X				X	
150	Lake Crowley	6			X			X
163	Lake Cunningham	2	X					X
37	Lake Davis	5			X			X
152	Lake del Valle	2	X					X
156	Lake Elizabeth	2	X					X
254	Lake Elsinore	8		X				X
243	Lake Evans	8	X					X
149	Lake George	6	X					X
224	Lake Gregory	6	X					X
216	Lake Havasu	7				X		X
253	Lake Hemet	8	X					X
98	Lake Henne	2	X				X	
257	Lake Henshaw	9		X				X
262	Lake Hodges	9	X					X
204	Lake Hughes	4	X					X
269	Lake Jennings	9	X					X

Table 1b. (continued) Lakes sampled, ordered by name. Note: These station numbers were assigned only for the purpose of identification on these maps. These are not related to the official station identification numbers in the database.

			Lake Size				Lake Selection	
Station Number	Station Name	Regional Board	Small	Medium	Large	Extra-large	Random	Targeted
191	Lake Kaweah	5		X				X
228	Lake Lindero	4	X					X
103	Lake Madigan	2	X				X	
147	Lake Mamie	6	X					X
148	Lake Mary	6	X					X
248	Lake Mathews	8			X		X	
145	Lake McClure	5			X			X
158	Lake McSwain	5	X					X
69	Lake Mendocino	1		X				X
195	Lake Nacimiento	3			X			X
94	Lake Natomas	5	X					X
78	Lake of the Pines	5	X				X	
47	Lake Oroville	5				X		X
56	Lake Pillsbury	1		X				X
215	Lake Piru	4	X					X
264	Lake Poway	9	X					X
171	Lake Sabrina	6	X					X
194	Lake San Antonio	3			X			X
9	Lake Shastina	1	X					X
231	Lake Sherwood	4	X					X
90	Lake Sonoma	1		X				X
61	Lake Spaulding	5	X					X
260	Lake Sutherland	9	X					X
76	Lake Tahoe	6				X		X
167	Lake Vasona	2	X					X
198	Lake Webb	5	X					X
258	Lake Wohlford	9	X					X
232	Las Virgenes Reservoir	4	X				X	
252	Lee Lake/Corona Lake	8	X					X
241	Legg Lake	4	X					X
23	Lewiston Lake	1	X					X
2	Lily Lake	5	X					X
238	Lincoln Park Lake	4	X					X
44	Little Grass Valley Reservoir	5		X				X
201	Little Oso Flaco Lake	3	X					X
214	Little Rock Reservoir	6	X					X
177	Loch Lomond Reservoir	3	X					X
81	Loon Lake	5	X					X
199	Lopez Lake	3	X					X
185	Los Banos Reservoir	5	X					X
135	Los Vaqueros Reservoir	5		X				X
270	Loveland Reservoir	9	X				X	
99	Lower Bear River Reservoir	5	X					X
71	Lower Blue Lake	5	X				X	
96	Lower Blue Lake (Alpine County)	5	X					X
39	Lower Bucks Lake	5	X				X	
157	Lower Crystal Springs Reserv	2	X				X	
273	Lower Otay Reservoir	9	X					X
119	Lundy Lake	6	X					X
234	Malibou Lake	4	X				X	
162	Mammoth Pool Reservoir	5	X					X
190	Marsh in Fresno Slough	5	X				X	
30	McCumber Reservoir	5	X					X
107	Meadows Slough	5	X				X	
7	Medicine Lake	5	X					X
182	Millerton Lake	5			X			X
144	Modesto Reservoir	5		X				X
17	Moon Lake	5			X		X	
272	Morena Reservoir	9	X					X
54	New Bullards Bar Reservoir	5			X			X
112	New Hogan Lake	5			X			X
123	New Melones Lake	5		X				X
116	Nicasio Lake	2	X					X
28	North Battle Creek Reservoir	5	X					X
172	Oiger Quarry Ponds	2	X				X	
180	O'Neill Forebay	5		X				X
209	Palmdale Lake	6	X				X	

Table 1b. (continued) Lakes sampled, ordered by name. Note: These station numbers were assigned only for the purpose of identification on these maps. These are not related to the official station identification numbers in the database.

			Lake Size				Lake Selection	
Station Number	Station Name	Regional Board	Small	Medium	Large	Extra-large	Random	Targeted
42	Paradise Lake	5	X					X
235	Peck Road Water Conservation Park	4	X					X
247	Perris Reservoir	8		X				X
155	Pilarcitos Lake	2	X				X	
187	Pine Flat Lake	5			X		X	
111	Pinecrest	5	X					X
186	Pinto Lake	3	X					X
45	Plaskett Lake	1	X					X
161	Pleasant Valley Reservoir	6	X					X
245	Prado Lake	8	X					X
59	Prosser Creek Reservoir	6	X					X
236	Puddingstone Reservoir	4	X					X
206	Pyramid Lake	4		X				X
261	Ramer Lake	7	X					X
6	Reservoir C	5	X					X
8	Reservoir F	1	X				X	
160	Rock Creek Lake	6	X					X
72	Rollins Reservoir	5	X					X
32	Ruth Lake	1	X					X
120	Saddlebag Lake	6	X					X
256	Salton Sea	7				X		X
184	San Luis Reservoir	5				X		X
129	San Pablo Reservoir	2	X					X
266	San Vicente Reservoir	9	X					X
233	Santa Fe Reservoir	4	X					X
197	Santo Margarita Lake	3	X					X
68	Scotts Flat Reservoir	5	X					X
267	Senator Wash Reservoir	7	X				X	
226	Sepulveda Lake	4	X					X
143	Shadow Cliffs Reservoir	2	X					X
24	Shasta Lake	5				X		X
93	Silver Lake	5	X					X
137	Silver Lake (Region 6)	6	X					X
220	Silverwood Lake	6	X					X
12	Siskiyou Lake	5	X					X
114	Soulejoule Lake	2	X					X
102	Spicer Meadow Reservoir	5	X					X
101	Spring Lake	1	X					X
212	Spring Valley Lake	6	X				X	
51	Stampede Reservoir	6			X			X
165	Stevens Creek Reservoir	2	X					X
48	Stony Gorge Reservoir	5		X				X
84	Stump Meadow Lake	5	X				X	
193	Success Lake	5			X			X
271	Sweetwater Reservoir	9	X					X
52	Thermalito Afterbay	5		X			X	
127	Tioga Lake	6	X					X
229	Toluca Lake	4	X					X
92	Topaz Lake	6	X					X
22	Trinity Lake	1				X		X
131	Tulloch Reservoir	5	X					X
20	Tunnel Reservoir	5	X				X	
151	Turlock Lake	5			X			X
146	Twin Lakes	6	X					X
85	Union Valley Reservoir	5		X				X
188	Unnamed Lake 1	5	X				X	
117	Unnamed Lake 2	5	X				X	
95	Upper Blue Lake	5	X					X
138	Upper San Leandro Reservoir	2	X				X	
113	Upper Twin Lake	6	X				X	
181	Uvas Reservoir	3	X					X
118	Virginia Lakes	6	X					X
15	West Valley Reservoir	5	X				X	
230	Westlake Lake	4	X					X
26	Whiskeytown Lake	5			X			X
105	White Pines Lake	5	X				X	
263	Wiest Lake	7	X					X

Table 1b. (continued) Lakes sampled, ordered by name. Note: These station numbers were assigned only for the purpose of identification on these maps. These are not related to the official station identification numbers in the database.

			Lake Size				Lake Selection	
Station Number	Station Name	Regional Board	Small	Medium	Large	Extra-large	Random	Targeted
183	Wishon Reservoir	5	X					X
133	Woodward Reservoir	5		X				X
122	Yosemite Lake	5	X					X
74	Zayak/Swan Lake	5	X				X	

Table 2. **Scientific and common names of fish species collected,** the number of lakes in which they were sampled, their minimum, median, and maximum total lengths (mm), and whether they were analyzed as composites or individuals.

Species Name	Common Name	Number of Lakes Sampled	Minimum Length (mm)	Median Length (mm)	Maximum Length (mm)	Analyzed as Composites	Analyzed as Individuals
Pomoxis nigromaculatus	Black Crappie	3	225	290	335	x	
Lepomis macrochirus	Bluegill	2	117	135	165	x	
Salvelinus fontinalis	Brook Trout	2	200	264	308	x	
Ameiurus nebulosus	Brown Bullhead	13	149	292	417	x	
Salmo trutta	Brown Trout	12	203	347	485	x	x
Ictalurus punctatus	Channel Catfish	12	386	509	766	x	
Cyprinus carpio	Common Carp	78	290	551	886	x	x
Oncorhynchus mykiss aquilarum	Eagle Lake Trout	1	448	504	547	x	
Carassius auratus	Goldfish	1	309	333	350	x	
Mylopharodon conocephalus	Hardhead	1	140	148	161	x	
Lavinia exilicauda	Hitch	1	204	240	292	x	
Oncorhynchus nerka	Kokanee	2	326	343	359		x
Salvelinus namaycush	Lake Trout	2	356	408	460	x	x
Micropterus salmoides	Largemouth Bass	144	157	350	623	x	x
Lepomis gibbosus	Pumpkinseed	1	120	135	150	x	
Oncorhynchus mykiss	Rainbow Trout	79	140	301	598	x	x
Lepomis microlophus	Redear Sunfish	1	206	220	242	x	
Ptychocheilus grandis	Sacramento Pikeminnow	2	354	407	493	x	x
Catostomus occidentalis	Sacramento Sucker	15	211	431	564	x	
Micropterus dolomieu	Smallmouth Bass	10	151	309	529	x	x
Micropterus punctulatus	Spotted Bass	2	126	248	480		x
Morone saxatilis	Striped Bass	1	486	534	582	x	x
Tilapia leucosticta	Tilapia	1	253	276	299	x	

Table 3. Thresholds selected for triggering followup analysis of archived composite samples. Triggers were 75% of a threshold for concern (see Davis et al. 2007a). All samples were analyzed for mercury, so a threshold for followup analysis was not needed.

Pollutant	Threshold for Followup Analysis (ppb wet weight)
PCBs	22
DDTs	622
Dieldrin	18
Chlordanes	225
Selenium	2,947
PBDEs	Not available

Table 4. **Thresholds for concern based on an assessment of human health risk from these pollutants by OEHHA** (Klasing and Brodberg, 2008). All values given in ng/g (ppb). The lowest available threshold for each pollutant is in bold font. One serving is defined as 8 ounces (227 g) prior to cooking. The FCG and ATLs for mercury are for the most sensitive population (i.e., women aged 18 to 45 years and children aged 1 to 17 years).

Pollutant	Fish Contaminant Goal	Advisory Tissue Level (3 servings/week)	Advisory Tissue Level (2 servings/week)	Advisory Tissue Level (No Consumption)
Chlordanes	**5.6**	190	280	560
DDTs	**21**	520	1000	2100
Dieldrin	**0.46**	15	23	46
Mercury	220	**70**	150	440
PCBs	**3.6**	21	42	120
Selenium	7400	**2500**	4900	15000

Table 5. Analytes included in the study, detection limits, and frequencies of detection and reporting. Frequency of detection includes all results above detection limits. Frequency of reporting includes all results that were reportable (above the detection limit and passing all QA review).

Class	Analyte	MDL	Number of Observations	Frequency of Detection (%)	Frequency of Reporting (%)
Metals/Metalloids	Mercury	0.01	3158	99%	99%
	Selenium	0.12	209	86%	86%
Cyclodienes	Dieldrin	0.42	360	29%	29%
Chlordanes	Nonachlor, cis-	0.30	360	36%	36%
	Chlordane, cis-	0.39	360	44%	33%
	Nonachlor, trans-	0.19	360	68%	59%
	Chlordane, trans-	0.44	360	41%	28%
	Oxychlordane	0.46	360	6%	6%
DDTs	DDE(o,p')	0.17	360	8%	8%
	DDE(p,p')	0.47	360	93%	92%
	DDT(o,p')	0.21	360	4%	4%
	DDT(p,p')	0.15	360	19%	19%
	DDD(o,p')	0.09	360	30%	30%
	DDD(p,p')	0.12	360	71%	71%
PCB Congeners	PCB 008	0.14	364	3%	3%
	PCB 018	0.13	364	15%	15%
	PCB 027	0.11	364	5%	5%
	PCB 028	0.16	364	27%	27%
	PCB 029	0.11	364	0%	0%
	PCB 031	0.15	364	23%	23%
	PCB 033	0.15	364	12%	12%
	PCB 044	0.15	364	32%	32%
	PCB 049	0.11	364	40%	40%
	PCB 052	0.17	364	40%	38%
	PCB 056	0.10	364	38%	23%
	PCB 060	0.11	364	29%	27%
	PCB 064	0.10	364	25%	24%
	PCB 066	0.13	364	48%	41%
	PCB 070	0.19	364	45%	35%
	PCB 074	0.12	364	38%	36%
	PCB 077	0.11	364	15%	15%
	PCB 087	0.15	364	51%	39%
	PCB 095	0.18	364	54%	41%
	PCB 097	0.11	364	45%	38%
	PCB 099	0.12	364	58%	55%
	PCB 101	0.18	364	66%	54%
	PCB 105	0.15	364	40%	39%
	PCB 110	0.21	364	59%	43%
	PCB 114	0.10	364	10%	7%
	PCB 118	0.24	364	54%	49%
	PCB 126	0.11	364	2%	2%
	PCB 128	0.11	364	44%	43%
	PCB 137	0.10	364	23%	23%
	PCB 138	0.19	364	64%	63%
	PCB 141	0.11	364	36%	36%
	PCB 146	0.10	364	35%	35%
	PCB 149	0.12	364	60%	57%
	PCB 151	0.09	364	45%	45%
	PCB 153	0.18	364	69%	68%
	PCB 156	0.11	364	30%	29%
	PCB 157	0.10	364	10%	10%
	PCB 158	0.10	364	38%	37%
	PCB 169	0.10	364	6%	3%
	PCB 170	0.12	364	32%	32%
	PCB 174	0.11	364	32%	32%
	PCB 177	0.09	364	32%	32%
	PCB 180	0.10	364	65%	64%
	PCB 183	0.10	364	38%	38%
	PCB 187	0.11	364	55%	55%
	PCB 189	0.10	364	4%	4%
	PCB 194	0.10	364	30%	30%
	PCB 195	0.11	364	12%	12%
	PCB 198/199	0.09	364	14%	2%
	PCB 200	0.10	364	9%	9%
	PCB 201	0.11	364	37%	37%
	PCB 203	0.09	364	38%	38%
	PCB 206	0.11	364	26%	23%
	PCB 209	0.09	364	15%	15%

Table 6. **Percentages of lakes in different methylmercury concentration categories by region.** Concentrations in ppm. Note: Some lakes did not fall into these three regional categories.

Region	**Number of Lakes**	**Percentage of Lakes in Each Concentration Category**				
		< 0.07	**0.07-0.15**	**0.15-0.22**	**0.22-0.44**	**>0.44**
California	272	32	13	13	22	21
Northern California Trout Lakes	87	71	16	6	5	2
Northern California Lower Elevation (<2000 ft)	82	2	5	11	34	48
Southern California	83	27	12	20	25	16

Table 7. **Average concentrations of mercury in each species sampled in this survey.** Averages based on the total number of composites or estimated averages for all locations (i.e., all of the data points shown in Appendix 1). Concentrations in ppm. Averages by species are shown for the entire statewide dataset, and for the three regions with the largest numbers of samples. Almaden Lake in Region 2 had high concentrations and a large influence on the Region 2 averages for largemouth and common carp. Without the data from Almaden Lake, the average was 0.23 ppm for common carp, 0.58 ppm for largemouth bass, and 0.36 ppm for Region 2 as a whole.

	California		Region 2		Region 4		Region 5	
Species	**N**	**Concentration**	**N**	**Concentration**	**N**	**Concentration**	**N**	**Concentration**
Smallmouth Bass	22	0.42					19	0.33
Largemouth Bass	199	0.41	22	0.65	26	0.31	93	0.42
Spotted Bass	6	0.32					6	0.32
Sacramento Sucker	28	0.27	2	0.29			18	0.31
Sacramento Pikeminnow	2	0.27					2	0.27
Striped Bass	3	0.21						
Brown Trout	19	0.20					17	0.21
Pumpkinseed	1	0.19			1	0.19		
Common Carp	172	0.18	20	0.31	31	0.05	61	0.22
Channel Catfish	20	0.17	7	0.12	3	0.10	6	0.36
Lake Trout	2	0.16						
Brook Trout	4	0.13					4	0.13
Hardhead	2	0.11						
Kokanee	1	0.10					1	0.10
Brown Bullhead	24	0.08			8	0.14	15	0.05
Bluegill	3	0.08	2	0.10				
Goldfish	2	0.07						
Eagle Lake Trout	4	0.06						
Rainbow Trout	152	0.05	2	0.26	1	0.03	76	0.04
Black Crappie	4	0.04					1	0.08
Hitch	2	0.03						
Redear Sunfish	2	0.02			2	0.02		
Tilapia1	4	0.01						
Overall	**678**	**0.22**	**55**	**0.41**	**73**	**0.16**	**319**	**0.24**

Table 8. **Lakes with mercury above 0.44 ppm in average concentrations or composite samples.** Data are sorted by region. Data for samples of individual fish are not included in this table. # indicates lakes that already have consumption guidelines in place. NOTE: Formatting will be better in the final report.

Regional Board	Station Name	Study Year	Lake Size	Lake Type	Common Name	Total Length Average (mm)	Result (ppm)	Location Code	Composite Number	Number Fish In Sample	Sample Type
1	Lake Pillsbury	Year1	medium	targeted	Largemouth Bass	350	1.34	L1	NA	11	350 mm Standard Size
1	Lake Pillsbury	Year1	medium	targeted	Largemouth Bass	350	1.29	L2	NA	11	350 mm Standard Size
1	Lake Sonoma	Year1	medium	targeted	Largemouth Bass	350	0.71	L2	NA	11	350 mm Standard Size
1	Lake Sonoma	Year1	medium	targeted	Largemouth Bass	350	0.64	L1	NA	11	350 mm Standard Size
1	Ruth Lake	Year2	small	targeted	Largemouth Bass	350	0.71	L1	NA	11	350 mm Standard Size
1	Ruth Lake	Year2	small	targeted	Brown Bullhead	324	0.13	L1	1	5	Location Composite
1	Lake Mendocino	Year1	medium	targeted	Largemouth Bass	350	0.55	L1	NA	11	350 mm Standard Size
1	Lake Mendocino	Year1	medium	targeted	Largemouth Bass	350	0.54	L2	NA	11	350 mm Standard Size
1	Lake Mendocino	Year1	medium	targeted	Common Carp	492	0.10	L2	1	5	Location Composite
1	Lake Mendocino	Year1	medium	targeted	Common Carp	479	0.07	L1	1	5	Location Composite
2	Almaden Lake	Year2	small	targeted	Largemouth Bass	350	2.15	L1	NA	11	350 mm Standard Size
2	Almaden Lake	Year2	small	targeted	Common Carp	669	1.05	L1	1	5	Location Composite
2	Almaden Lake	Year2	small	targeted	Common Carp	668	1.02	L1	2	5	Location Composite
2	Calero Reservoir	Year2	small	targeted	Largemouth Bass	350	1.05	L1	NA	16	350 mm Standard Size
2	Upper San Leandro Reservoir	Year1	small	random	Largemouth Bass	350	1.01	L1	NA	11	350 mm Standard Size
2	Anderson Lake	Year1	small	targeted	Largemouth Bass	350	0.98	L1	NA	11	350 mm Standard Size
2	Anderson Lake	Year1	small	targeted	Common Carp	501	0.52	L1	2	5	Location Composite
2	Anderson Lake	Year1	small	targeted	Common Carp	503	0.32	L1	1	5	Location Composite
2	Soulejoule Lake	Year1	small	targeted	Largemouth Bass	350	0.94	L1	NA	16	350 mm Standard Size
2	Calaveras Reservoir	Year1	medium	random	Largemouth Bass	350	0.86	L1	NA	11	350 mm Standard Size
2	Calaveras Reservoir	Year1	medium	random	Largemouth Bass	350	0.31	L2	NA	11	350 mm Standard Size
2	Lower Crystal Springs Reservoir	Year1	small	random	Largemouth Bass	350	0.85	L1	NA	11	350 mm Standard Size
2	Coyote Lake	Year2	small	targeted	Largemouth Bass	350	0.76	L1	NA	11	350 mm Standard Size
2	Coyote Lake	Year2	small	targeted	Common Carp	637	0.47	L1	1	5	Location Composite
2	Coyote Lake	Year2	small	targeted	Common Carp	633	0.35	L1	2	5	Location Composite
2	Stevens Creek Reservoir	Year1	small	targeted	Largemouth Bass	350	0.70	L1	NA	11	350 mm Standard Size
2	Stevens Creek Reservoir	Year1	small	targeted	Common Carp	601	0.32	L1	2	5	Location Composite
2	Stevens Creek Reservoir	Year1	small	targeted	Common Carp	606	0.29	L1	1	5	Location Composite
2	Lake Chabot (San Leandro)	Year1	small	random	Largemouth Bass	350	0.57	L1	NA	11	350 mm Standard Size
2	Lake Chabot (San Leandro)	Year1	small	targeted	Common Carp	521	0.54	L1	1	5	Location Composite
2	Lake Chabot (San Leandro)	Year1	small	targeted	Common Carp	521	0.29	L1	2	5	Location Composite
2	Lake del Valle	Year2	small	targeted	Largemouth Bass	350	0.56	L1	NA	11	350 mm Standard Size
2	Lake del Valle	Year2	small	targeted	Channel Catfish	507	0.32	L1	2	5	Location Composite
2	Lake del Valle	Year2	small	targeted	Channel Catfish	507	0.13	L1	1	5	Location Composite
2	San Pablo Reservoir	Year1	small	targeted	Largemouth Bass	350	0.48	L1	NA	11	350 mm Standard Size
2	San Pablo Reservoir	Year1	small	targeted	Common Carp	500	0.17	L1	2	4	Location Composite
2	San Pablo Reservoir	Year1	small	targeted	Common Carp	506	0.09	L1	1	5	Location Composite
2	Oiger Quarry Ponds	Year1	small	random	Largemouth Bass	350	0.45	L1	NA	11	350 mm Standard Size
2	Oiger Quarry Ponds	Year1	small	targeted	Sacramento Sucker	438	0.31	L1	1	5	Location Composite
2	Oiger Quarry Ponds	Year1	small	targeted	Sacramento Sucker	436	0.26	L1	2	5	Location Composite
3	Chesbro Reservoir	Year1	small	targeted	Largemouth Bass	350	1.04	L1	NA	11	350 mm Standard Size
3	Chesbro Reservoir	Year1	small	targeted	Common Carp	524	0.55	L1	1	5	Location Composite
3	Chesbro Reservoir	Year1	small	targeted	Common Carp	523	0.51	L1	2	5	Location Composite
3	Uvas Reservoir	Year1	small	targeted	Largemouth Bass	350	0.91	L1	NA	11	350 mm Standard Size
3	Hernandez Reservoir	Year2	small	targeted	Largemouth Bass	350	0.83	L1	NA	16	350 mm Standard Size
3	Lake Cachuma	Year2	large	targeted	Largemouth Bass	350	0.61	L1	NA	6	350 mm Standard Size

Table 8. (continued) **Lakes with mercury above 0.44 ppm in average concentrations or composite samples.** Data for samples of individual fish are not included in this table. # indicates lakes that already have consumption guidelines in place.

Regional Board	Station Name	Study Year	Lake Size	Lake Type	Common Name	Total Length Average (mm)	Result (ppm)	Location Code	Composite Number	Number Fish In Sample	Sample Type
3	Lake Cachuma	Year2	large	targeted	Largemouth Bass	350	0.48	L2	NA	11	350 mm Standard Size
3	Lake Cachuma	Year2	large	targeted	Largemouth Bass	350	0.40	L3	NA	11	350 mm Standard Size
3	Lake Cachuma	Year2	large	targeted	Common Carp	536	0.20	L3	1	5	Location Composite
3	Lake Cachuma	Year2	large	targeted	Common Carp	529	0.18	L1	1	5	Location Composite
3	Lake Cachuma	Year2	large	targeted	Common Carp	537	0.16	L2	1	5	Location Composite
3	Lake Nacimiento	Year1	large	targeted	Common Carp	503	0.56	L2	1	5	Location Composite
3	Lake Nacimiento	Year1	large	targeted	Common Carp	510	0.50	L3	1	5	Location Composite
3	Lake Nacimiento	Year1	large	targeted	Common Carp	421	0.37	L1	1	5	Location Composite
4	Crystal Lake	Year1	small	targeted	Largemouth Bass	350	0.95	L1	NA	5	350 mm Standard Size
4	Crystal Lake	Year1	small	targeted	Pumpkinseed	135	0.19	L1	1	5	Location Composite
4	Santa Fe Reservoir	Year1	small	targeted	Largemouth Bass	350	0.59	L1	NA	16	350 mm Standard Size
4	Santa Fe Reservoir	Year1	small	targeted	Common Carp	532	0.16	L1	1	5	Location Composite
4	Santa Fe Reservoir	Year1	small	targeted	Common Carp	531	0.12	L1	2	5	Location Composite
4	Lake Sherwood	Year1	small	targeted	Largemouth Bass	350	0.54	L1	NA	16	350 mm Standard Size
4	Hansen Lake	Year1	small	targeted	Largemouth Bass	350	0.49	L1	NA	16	350 mm Standard Size
4	Hansen Lake	Year1	small	targeted	Common Carp	547	0.12	L1	2	5	Location Composite
4	Hansen Lake	Year1	small	targeted	Common Carp	548	0.08	L1	1	5	Location Composite
4	Lake Piru	Year1	small	targeted	Largemouth Bass	350	0.46	L1	NA	16	350 mm Standard Size
4	Lake Piru	Year1	small	targeted	Brown Bullhead	296	0.10	L1	2	5	Location Composite
4	Lake Piru	Year1	small	targeted	Brown Bullhead	297	0.06	L1	1	5	Location Composite
5	New Melones Lake	Year2	medium	targeted	Largemouth Bass	350	1.22	L1	NA	11	350 mm Standard Size
5	New Melones Lake	Year2	medium	targeted	Largemouth Bass	350	1.03	L2	NA	11	350 mm Standard Size
5	New Melones Lake	Year2	medium	targeted	Common Carp	587	0.26	L1	1	5	Location Composite
5	New Melones Lake	Year2	medium	targeted	Common Carp	544	0.20	L2	1	5	Location Composite
5	Cosumnes River	Year1	small	random	Largemouth Bass	350	1.15	L1	NA	16	350 mm Standard Size
5	New Hogan Lake	Year2	large	targeted	Largemouth Bass	350	0.51	L3	NA	11	350 mm Standard Size
5	New Hogan Lake	Year2	large	targeted	Largemouth Bass	350	0.41	L1	NA	11	350 mm Standard Size
5	New Hogan Lake	Year2	large	targeted	Largemouth Bass	350	0.37	L2	NA	11	350 mm Standard Size
5	Eastman Lake	Year2	medium	targeted	Largemouth Bass	350	1.05	L2	NA	11	350 mm Standard Size
5	Eastman Lake	Year2	medium	targeted	Largemouth Bass	350	1.03	L1	NA	11	350 mm Standard Size
5	Eastman Lake	Year2	medium	targeted	Common Carp	671	0.33	L1	1	5	Location Composite
5	Eastman Lake	Year2	medium	targeted	Common Carp	653	0.27	L2	1	5	Location Composite
5	Zayak/Swan Lake	Year1	small	random	Largemouth Bass	350	0.98	L1	NA	16	350 mm Standard Size
5	Hetch Hetchy Reservoir	Year1	medium	targeted	Brown Trout	462	0.96	L2	1	3	Location Composite
5	Hetch Hetchy Reservoir	Year1	medium	targeted	Brown Trout	444	0.54	L1	1	5	Location Composite
5	Hensley Lake	Year1	medium	targeted	Largemouth Bass	350	0.80	L2	NA	12	350 mm Standard Size
5	Hensley Lake	Year1	medium	targeted	Largemouth Bass	350	0.72	L1	NA	10	350 mm Standard Size
5	Hensley Lake	Year1	medium	targeted	Common Carp	469	0.16	L1	1	5	Location Composite
5	Hensley Lake	Year1	medium	targeted	Common Carp	480	0.13	L2	1	5	Location Composite
5	Shasta Lake	Year1	ex-large	targeted	Channel Catfish	593	0.80	L2	1	5	Location Composite
5	Shasta Lake	Year1	ex-large	targeted	Channel Catfish	682	0.36	L1	1	4	Location Composite
5	Lake McClure	Year1	large	targeted	Largemouth Bass	350	0.79	L2	NA	11	350 mm Standard Size
5	Lake McClure	Year1	large	targeted	Largemouth Bass	350	0.77	L3	NA	11	350 mm Standard Size
5	Lake McClure	Year1	large	targeted	Largemouth Bass	350	0.75	L1	NA	11	350 mm Standard Size
5	Lake McClure	Year1	large	targeted	Common Carp	445	0.17	L2	1	5	Location Composite
5	Lake McClure	Year1	large	targeted	Common Carp	425	0.13	L3	1	5	Location Composite

Table 8. (continued) **Lakes with mercury above 0.44 ppm in average concentrations or composite samples.** Data for samples of individual fish are not included in this table. # indicates lakes that already have consumption guidelines in place.

Regional Board	Station Name	Study Year	Lake Size	Lake Type	Common Name	Total Length Average (mm)	Result (ppm)	Location Code	Composite Number	Number Fish In Sample	Sample Type
5	Lake McClure	Year1	large	targeted	Common Carp	414	0.12	L1	1	5	Location Composite
5	Lake Combie	Year1	small	random	Largemouth Bass	350	0.78	L1	NA	11	350 mm Standard Size
5	Lake Combie	Year1	small	targeted	Sacramento Sucker	444	0.60	L1	1	5	Location Composite
5	Lake Combie	Year1	small	targeted	Sacramento Sucker	443	0.46	L1	2	5	Location Composite
5	Lake Berryessa	Year2	ex-large	targeted	Largemouth Bass	350	0.77	L1	NA	11	350 mm Standard Size
5	Lake Berryessa	Year2	ex-large	targeted	Largemouth Bass	350	0.60	L4	NA	11	350 mm Standard Size
5	Lake Berryessa	Year2	ex-large	targeted	Largemouth Bass	350	0.53	L3	NA	11	350 mm Standard Size
5	Lake Berryessa	Year2	ex-large	targeted	Largemouth Bass	350	0.51	L2	NA	11	350 mm Standard Size
5	Rollins Reservoir	Year2	small	targeted	Sacramento Sucker	449	0.68	L1	1	5	Location Composite
5	Harry L Englebright Lake	Year2	small	targeted	Sacramento Sucker	481	0.66	L1	1	5	Location Composite
5	Harry L Englebright Lake	Year2	small	targeted	Sacramento Sucker	480	0.59	L1	2	5	Location Composite
5	Harry L Englebright Lake	Year2	small	targeted	Rainbow Trout	306	0.08	L1	1	5	Location Composite
5	San Luis Reservoir	Year1	ex-large	targeted	Largemouth Bass	350	0.62	L4	NA	11	350 mm Standard Size
5	San Luis Reservoir	Year1	ex-large	targeted	Largemouth Bass	350	0.57	L2	NA	11	350 mm Standard Size
5	San Luis Reservoir	Year1	ex-large	targeted	Largemouth Bass	350	0.57	L3	NA	11	350 mm Standard Size
5	San Luis Reservoir	Year1	ex-large	targeted	Largemouth Bass	350	0.51	L1	NA	11	350 mm Standard Size
5	San Luis Reservoir	Year1	ex-large	targeted	Common Carp	768	0.35	L2	1	4	Location Composite
5	San Luis Reservoir	Year1	ex-large	targeted	Common Carp	728	0.25	L1	1	5	Location Composite
5	San Luis Reservoir	Year1	ex-large	targeted	Common Carp	801	0.19	L3	1	5	Location Composite
5	Lake Amador	Year2	small	targeted	Largemouth Bass	350	0.60	L1	NA	16	350 mm Standard Size
5	Folsom Lake	Year2	large	targeted	Largemouth Bass	350	0.59	L1	NA	11	350 mm Standard Size
5	Folsom Lake	Year2	large	targeted	Largemouth Bass	350	0.48	L2	NA	11	350 mm Standard Size
5	Folsom Lake	Year2	large	targeted	Largemouth Bass	350	0.34	L3	NA	11	350 mm Standard Size
5	Pine Flat Lake	Year1	large	random	Largemouth Bass	350	0.58	L3	NA	11	350 mm Standard Size
5	Pine Flat Lake	Year1	large	random	Largemouth Bass	350	0.55	L1	NA	11	350 mm Standard Size
5	Pine Flat Lake	Year1	large	random	Largemouth Bass	350	0.53	L2	NA	11	350 mm Standard Size
5	Pine Flat Lake	Year1	large	targeted	Common Carp	585	0.09	L1	1	5	Location Composite
5	Pine Flat Lake	Year1	large	targeted	Common Carp	590	0.07	L2	1	5	Location Composite
5	Los Banos Reservoir	Year1	small	targeted	Largemouth Bass	350	0.55	L1	NA	11	350 mm Standard Size
5	Lake Natomas	Year1	small	targeted	Largemouth Bass	350	0.54	L1	NA	11	350 mm Standard Size
5	Lake Natomas	Year1	small	targeted	Common Carp	579	0.26	L1	1	5	Location Composite
5	Lake Natomas	Year1	small	targeted	Common Carp	568	0.25	L1	2	5	Location Composite
5	New Bullards Bar Reservoir	Year2	large	targeted	Largemouth Bass	350	0.54	L3	NA	11	350 mm Standard Size
5	New Bullards Bar Reservoir	Year2	large	targeted	Largemouth Bass	350	0.38	L2	NA	11	350 mm Standard Size
5	New Bullards Bar Reservoir	Year2	large	targeted	Largemouth Bass	350	0.27	L1	NA	11	350 mm Standard Size
5	Lake Kaweah	Year2	medium	targeted	Largemouth Bass	350	0.54	L2	NA	11	350 mm Standard Size
5	Lake Kaweah	Year2	medium	targeted	Largemouth Bass	350	0.46	L1	NA	11	350 mm Standard Size
5	Lake Kaweah	Year2	medium	targeted	Common Carp	653	0.25	L1	1	5	Location Composite
5	Lake Kaweah	Year2	medium	targeted	Common Carp	685	0.17	L2	1	5	Location Composite
5	Lake McSwain	Year1	small	targeted	Largemouth Bass	350	0.54	L1	NA	9	350 mm Standard Size
5	Lake McSwain	Year1	small	targeted	Sacramento Sucker	407	0.15	L1	2	5	Location Composite
5	Lake McSwain	Year1	small	targeted	Sacramento Sucker	411	0.08	L1	1	5	Location Composite
5	Turlock Lake	Year1	large	targeted	Common Carp	495	0.52	L2	1	5	Location Composite
5	Turlock Lake	Year1	large	targeted	Common Carp	527	0.42	L3	1	5	Location Composite
5	Turlock Lake	Year1	large	targeted	Common Carp	489	0.28	L1	1	5	Location Composite
5	Turlock Lake	Year1	large	targeted	Largemouth Bass	350	0.24	L1	NA	11	350 mm Standard Size

Table 8. (continued) **Lakes with mercury above 0.44 ppm in average concentrations or composite samples.** Data for samples of individual fish are not included in this table. # indicates lakes that already have consumption guidelines in place.

Regional Board	Station Name	Study Year	Lake Size	Lake Type	Common Name	Total Length Average (mm)	Result (ppm)	Location Code	Composite Number	Number Fish In Sample	Sample Type
5	Turlock Lake	Year1	large	targeted	Largemouth Bass	350	0.23	L2	NA	11	350 mm Standard Size
5	Turlock Lake	Year1	large	targeted	Largemouth Bass	350	0.21	L3	NA	10	350 mm Standard Size
5	East Park Reservoir	Year1	medium	targeted	Largemouth Bass	350	0.52	L2	NA	11	350 mm Standard Size
5	East Park Reservoir	Year1	medium	targeted	Largemouth Bass	350	0.39	L1	NA	11	350 mm Standard Size
5	East Park Reservoir	Year1	medium	targeted	Common Carp	451	0.25	L2	1	5	Location Composite
5	East Park Reservoir	Year1	medium	targeted	Common Carp	453	0.18	L1	1	5	Location Composite
5	Loon Lake	Year1	small	targeted	Brown Trout	430	0.50	L1	1	5	Location Composite
5	Loon Lake	Year1	small	targeted	Brown Trout	429	0.30	L1	2	5	Location Composite
5	Meadows Slough	Year1	small	targeted	Sacramento Sucker	519	0.47	L1	2	5	Location Composite
5	Meadows Slough	Year1	small	random	Largemouth Bass	350	0.45	L1	NA	11	350 mm Standard Size
5	Meadows Slough	Year1	small	targeted	Sacramento Sucker	519	0.38	L1	1	5	Location Composite
5	Don Pedro Reservoir	Year1	large	targeted	Largemouth Bass	350	0.46	L3	NA	11	350 mm Standard Size
5	Don Pedro Reservoir	Year1	large	targeted	Largemouth Bass	350	0.46	L1	NA	11	350 mm Standard Size
5	Don Pedro Reservoir	Year1	large	targeted	Largemouth Bass	350	0.40	L2	NA	11	350 mm Standard Size
5	Don Pedro Reservoir	Year1	large	targeted	Common Carp	563	0.20	L2	1	5	Location Composite
5	Don Pedro Reservoir	Year1	large	targeted	Common Carp	516	0.16	L3	1	5	Location Composite
5	Don Pedro Reservoir	Year1	large	targeted	Common Carp	556	0.15	L1	1	5	Location Composite
5	Stony Gorge Reservoir	Year1	medium	targeted	Largemouth Bass	350	0.45	L2	NA	11	350 mm Standard Size
5	Stony Gorge Reservoir	Year1	medium	targeted	Largemouth Bass	350	0.34	L1	NA	11	350 mm Standard Size
5	Stony Gorge Reservoir	Year1	medium	targeted	Sacramento Sucker	322	0.14	L2	1	5	Location Composite
5	Stony Gorge Reservoir	Year1	medium	targeted	Sacramento Sucker	313	0.11	L1	1	5	Location Composite
5	Camp Far West Reservoir	Year1	medium	targeted	Channel Catfish	418	0.44	L2	1	5	Location Composite
5	Camp Far West Reservoir	Year1	medium	targeted	Channel Catfish	459	0.32	L1	1	5	Location Composite
5	Isabella Lake	Year2	large	targeted	Common Carp	498	0.44	L2	1	5	Location Composite
5	Isabella Lake	Year2	large	targeted	Common Carp	495	0.41	L1	1	5	Location Composite
5	Isabella Lake	Year2	large	targeted	Common Carp	529	0.35	L3	1	5	Location Composite
5	Isabella Lake	Year2	large	targeted	Largemouth Bass	350	0.21	L2	NA	11	350 mm Standard Size
5	Isabella Lake	Year2	large	targeted	Largemouth Bass	350	0.19	L1	NA	11	350 mm Standard Size
5	Isabella Lake	Year2	large	targeted	Largemouth Bass	350	0.16	L3	NA	11	350 mm Standard Size
6	Little Rock Reservoir	Year2	small	targeted	Largemouth Bass	350	0.92	L1	NA	11	350 mm Standard Size
6	Little Rock Reservoir	Year2	small	targeted	Common Carp	497	0.43	L1	1	5	Location Composite
6	Little Rock Reservoir	Year2	small	targeted	Common Carp	497	0.37	L1	2	5	Location Composite
6	Silverwood Lake	Year1	small	targeted	Largemouth Bass	350	0.49	L1	NA	16	350 mm Standard Size
8	Irvine Lake	Year1	small	targeted	Largemouth Bass	350	0.48	L1	NA	11	350 mm Standard Size
8	Irvine Lake	Year1	small	targeted	Common Carp	596	0.11	L1	2	5	Location Composite
8	Irvine Lake	Year1	small	targeted	Common Carp	597	0.09	L1	1	5	Location Composite
9	Loveland Reservoir	Year1	small	random	Largemouth Bass	350	0.63	L1	NA	11	350 mm Standard Size
9	Loveland Reservoir	Year1	small	targeted	Common Carp	456	0.11	L1	2	5	Location Composite
9	Loveland Reservoir	Year1	small	targeted	Common Carp	456	0.09	L1	1	5	Location Composite

Table 9. **Watershed attributes of selected lakes from this survey.** The list includes lakes with largemouth bass that had 1) the highest average concentrations, 2) the lowest average concentrations, and 3) the lakes included in the quantitative study of lake and watershed attributes influencing methylmercury in fish and the bioaccumulation factor study (Melwani et al. 2010, Negrey et al. 2010). Highest values within each category shaded in green, lowest shaded in blue.

Station Name	Avg Hg in Largemouth	# Mines in Watershed	POTWs	# Soil Data Points	Avg Hg in Soil	Max Hg in Soil	Watershed Area (Square Miles)	Forested Area (%)	Wetland Area (%)
Almaden Lake	2.15	47	0	1	0.20	0.20	53	0	0.4
Lake Pillsbury	1.31	3	0	2	0.06	0.06	289	96	0.0
New Melones Lake	1.12	823	0	10	0.01	0.05	904	78	1.2
Calero Reservoir	1.05	0	0				7	0	0.7
Eastman Lake_BOG	1.04	59	0	2	0.01	0.02	235	80	0.2
Chesbro Reservoir	1.04	3	0				19	0	0.5
Upper San Leandro Reservoir	1.01	0	0				31	0	1.0
Crystal Lake	0.95	0	0				1	95	0.5
Soulejoule Lake	0.94	1	0	2	0.03	0.03	19	0	0.8
Little Rock Reservoir	0.92	2	0				64	21	0.1
Uvas Reservoir	0.91	0	0	1	0.18	0.18	31	0	0.4
Lower Crystal Springs Reserv	0.85	0	0				15	0	1.5
Lake McClure	0.77	892	0	13	0.07	0.19	1038	76	1.1
Lake Sonoma	0.68	2	0	2	0.10	0.10	130	100	0.0
San Luis Reservoir	0.56	0	0	1	0.05	0.05	82	0	0.0
Lake Mendocino	0.54	0	0	2	0.06	0.06	105	79	0.0
Lake Natomas	0.54	2539	0	22	0.03	0.17	1904	75	0.7
Lake McSwain	0.54	904	0	14	0.07	0.19	1063	74	1.1
Irvine Lake	0.48	2	0				63	15	0.0
Folsom Lake	0.47	2510	0	22	0.03	0.17	1863	76	0.7
Don Pedro Reservoir	0.44	701	1	12	0.07	0.13	1535	59	1.6
Lake San Antonio	0.30	1	0	6	0.05	0.14	323	30	1.2
O'Neill Forebay	0.23	0	0	1	0.05	0.05	102	0	0.1
Thermalito Afterbay	0.21	1009	3	40	0.03	0.12	3639	78	3.4
Big Bear Lake	0.18	46	0				73	41	0.7
Lake Elsinore	0.12	51	0	7	0.02	0.03	771	6	0.2
Perris Reservoir	0.10	0	0				10	0	0.0
Bass Lake	0.09	2	0	1	0.04	0.04	50	97	0.9
Ferguson Lake_BOG	0.09	1	0	1	0.05	0.05	20	0	3.5
Westlake Lake	0.09	0	0	2	0.03	0.04	28	0	0.4
Echo Lake - Reg 4	0.08	0	0				1	0	0.1
Prado Lake	0.07	0	0				27	0	0.1
Dixon Lake	0.06	1	0				4	0	1.6
Lake Hemet	0.06	10	0	1	0.00	0.00	66	18	1.0
Lake Wohlford	0.05	0	0				8	0	1.4
Lake Poway	0.05	0	0				2	0	0.2
Lake Evans	0.03	58	5	12	0.05	0.15	761	24	0.1
Toluca Lake	0.00	30	1	4	0.44	1.65	423	5	0.0

Table 10. **Percentages of lakes in different PCB concentration categories by region.** Concentrations in ppb. Note: Some lakes did not fall into the three regional categories.

Region	**Number of Lakes**	**Percentage of Lakes in Each Concentration Category**				
		<3.6	**3.6-21**	**21-42**	**42-120**	**>120**
California	272	67	25	3	4	1
Northern California Trout Lakes	87	92	7	1	0	0
Northern California Lower Elevation (<2000 ft)	82	60	29	2	7	1
Southern California	83	40	46	5	7	2

Table 11. **The lakes with the highest PCB concentrations (ppb) in average concentrations or composite samples.** Data for samples of individual fish are not included in this table. # indicates lakes that already have consumption guidelines in place.

Regional Board	Station Name	Study Year	Lake Size	Lake Type	Common Name	Total Length Average (mm)	Result (ppb)	Location Code	Composite Number	Number Fish In Sample	Sample Type
2	Lake Chabot (San Leandro)	Year1	small	targeted	Common Carp	521	148	L1	1	5	Location Composite
2	Lake Chabot (San Leandro)	Year1	small	targeted	Common Carp	521	48	L1	2	5	Location Composite
2	Lake Vasona	Year2	small	targeted	Common Carp	591	204	L1	1	5	Location Composite
2	Lake Vasona	Year2	small	targeted	Common Carp	590	89	L1	2	5	Location Composite
4	Pyramid Lake	Year1	medium	targeted	Brown Bullhead	319	416	L1	1	5	Location Composite
4	Pyramid Lake	Year1	medium	targeted	Brown Bullhead	353	195	L1; L2	NA	10	Lake-wide Composite
4	Pyramid Lake	Year1	medium	targeted	Largemouth Bass	359	66	L1; L2	NA	10	Lake-wide Composite
4	Pyramid Lake	Year1	medium	targeted	Largemouth Bass	361	66	L1	1	5	Location Composite
4	Pyramid Lake	Year1	medium	targeted	Brown Bullhead	387	60	L2	1	5	Location Composite
4	Pyramid Lake	Year1	medium	targeted	Largemouth Bass	357	35	L2	1	5	Location Composite
4	Elderberry Forebay	Year1	small	targeted	Channel Catfish	587	146	L1	2	5	Location Composite
4	Elderberry Forebay	Year1	small	targeted	Channel Catfish	594	116	L1	1	5	Location Composite
4	Elderberry Forebay	Year1	small	targeted	Largemouth Bass	350	32	L1	1	5	Location Composite
4	Elderberry Forebay	Year1	small	targeted	Largemouth Bass	347	20	L1	2	5	Location Composite
4	Echo Lake - Reg 4	Year1	small	targeted	Common Carp	501	119	L1	1	5	Location Composite
4	Echo Lake - Reg 4	Year1	small	targeted	Common Carp	498	83	L1	2	5	Location Composite
4	Echo Lake - Reg 4	Year1	small	targeted	Largemouth Bass	380	65	L1	1	5	Location Composite
4	Echo Lake - Reg 4	Year1	small	targeted	Largemouth Bass	380	31	L1	2	5	Location Composite
5	San Luis Reservoir	Year1	ex-large	targeted	Common Carp	801	133	L3	1	5	Location Composite
5	San Luis Reservoir	Year1	ex-large	targeted	Common Carp	766	100	L1; L2; L3	NA	14	Lake-wide Composite
5	San Luis Reservoir	Year1	ex-large	targeted	Common Carp	728	81	L1	1	5	Location Composite
5	San Luis Reservoir	Year1	ex-large	targeted	Common Carp	768	42	L2	1	4	Location Composite
6	Silverwood Lake	Year1	small	targeted	Largemouth Bass	368	131	L1	1	5	Location Composite
6	Silverwood Lake	Year1	small	targeted	Largemouth Bass	367	55	L1	2	5	Location Composite

Table 12. **Percentages of lakes in different dieldrin concentration categories by region.** Concentrations in ppb. Note: Some lakes did not fall into the three regional categories.

Region	Number of Lakes	Percentage of Lakes in Each Concentration Category				
		< .46	.46-15	15-23	23-46	>46
California	272	80	20	0	0	0
Northern California Trout Lakes	87	89	11	0	0	0
Northern California Lower Elevation (<2000 ft)	82	72	28	0	0	0
Southern California	83	73	25	0	0	1

Table 13. **Percentages of lakes in different DDT concentration categories by region.** Concentrations in ppb. Note: Some lakes did not fall into the three regional categories.

Region	Number of Lakes	Percentage of Lakes in Each Concentration Category				
		<21	21-520	520-1000	1000-2100	>2100
California	272	87	13	0	0	0
Northern California Trout Lakes	87	99	1	0	0	0
Northern California Lower Elevation (<2000 ft)	82	76	24	0	0	0
Southern California	83	82	17	0	0	1

Table 14. Percentages of lakes in different chlordane concentration categories by region. Concentrations in ppb. Note: Some lakes did not fall into the three regional categories.

Region	Number of Lakes	Percentage of Lakes in Each Concentration Category				
		<5.6	5.6-190	190-280	280-560	>560
California	272	91	9	0	0	0
Northern California Trout Lakes	87	99	1	0	0	0
Northern California Lower Elevation (<2000 ft)	82	87	13	0	0	0
Southern California	83	86	14	0	0	0

Table 15. Percentages of lakes in different selenium concentration categories by region. Concentrations in ppb. Note: Some lakes did not fall into the three regional categories.

Region	Number of Lakes	Percentage of Lakes in Each Concentration Category				
		<2500	2500-4900	4900-7400	7400-15000	15000
California	189	98	2	0	0	0
Northern California Trout Lakes	8	100	0	0	0	0
Northern California Lower Elevation (<2000 ft)	81	99	1	0	0	0
Southern California	80	96	4	0	0	0

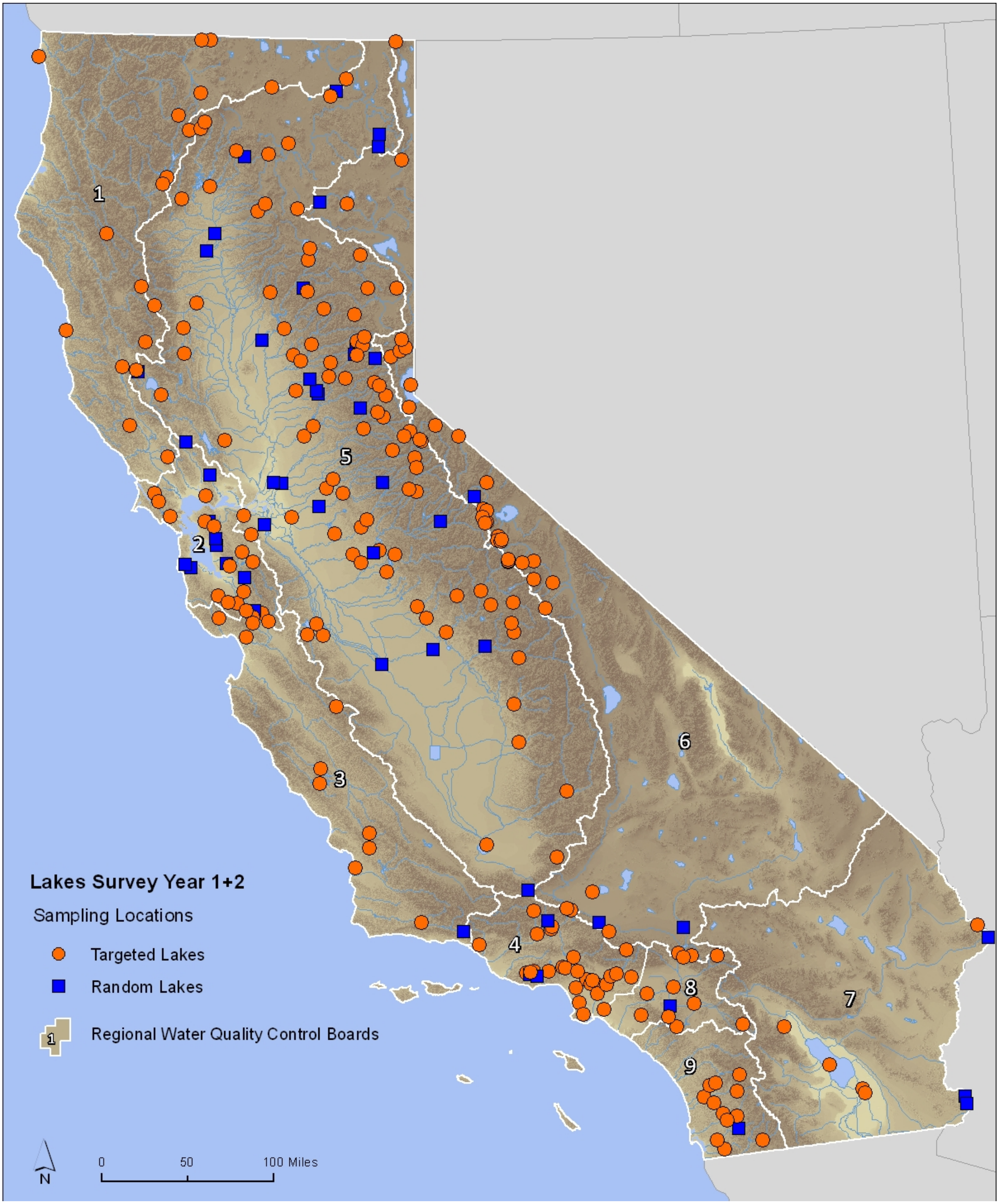


Figure 1a. Lakes sampled in the Lakes Survey. Circles represent 222 lakes that were targeted and squares represent 50 lakes sampled randomly.

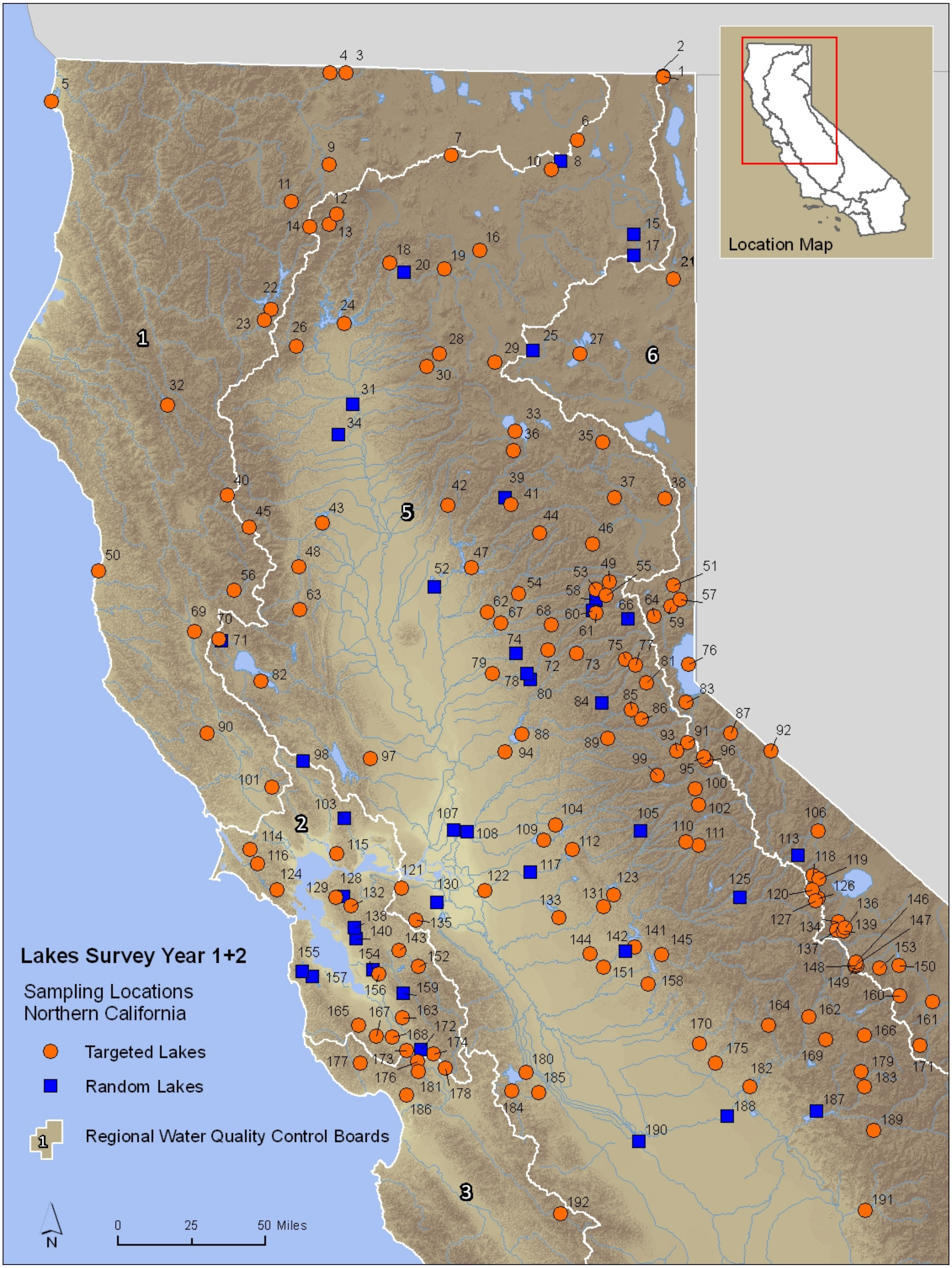


Figure 1b. Northern California lakes sampled in the Lakes Survey. Circles represent lakes that were targeted and squares represent those sampled randomly. Numbers on map relate to lake names given in Table 1.

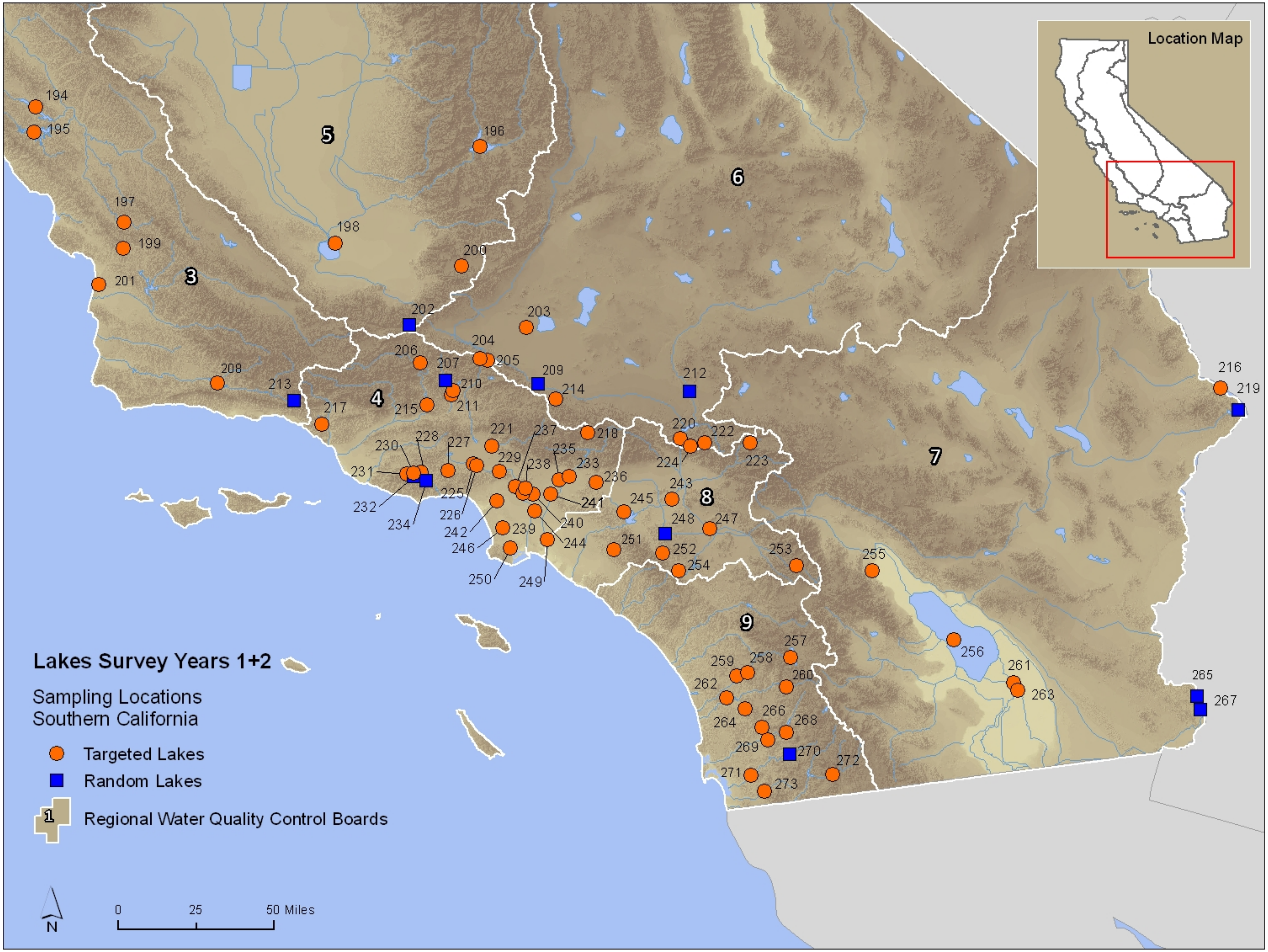


Figure 1c. Southern California lakes sampled in the Lakes Survey. Circles represent lakes that were targeted and squares represent those sampled randomly. Numbers on map relate to lake names given in Table 1.

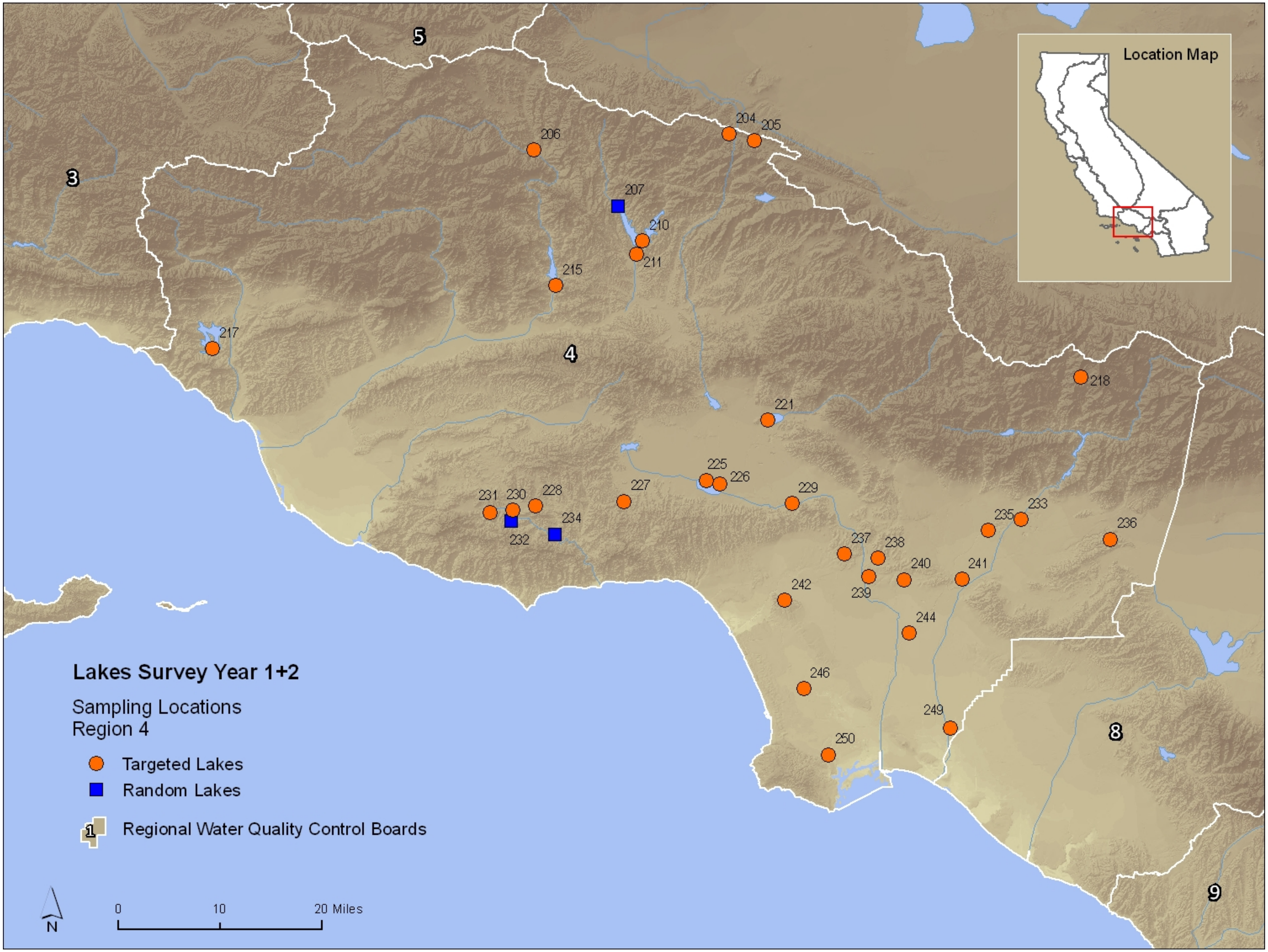


Figure 1d. Region 4 lakes sampled in the Lakes Survey. The Region 4 Water Board augmented the Survey with additional funding to sample a larger number of lakes in their region. Circles represent lakes that were targeted and squares represent those sampled randomly. Numbers on map relate to lake names given in Table 1.

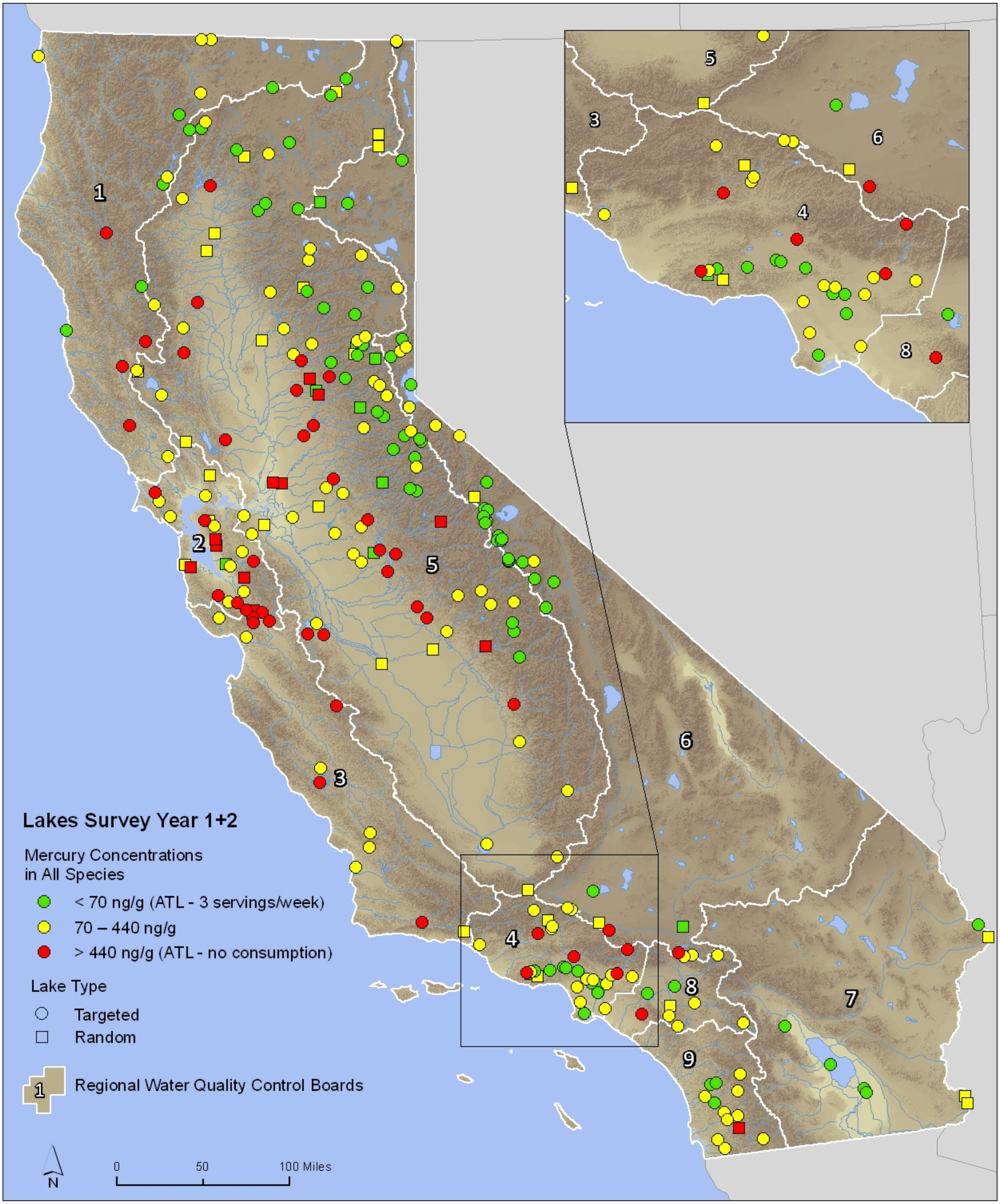


Figure 2. **Highest species-average mercury concentrations** at lakes sampled in the Lakes Survey, 2007-2008. Concentrations based on location composites and individual fish, from both targeted (circles) and random (squares) lakes.

Figure 3a. Cumulative distribution function (CDF) plot for mercury at random lakes, shown as percent of lake area (left) and percent of lakes (right). Concentrations are the highest species average for each lake, based on location composites and individual fish at randomly sampled lakes in the Lakes Survey. Vertical lines are threshold values. Data in µg/g, or ppm.

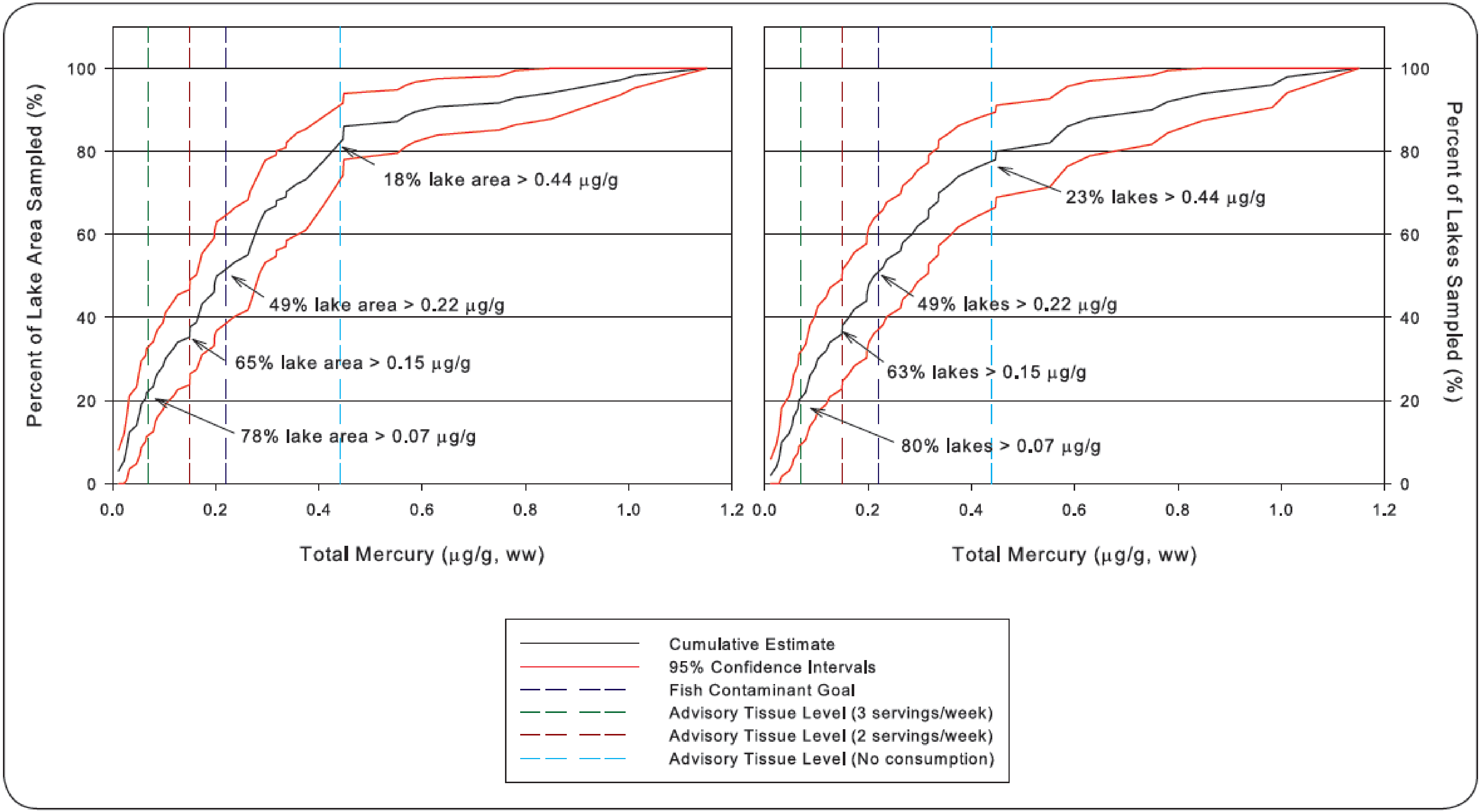


Figure 3b. **Cumulative distribution function (CDF) plot for mercury at targeted lakes**, shown as percent of lakes sampled. Concentrations are the highest species average for each lake, based on location composites and individual fish at targeted lakes in the Lakes Survey. Vertical lines are threshold values. Data in µg/g, or ppm. Xx Aroon: need to label the thresholds and percentages. Can you make the graph wider so it is easier to see the action in the 0 to 0.3 range?

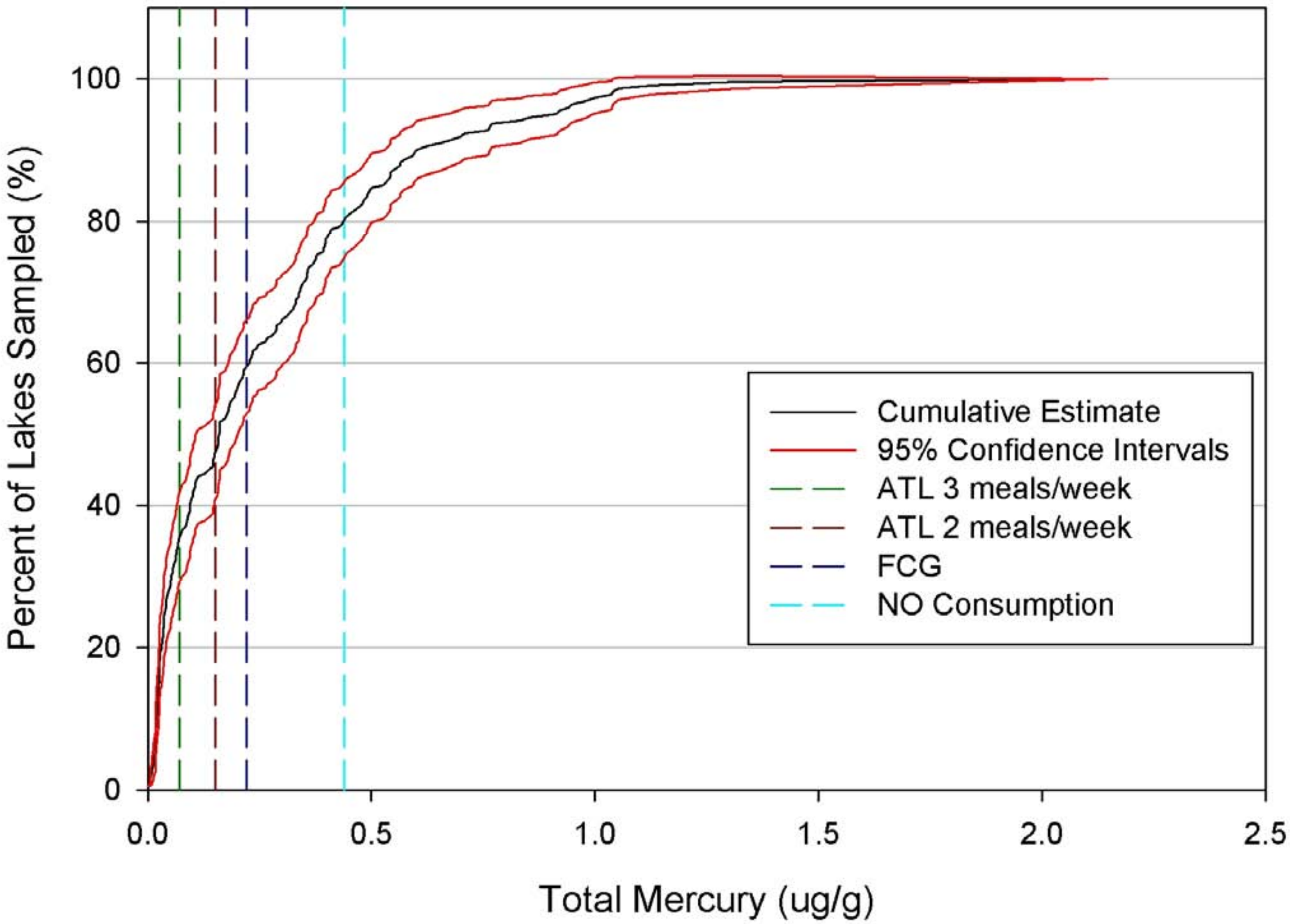
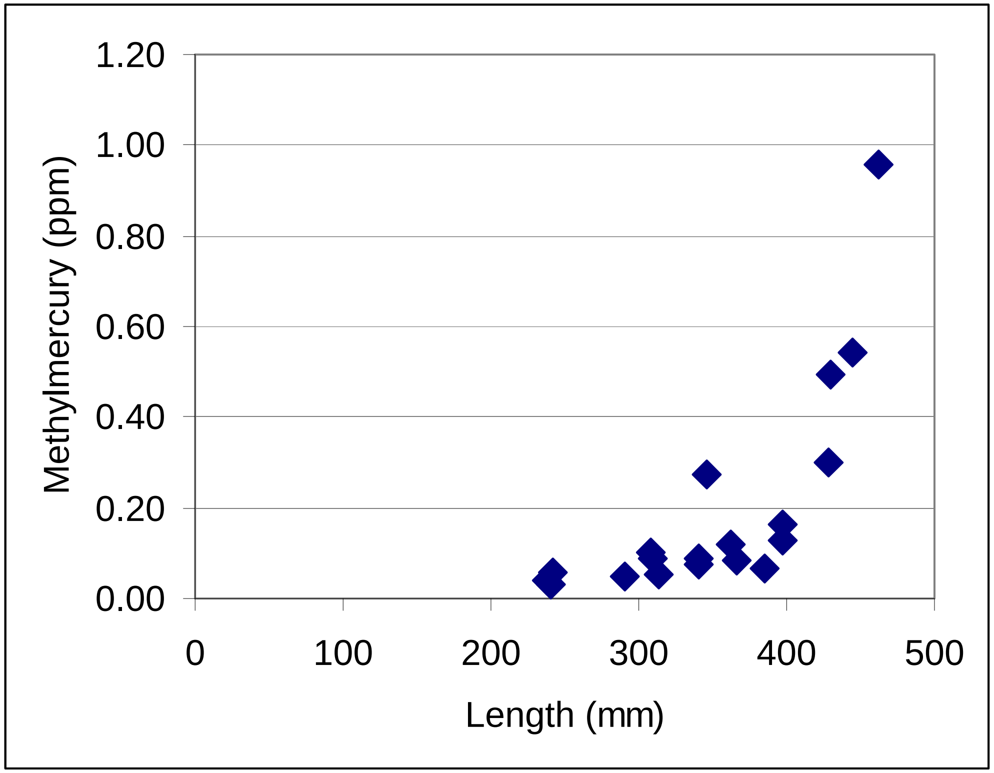


Figure 4. Methylmercury concentration versus average length for brown trout composites. Data from 11 lakes in the Sierra Nevada.



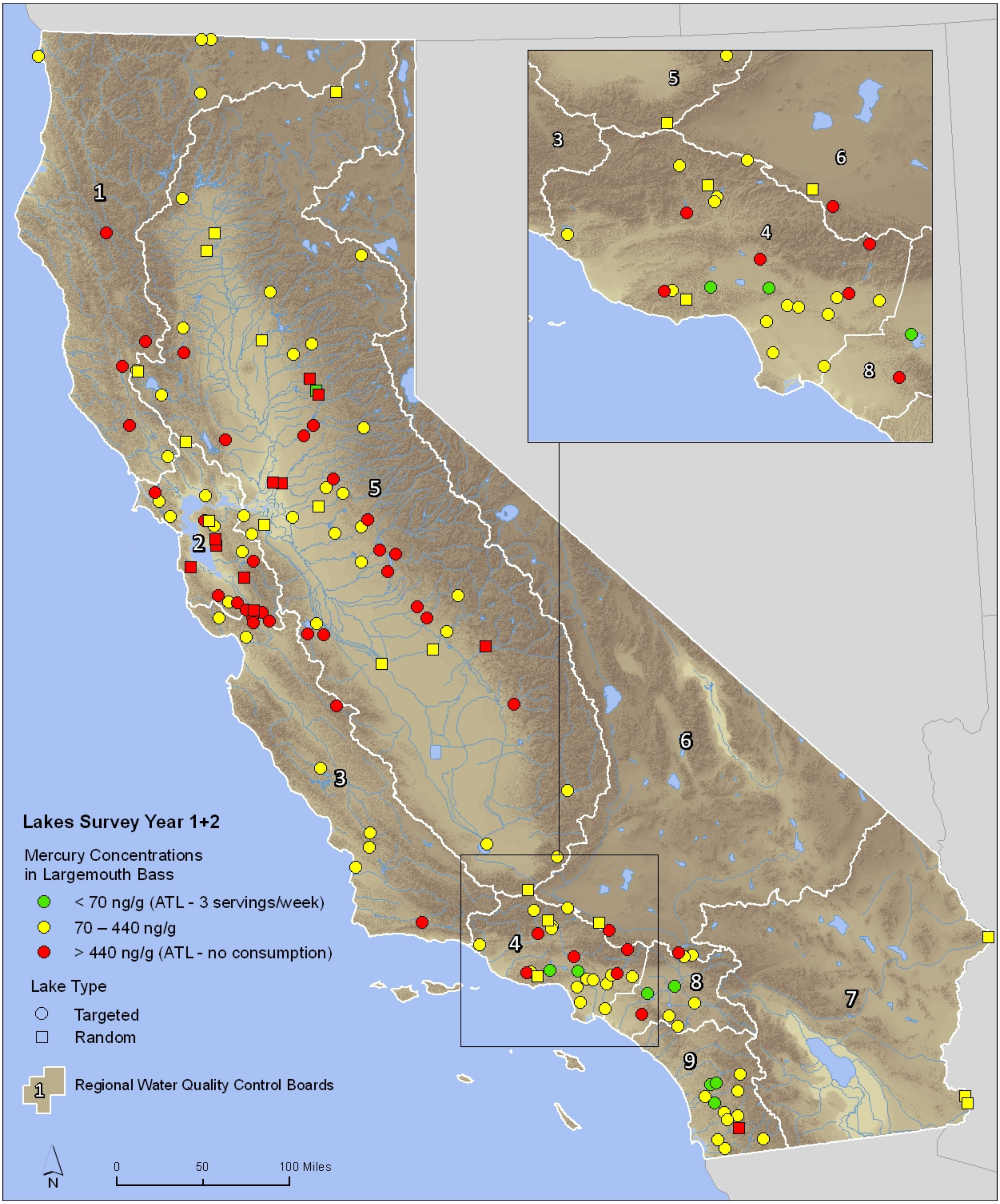


Figure 5. **Lake-wide average mercury concentrations in standard-sized (350 mm) largemouth bass** at lakes sampled in the Lakes Survey, from both targeted (circles) and random (squares) lakes.

Figure 6. Correlations of methylmercury concentrations in largemouth bass with concentrations in other species.

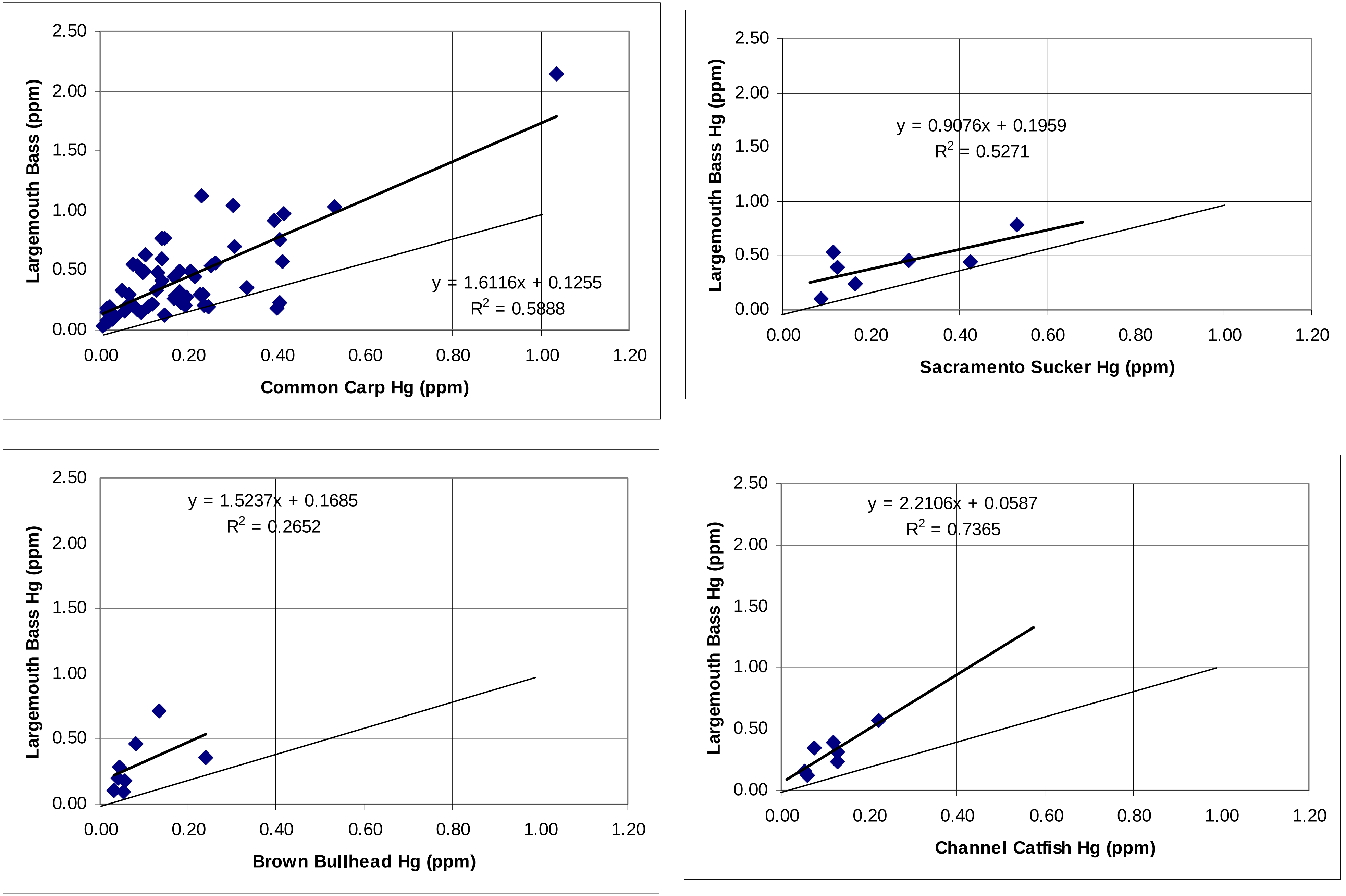


Figure 7. Geologic map of mercury mining areas in the California Coast Range, distinguishing between silica-carbonate deposits and hot-spring Hg deposits. From Kim et al. (2005).

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Figure 8. Simplified geologic map of California.

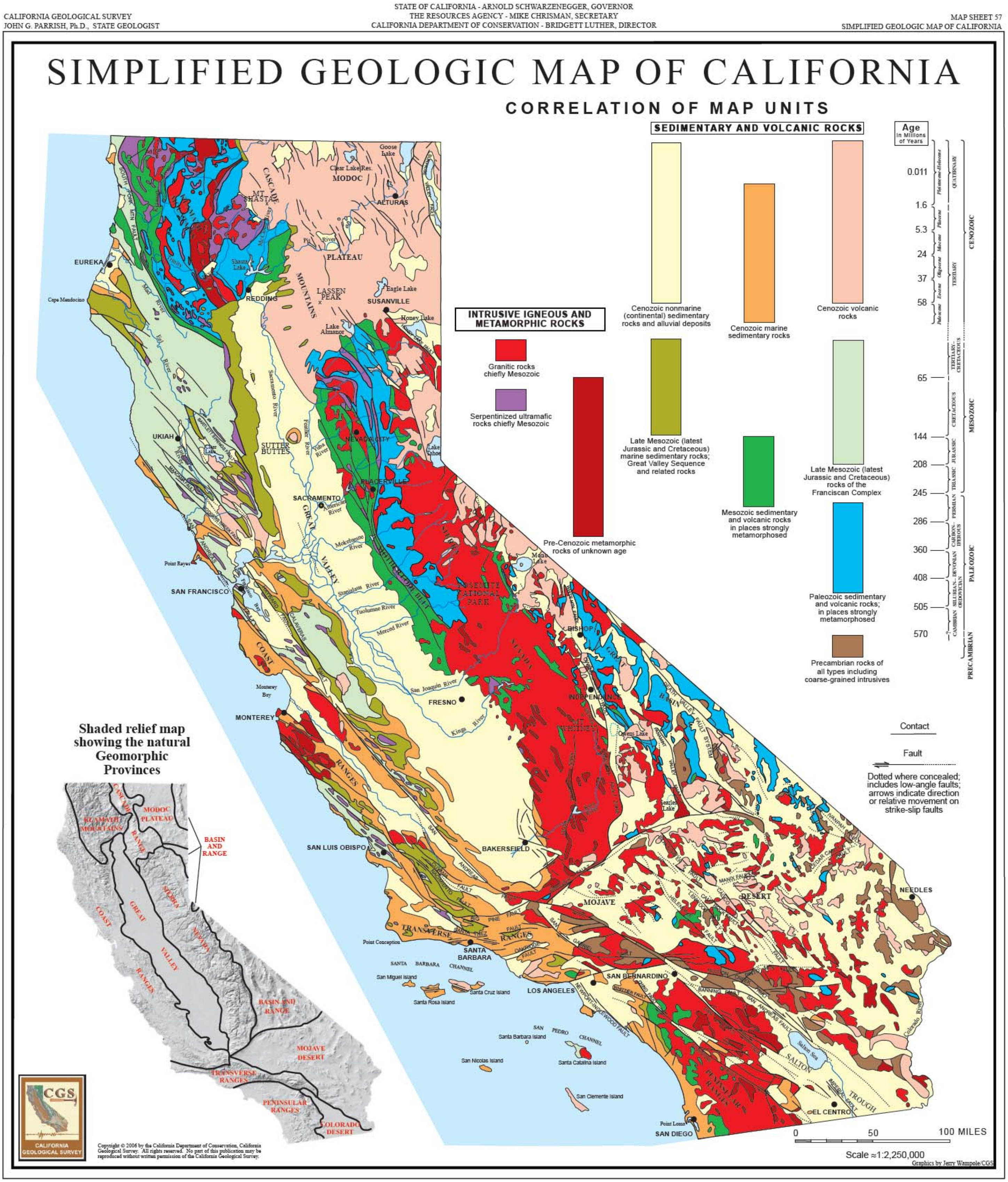

Figure 9. Serpentine soil-based grasslands in the San Francisco Bay Area. From Murphy and Weiss (1992).

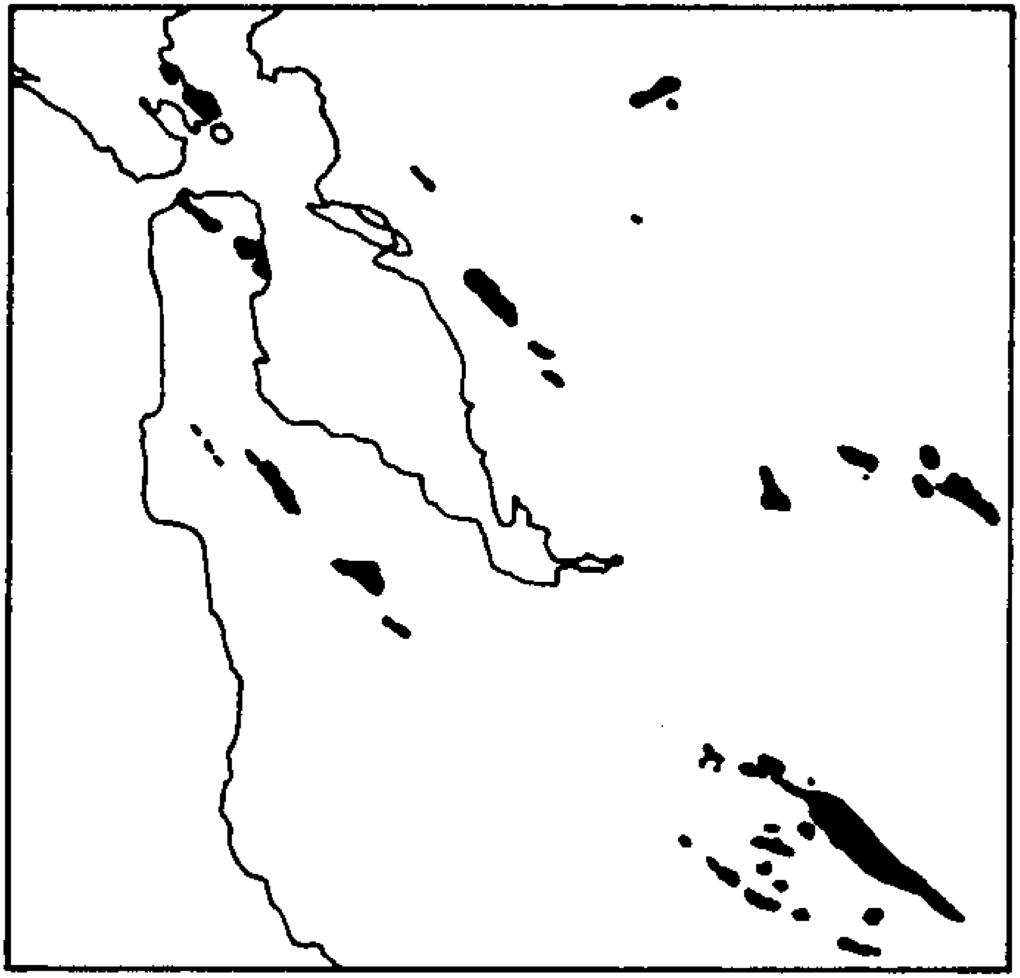

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Figure 10a. Mercury in fish from lakes in regions with low mining activity. Base map of mercury, gold, and silver mines from Wiener and Suchanek (2008).

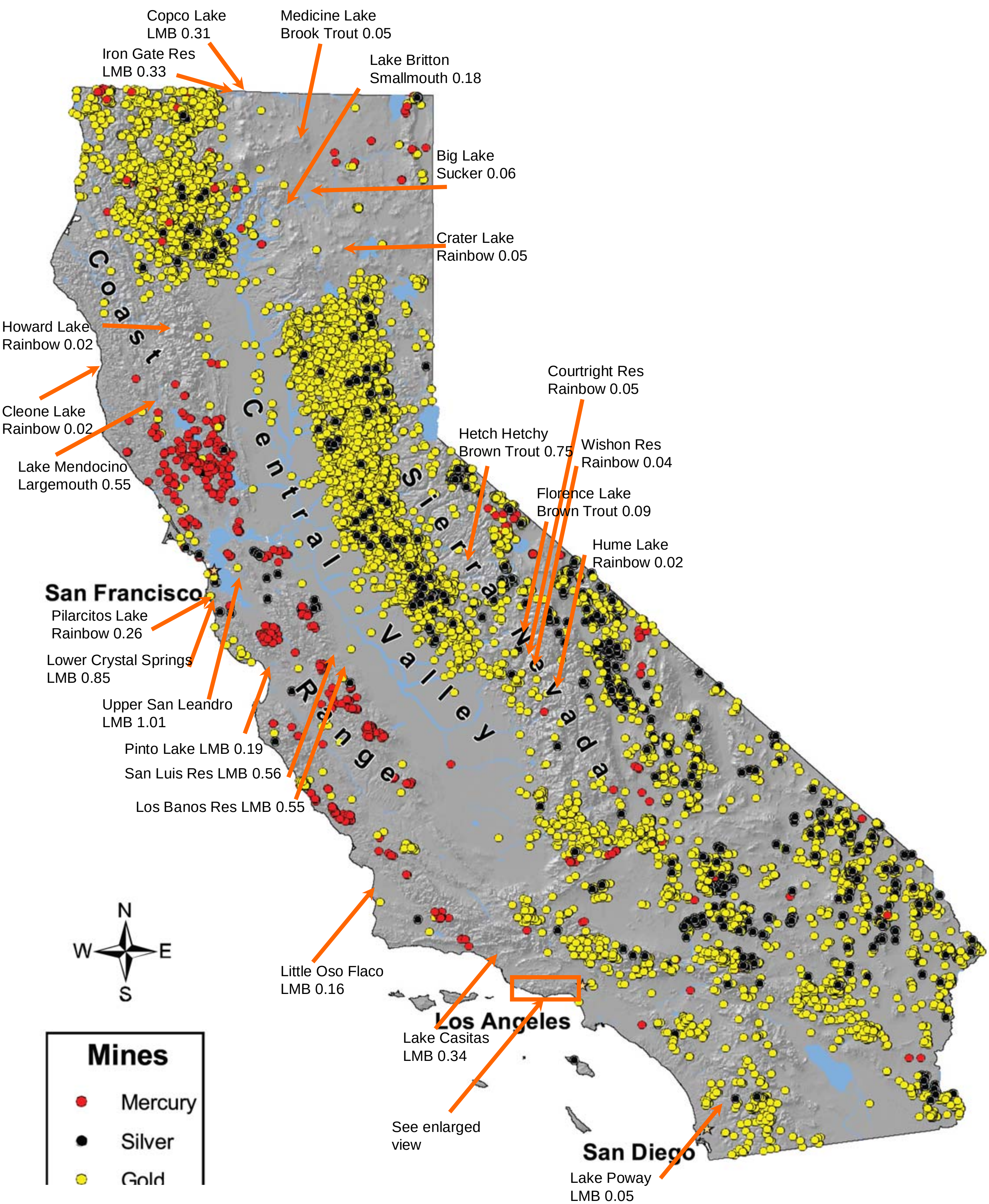

Figure 10b. Mercury in fish from lakes in regions with apparently low mining activity in the Santa Monica Mountains.

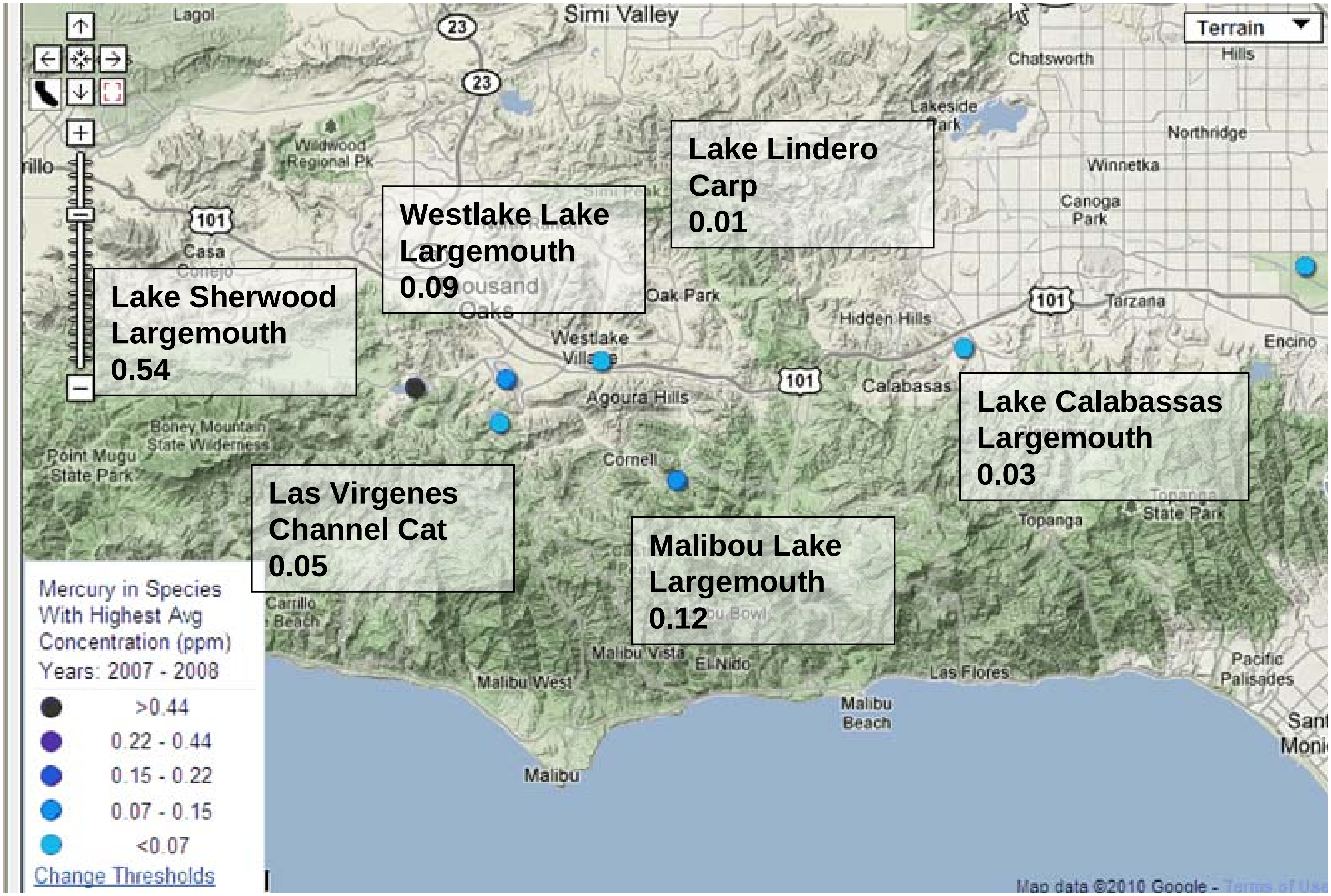

Figure 11. Methylmercury in largemouth bass sampled in the USEPA national survey of contaminants in fish (Stahl et al. 2009).

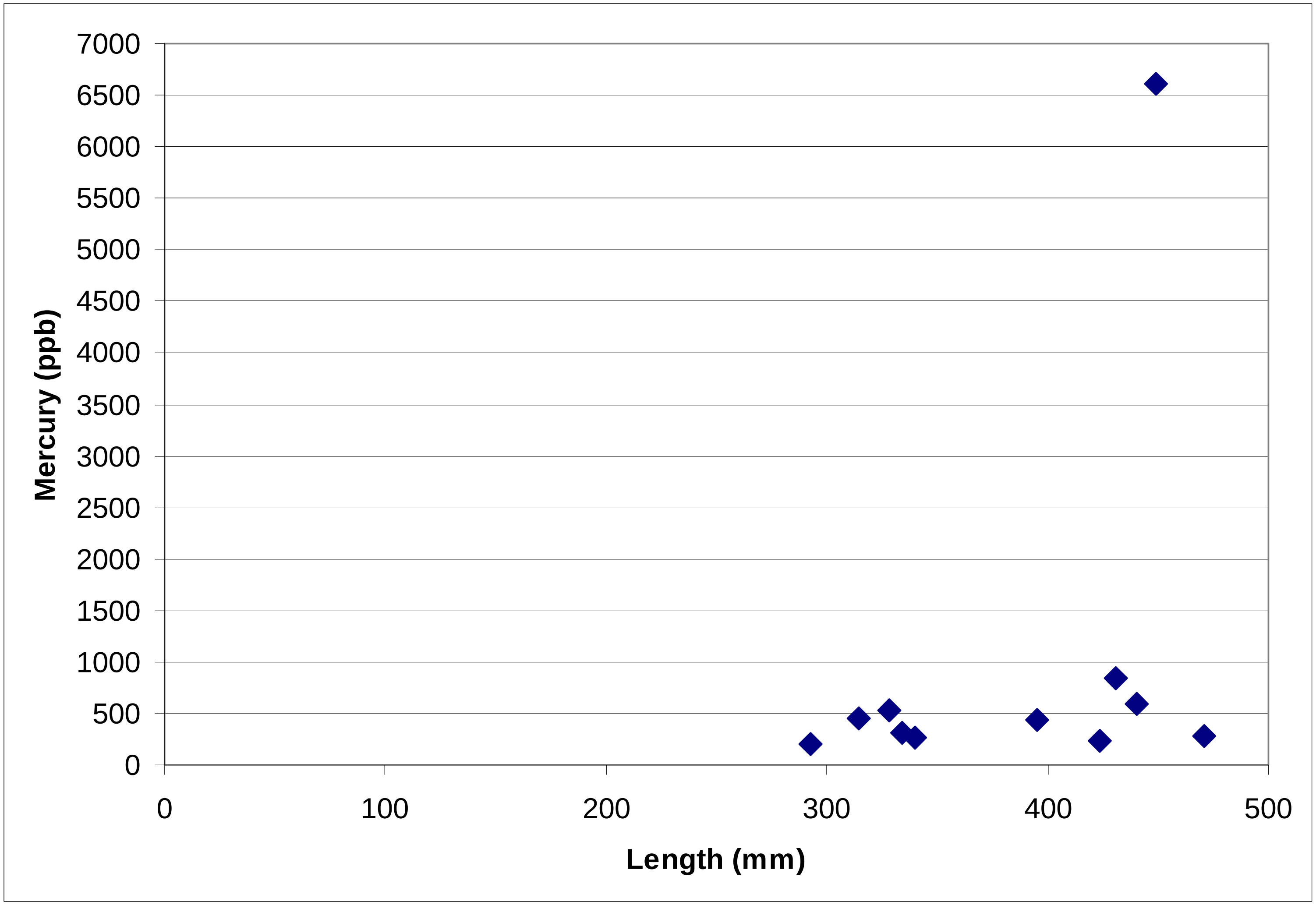

Figure 12. **Highest species-average PCB concentrations** at lakes sampled in the Lakes Survey. Concentrations based on lake-wide and location composites, from both targeted (circles) and random (squares) lakes. Note different scale from the methylmercury maps, with the two serving ATL as the highest threshold.

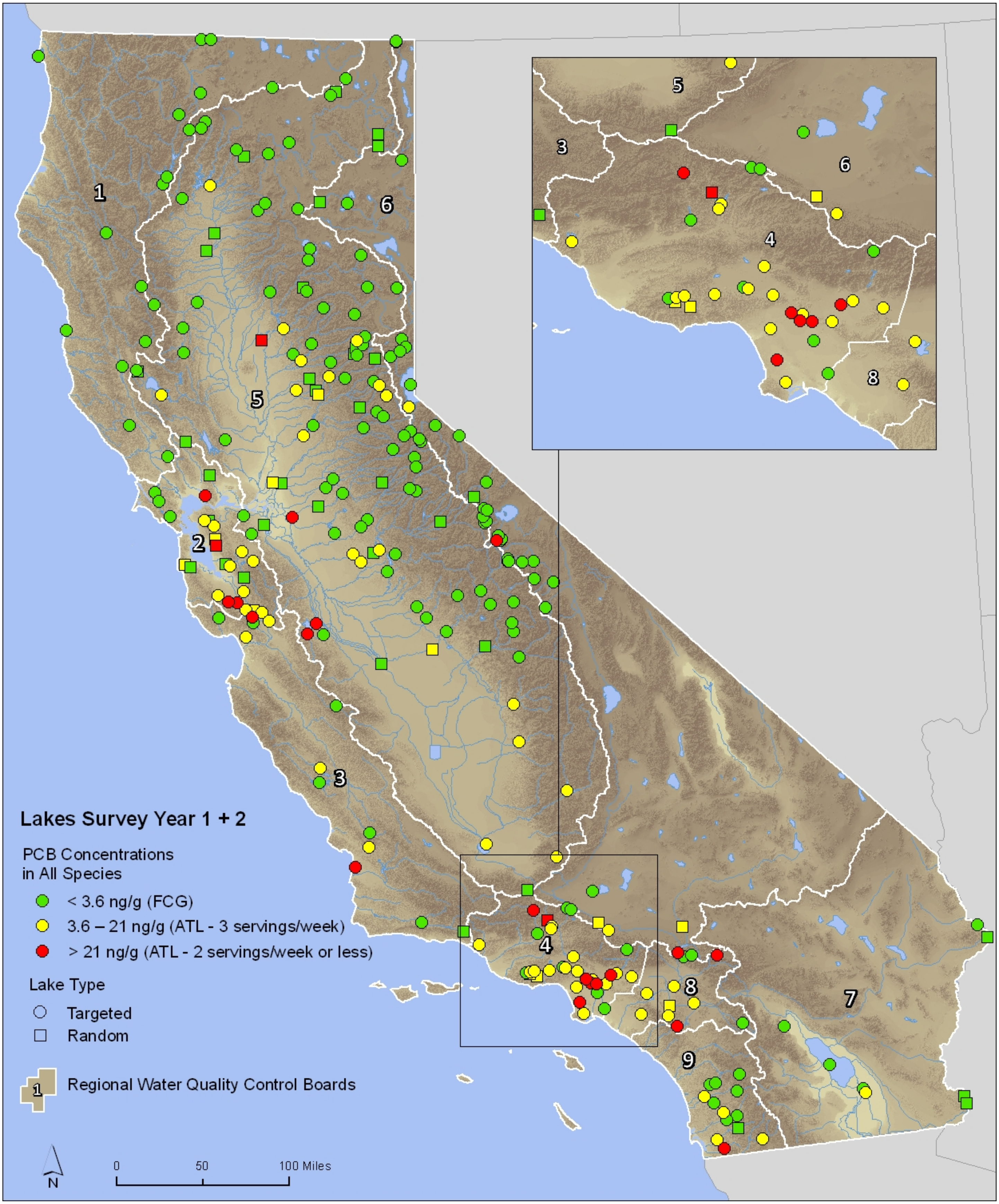

Figure 13a. **Cumulative distribution function (CDF) plot for PCBs at random lakes**, shown as percent of lake area (left) and percent of lakes (right). Concentrations are the highest species average for each lake, based on lake-wide composites at randomly sampled lakes in the Lakes Survey. Vertical lines are threshold values. Text on figure describes the percent of lake area or lakes that exceed each threshold value.

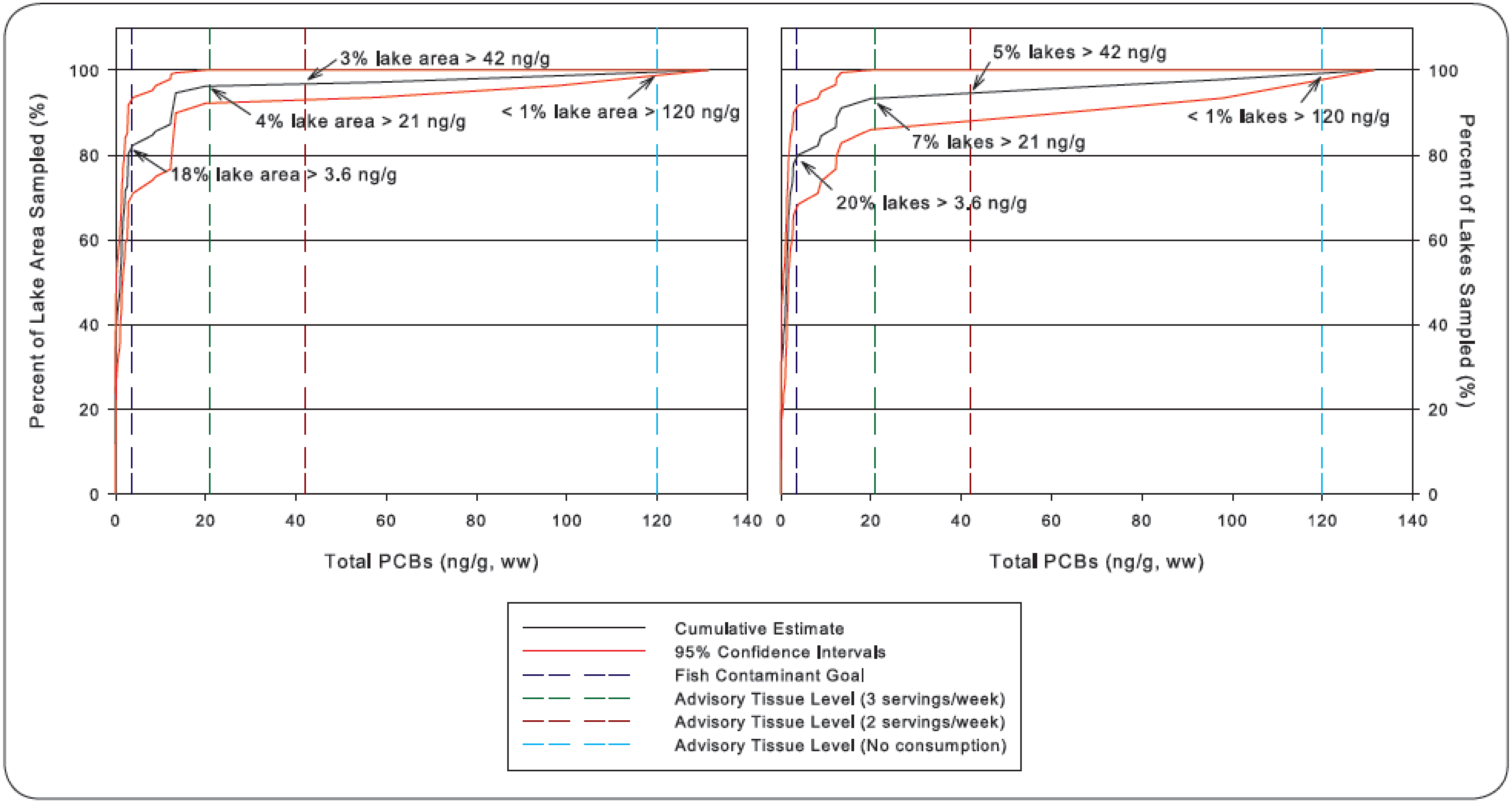

Figure 13b. **Cumulative Distribution Function (CDF) plot for PCBs at targeted lakes**, shown as percent of lakes sampled. Concentrations are the highest species average for each lake, based on lake-wide composites at targeted lakes in the Lakes Survey. Vertical lines are threshold values. Text on figurexx describes the percent of lakes that exceed each threshold value.

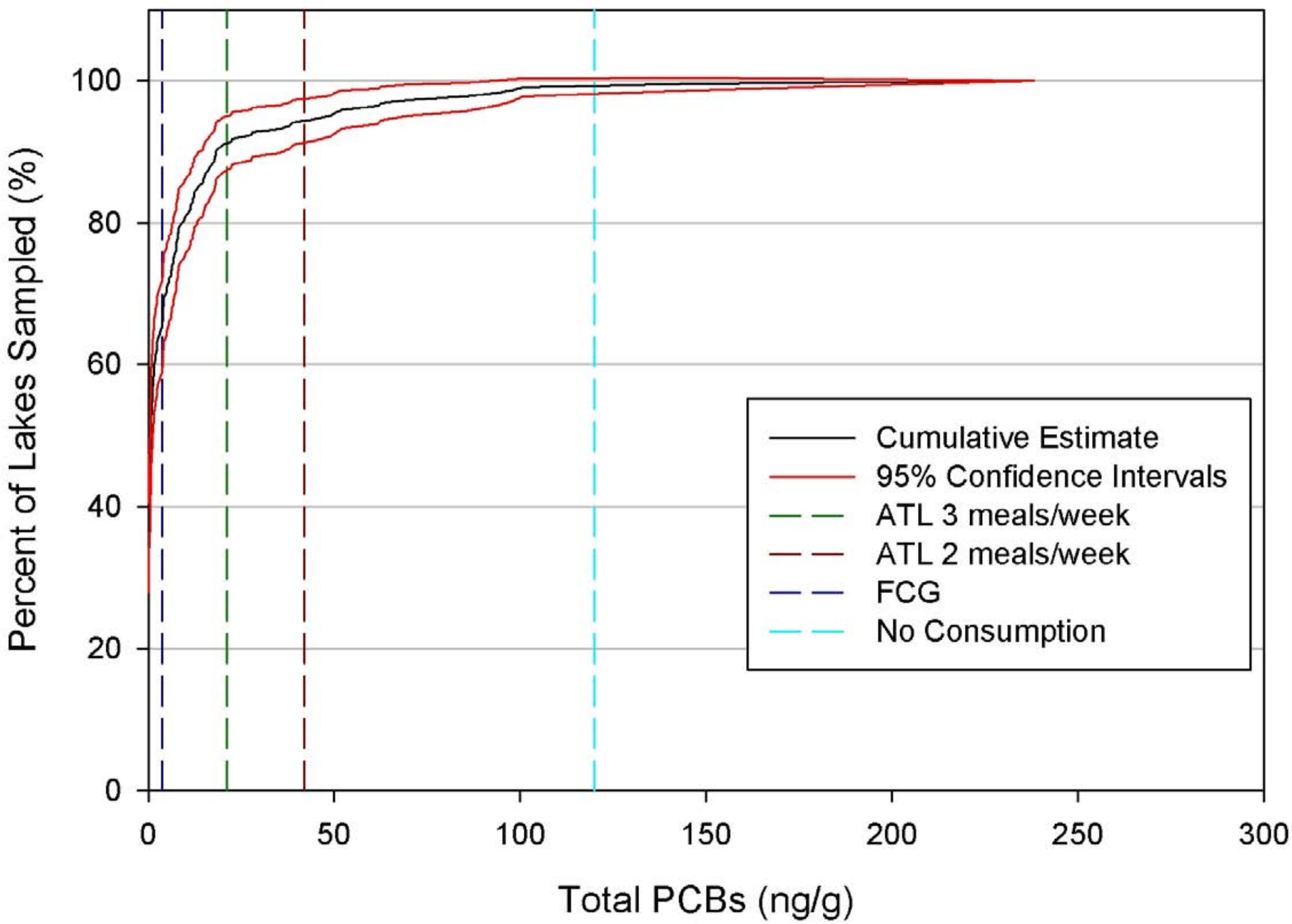

Figure 14. **Lake-wide average PCB concentrations in common carp and channel catfish** at lakes sampled in the Lakes Survey, from both targeted (circles) and random (squares) lakes. Note different scale from the methylmercury maps, with the two serving ATL as the highest threshold.

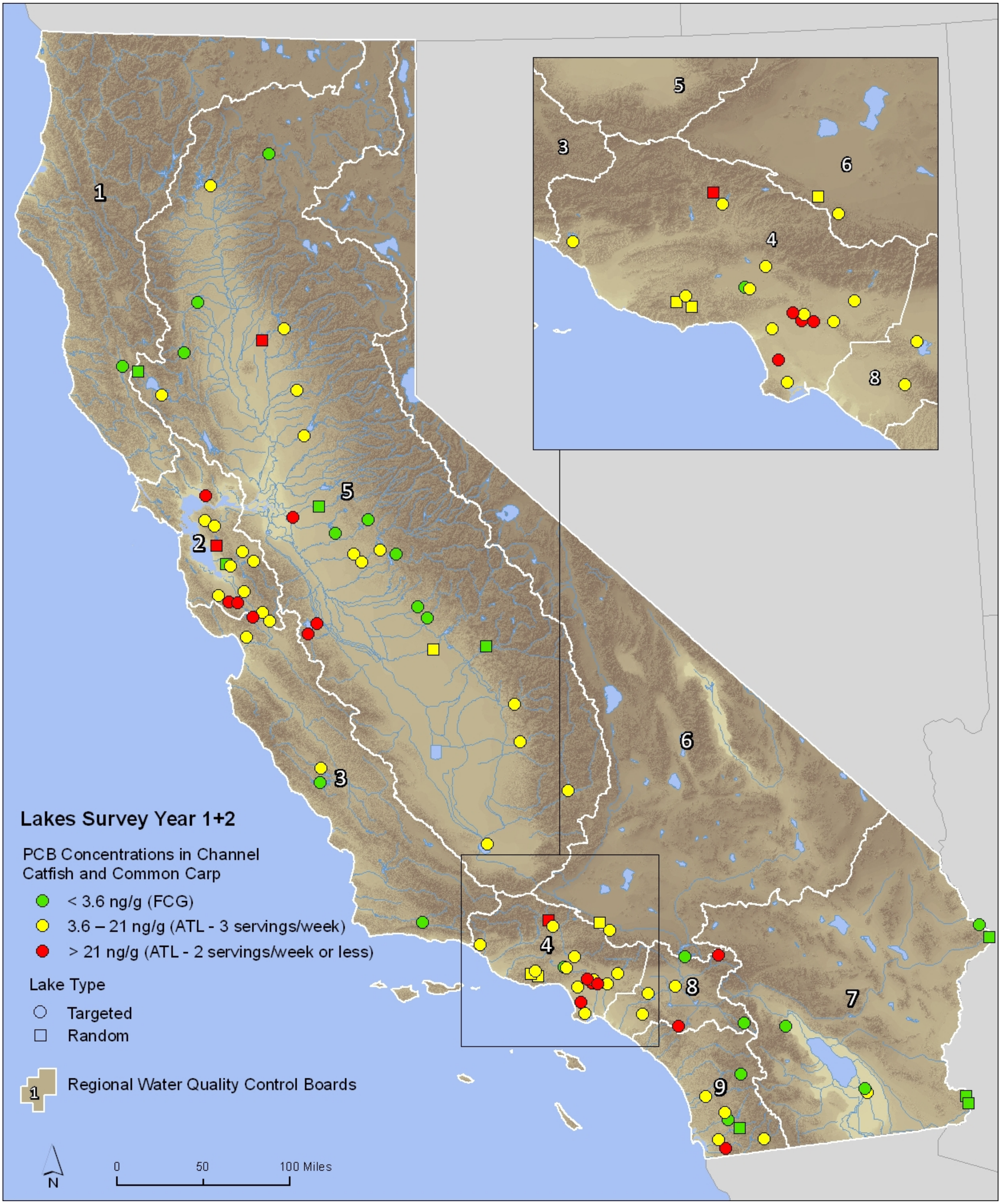

Figure 15. **Highest species-average dieldrin concentrations** at lakes sampled in the Lakes Survey. Concentrations based on lake-wide and location composites, from both targeted (circles) and random (squares) lakes. Colors represent dieldrin concentration categories. Note different scale from the methylmercury maps, with the two serving ATL as the highest threshold.

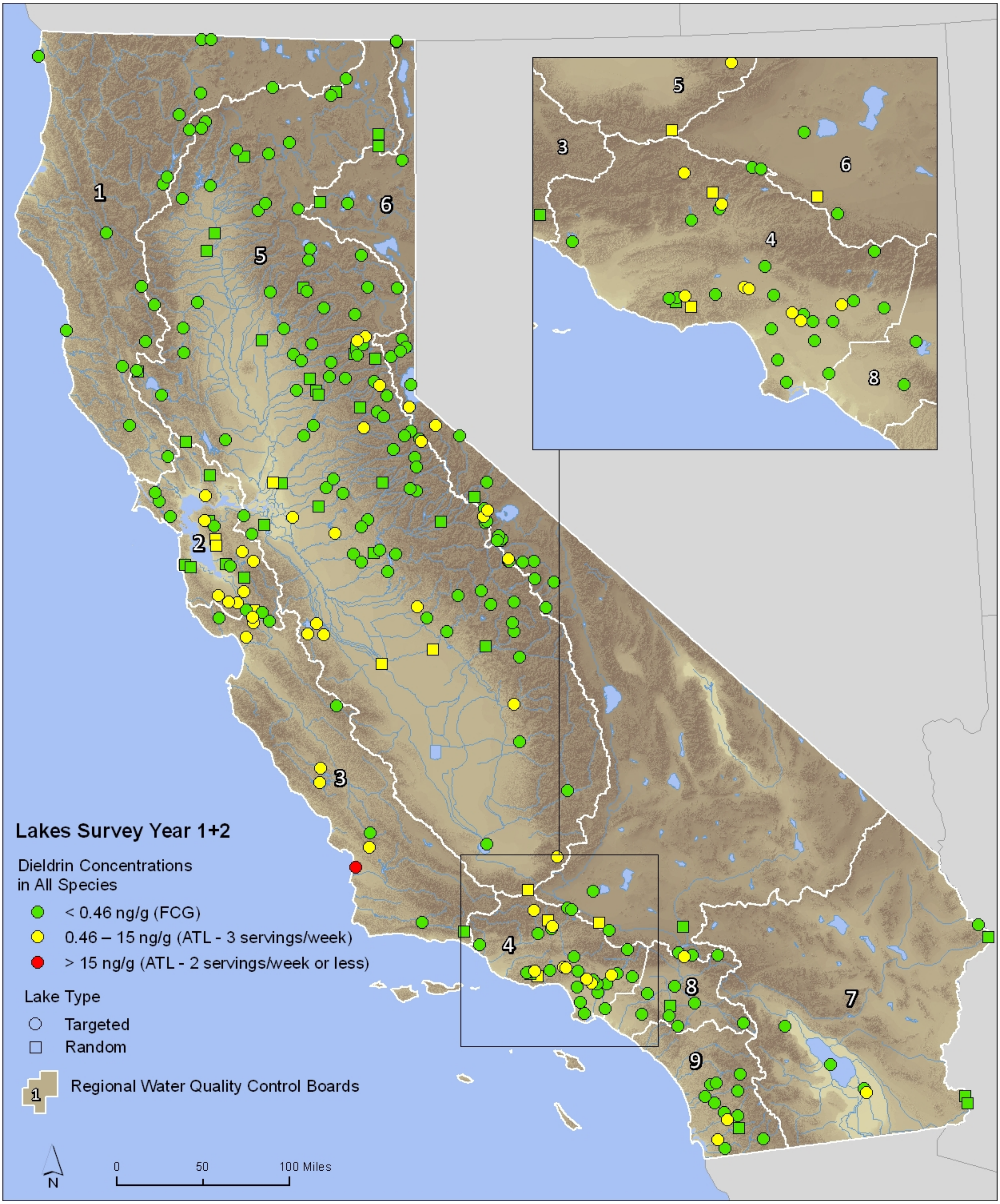

Figure 16. Satellite view of Little Oso Flaco Lake.

Figure 17. **Highest species-average DDT concentrations** at lakes sampled in the Lakes Survey. Concentrations based on lake-wide and location composites, from both targeted (circles) and random (squares) lakes. Note different scale from the methylmercury maps, with the two serving ATL as the highest threshold.

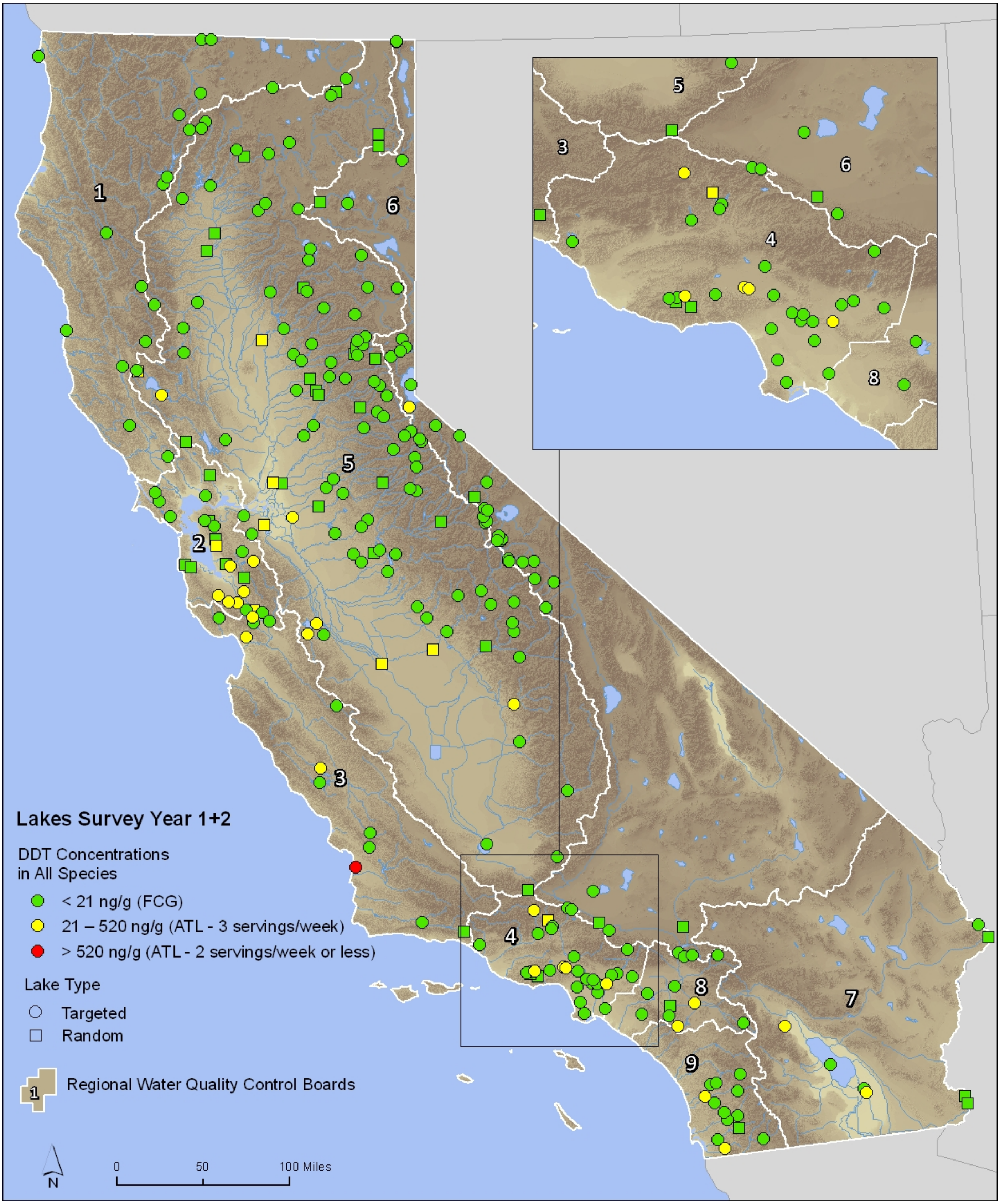

Figure 18. **Highest species-average chlordane concentrations** at lakes sampled in the Lakes Survey. Concentrations based on lake-wide and location composites, from both targeted (circles) and random (squares) lakes. Note different scale from the methylmercury maps, with the two serving ATL as the highest threshold.

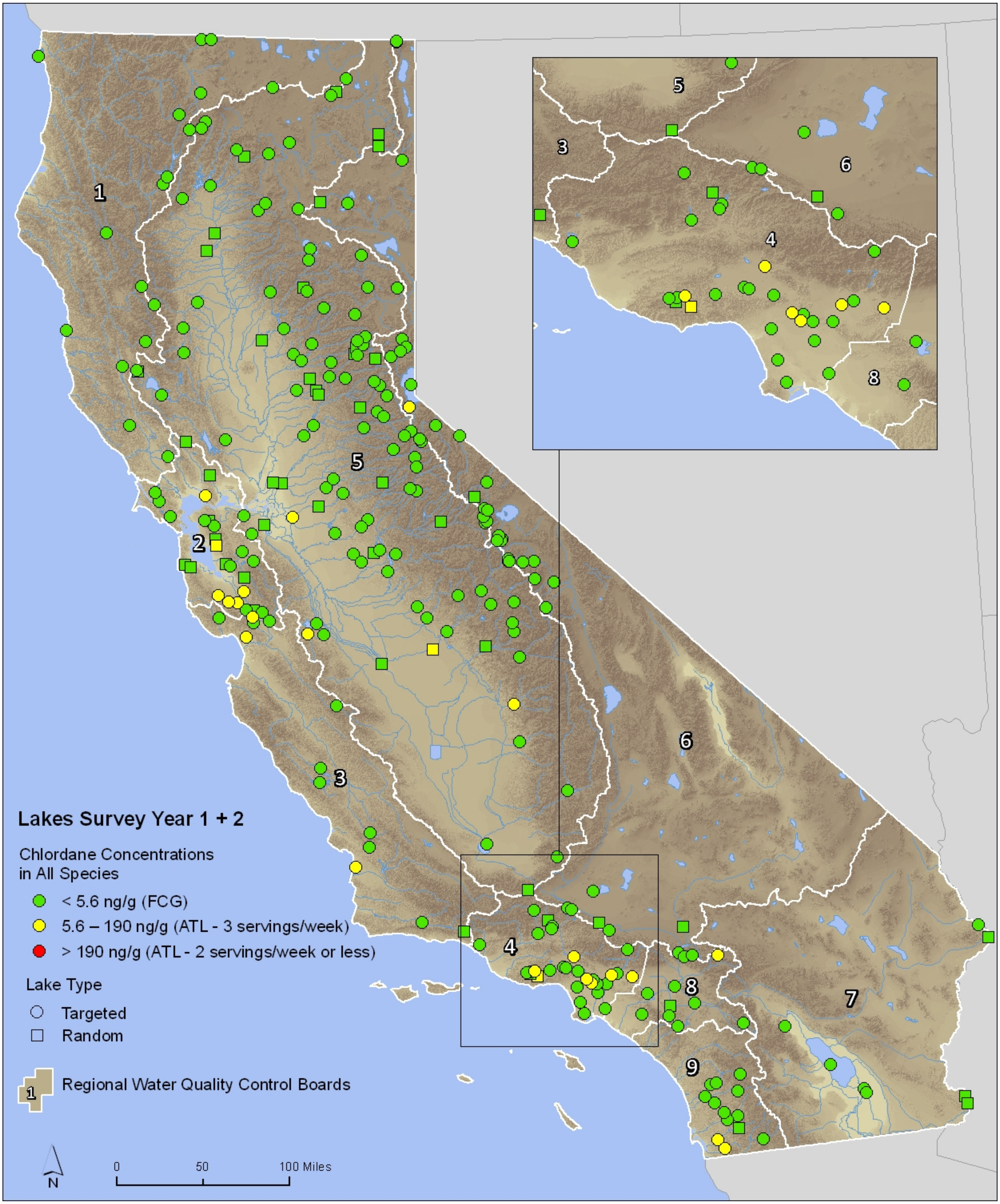

Figure 19. **Highest species-average selenium concentrations** at lakes sampled in the Lakes Survey. Concentrations based on lake-wide and location composites, from both targeted (circles) and random (squares) lakes. Note different scale from the methylmercury maps, with the two serving ATL as the highest threshold.