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Sampling and Analysis Plan for a Screening Study of Bioaccumulation in California Lakes and Reservoirs

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SAMPLING AND ANALYSIS PLAN FOR A SCREENING STUDY OF BIOACCUMULATION IN CALIFORNIA LAKES AND RESERVOIRS

The Bioaccumulation Oversight Group (BOG)

Surface Water Ambient Monitoring Program

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THE BIOACCUMULATION OVERSIGHT GROUP

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I. INTRODUCTION

This document presents a plan for sampling and analysis of sport fish in the first year of a two-year screening survey of bioaccumulation in California lakes and reservoirs. This work will be performed as part of the State Water Resources Control Board's Surface Water Ambient Monitoring Program (SWAMP). This effort will mark the beginning of a new long-term Bioaccumulation Monitoring Project that will provide comprehensive monitoring of bioaccumulation in California water bodies.

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 USEPA, the Department of Fish and Game, the Office of Environmental Health Hazard Assessment, and the University of California. Interested parties, including members of other agencies, consultants, or other stakeholders are also welcome to participate.

The Roundtable has formed a subcommittee, the Bioaccumulation Oversight Group (BOG) that focuses on the Bioaccumulation Monitoring Project. 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, the Office of Environmental Health Hazard Assessment, and the San Francisco Estuary Institute. The members of the BOG individually and collectively possess extensive experience with bioaccumulation monitoring.

The BOG has also convened a Bioaccumulation Peer Review Panel that is providing programmatic evaluation and review of specific deliverables emanating from the Project, including this Sampling Plan. The members of the Panel are internationally-recognized authorities on bioaccumulation monitoring.

The BOG was formed and began developing a strategy for designing and implementing a statewide bioaccumulation monitoring program in September 2006. To date the efforts of the BOG have been focused on developing a short-term plan for obtaining the most critical information needed through a sampling effort that will begin in May 2007. After this short-term plan is completed, the BOG will develop a long-term Business Plan that will be a more comprehensive document that describes a strategy for establishing and implementing bioaccumulation monitoring over the next five years. The Long-term Business Plan will include a thorough presentation of both the planned activities and their rationale. Some of the elements to be included in the Long-term Plan are:

- Long-term (five-year) strategies for addressing the mission, goals, objectives, and assessment questions related to both the fishing and aquatic life beneficial uses in all water body types;
- An inventory of programs with common assessment questions;
- Plans for coordination with other programs;
- Evaluation of potential for models to forecast future trends and contribute to answering the assessment questions;
- Strategies for sustaining the program over the long-term; and
- Framework for integrating other monitoring efforts into statewide program.

The Long-term Business Plan will be completed in October 2007.

A draft Project Plan for the Bioaccumulation Monitoring Project has also been prepared that provides a more complete description of how this Project fits into the broader objectives of SWAMP (refxx).

II. OBJECTIVES AND ASSESSMENT QUESTIONS AND PLANS FOR ADDRESSING THEM

A. Addressing Multiple Beneficial Uses

Bioaccumulation in California water bodies has an adverse impact on both the fishing and aquatic life beneficial uses (Davis et al. 2007). The fishing beneficial use is affected by human exposure to bioaccumulative contaminants through consumption of sport fish. The aquatic life beneficial use is affected by exposure of wildlife to bioaccumulative contaminants, primarily piscivorous species exposed through consumption of small fish. Different indicators are used to monitor these different types of exposure. Monitoring of status and trends in human exposure is accomplished through sampling and analyzing sport fish. On the other hand, monitoring of status and trends in wildlife exposure can accomplished through sampling and analysis of wildlife prey (small fish, other prey species) or tissues of the species of concern (e.g., bird eggs or other tissues of juvenile or adults of the species at risk).

Over the long-term, a SWAMP bioaccumulation monitoring is envisioned that assesses progress in reducing impacts on both the fishing and aquatic life beneficial uses for all water bodies in California. In the near-term, however, funds are limited, and there is a need to demonstrate the value of a comprehensive statewide bioaccumulation monitoring program through successful execution of specific components of a comprehensive program. Consequently, with funds available for sampling in 2007 ($797,000) and additional funds of a similar magnitude anticipated for 2008, the BOG has decided to focus on sampling that addresses the issue of bioaccumulation in sport fish and impacts on the fishing beneficial use. This approach is intended to provide the information that the Legislature and the public would consider to be of highest priority. Monitoring focused on evaluating the aquatic life beneficial use will be included in the Project when expanded funding allows a broader scope.

B. Addressing Multiple Monitoring Objectives and Assessment Questions for the Fishing Beneficial Use

The BOG has developed a set of monitoring objectives and assessment questions for a statewide program evaluating the impacts of bioaccumulation on the fishing beneficial use (Table 1). This assessment framework is consistent with frameworks developed for other components of SWAMP, and is intended to guide the bioaccumulation monitoring program over the long-term. The four objectives can be summarized as 1) status; 2) trends; 3) sources and pathways; and 4) effectiveness of management actions.

Over the long-term, the primary emphasis of the statewide bioaccumulation monitoring program will be on evaluating status and trends. Bioaccumulation monitoring is a very effective and essential tool for evaluating status, and is often the most cost-effective tool for evaluating trends. Monitoring status and trends in bioaccumulation will provide some information on sources and pathways and effectiveness of management actions at a broader geographic scale. However, other types of monitoring (i.e., water and sediment monitoring) and other programs (regional TMDL programs) are more appropriate for addressing sources and pathways and effectiveness of management actions.

In the near-term, the primary emphasis of the statewide bioaccumulation monitoring program will be on evaluating Objective 1 (status). The reasons for this are:

1. a systematic statewide assessment of status has never been performed and is urgently needed;
2. we are starting a new program and establishing a foundation for future assessments of trends;
3. past monitoring of sport fish established very few time series that are useful in trend analysis that this program could have built upon.

C. Addressing Multiple Habitat Types

SWAMP has defined the following categories of water bodies:

- lakes and reservoirs;
- bays and estuaries;
- coastal waters;
- large rivers;
- wadeable streams; and
- wetlands.

Due to their vast number, high fishing pressure, and a relative lack of information on bioaccumulation (Davis et al. 2007), lakes and reservoirs were identified as the highest priority for monitoring. With over 9000 lakes in California, performing a statewide assessment of just this one water body type would be a challenge with the limited amount of funding available for bioaccumulation monitoring. The BOG therefore decided that sampling in 2007 (with funds already allocated – approximately $800,000) and 2008 (with additional funds anticipated – approximately $700,000) should focus on a thorough assessment of lakes and reservoirs. The long-term plan for bioaccumulation monitoring will include a strategy for monitoring bioaccumulation in the other water body types (for both the fishing and aquatic life beneficial uses).

In summary, focusing on one habitat type (lakes), one objective (status), and one beneficial use (fishing) will allow us to provide reasonable coverage and a thorough assessment of bioaccumulation in California’s lakes and reservoirs.

III. DESIGN OF THE LAKES SURVEY

A. Management Questions for this Survey

Three management questions have been articulated to guide the 2007-2008 survey of the status bioaccumulation in sport fish of California lakes and reservoirs. 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 (MQ1)

Should a specific lake be considered impaired and placed on the 303(d) list due to bioaccumulation of contaminants in sport fish?

Answering this question is critical to determining the need for cleanup actions to reduce contaminant exposure in specific water bodies. 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 Water Board has established a policy for placing water bodies on the 303(d) list. The information needed to make a listing determination is concentrations from two independent samples from the water body that exceed the relevant threshold of concern. The more representative the samples are of the water body, the better.

Management Question 2 (MQ2)

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

Answering this question is the goal of the biennial 305(b) reports that the State Water Resources Control Board submits to the U.S. Environmental Protection Agency pursuant to Section 305(b) of the federal Clean Water Act (e.g., SWRCB 2003). The 305(b) report provides water quality information to the general public and serves as the basis for U.S. EPA 's National Water Quality Inventory Report to Congress. The report provides a statewide, comprehensive assessment of the status of California water bodies with respect to support of designated beneficial uses. Answering this question also provides the state legislature and the public with information that helps establish the magnitude 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 bioaccumulative contaminants in each lake for an adequately large sampling of lakes.

Management Question 3 (MQ3)

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 determining the need for more thorough sampling in support of developing consumption guidelines. Consumption guidelines provide a mechanism for reducing human exposure in the short-term. The information requirements for consumption guidelines are more extensive than for 303(d) listing. The California Office of Environmental Health Hazard Assessment (OEHHA), the agency responsible for issuing consumption guidelines, needs samples representing 9 or more fish from a variety of species abundant in a water body in order to issue guidance. It is valuable 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 to be taken to answer these three questions is to perform a statewide screening study of bioaccumulation in sport fish. The highest priority for SWAMP in the short-term is to answer MQ1 and MQ2. 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 meet their needs and 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 effort would cost-effectively establish a foundation for this by identifying lakes where guidelines appear to be needed and more sampling is required.

It is anticipated that the screening study will lead to more detailed followup investigations of many water bodies that become placed on the 303(d) list or where consumption guidelines are needed. Funding for these followup studies will come from other local or regional programs rather than the statewide monitoring budget.

B. Selecting Lakes to Sample

California has over 9,000 lakes. Collecting and analyzing fish from all of these lakes would be prohibitively expensive, so a representative subset was selected to answer the management questions established for the survey.

Sampling of Popular Lakes

The primary emphasis of the sampling effort will be to address MQ1 for as many lakes as possible. The focus of this aspect of the survey will be on lakes that are of greatest interest to managers and the public – the lakes that are most popular for fishing. This approach is considered the most prudent use of the limited funds available. Eighty percent of the funds anticipated to be available in 2007 and 2008 are being allocated to sampling these popular lakes.

The 216 most popular fishing lakes and reservoirs in California (Table 2, Figure 1) were identified through review of published fishing guides (Stienstra xx, othersxx), websites, and consultation with Regional Board staff from each of the nine regions. The goal of the study is to sample as many of these popular lakes as possible. It is anticipated that, if funding for year two is obtained as expected, approximately 200 of these popular lakes will be sampled (approximately 80 in 2007 and 120 in 2008). Lakes to be sampled in year 1 are shown in Figure 2.

Given the uncertainty regarding how many popular lakes will be sampled, and the likelihood that the entire set will not be sampled, a probabilistic approach is being taken to sample this set of lakes. The lakes will be sampled in a random order indicated by the "Sampling Sequence" column in Table 2. The sequence was determined using the generalized random tessellation-stratified (GRTS) approach developed for USEPA's Environmental Monitoring and Assessment Program (Stevens and Olsen 2004). The GRTS approach achieves a random point distribution that is spatially balanced – in other words, it avoids the spatial clustering that often occurs in a conventional random sample. This balance is achieved even if only a subset of the population of interest is sampled as long as the samples are collected in the order specified. In the random selection of these lakes, each lake was assigned an equal probability of inclusion. Another advantage of this approach is that if the entire population of 216 lakes is not sampled, then inferences can still be drawn about the population as a whole, including the unsampled lakes. In addition, after the first year of sampling is completed, it will be possible to make a preliminary assessment based on inference about the status of all the popular lakes. For the popular lakes, no minimum size limit will be applied.

The second major emphasis of the sampling effort will be to provide a statewide assessment that addresses MQ2. The most cost-effective approach to obtaining a statewide assessment is through sampling of a random, unbiased selection of lakes from the entire population of lakes in the state. Twenty percent of the funds anticipated to be available in 2007 and 2008 are being allocated to this statewide assessment of "other" lakes (i.e., lakes not include in the list of popular lakes) (Table 3).

The minimum sample size needed for a reasonably precise statewide characterization of degrees of impairment due to bioaccumulation is 50 (Don Stevens, personal communication). As with the popular lakes, the other lakes were selected using the GRTS approach, and will be sampled in a random order indicated by the "Sampling Sequence" column in Table 3. Of the more than 9000 lakes in California, a vast majority are very small and not subject to much fishing pressure. 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 following the relationship illustrated in Figure 3. This weighting scheme skews the sampling as much toward larger lakes as possible without compromising the validity of the sample as a representation of the entire population of "other" lakes. Many of the lakes and reservoirs in California are inaccessible or unfishable. To avoid wasting sampling resources on these lakes, the population of "other" lakes was restricted to lakes greater than 4 ha in size, and that could be accessed and sampled within a one day period. These restrictions resulted in the exclusion of many lakes from the population to be sampled. Evaluating access to these lakes is a time-consuming task that is still being performed (as indicated in the "Sampleable" column).

The 50 "other" lakes will all be sampled in 2007 in order to provide an answer as quickly as possible to MQ2. After completion of collection and analysis of the 2007 samples, it will therefore be possible to prepare a report that provides a sound preliminary answer to MQ1 and a full answer to MQ2.

MQ3 will also be addressed through the sampling of both the popular and other lakes, but most effectively through sampling of the popular lakes.

C. Sampling Design Within Each Lake

1. Species Targeted

Given the focus of the screening study on the fishing beneficial use, the species to be sampled will be those that are commonly caught and consumed by anglers. Other factors considered include abundance, geographic distribution, and value as indicators for the contaminants of concern. The abundance and geographic distribution of species are factors that facilitate sample collection and assessment of spatial patterns in contamination. For example, largemouth bass is very common and widely distributed, and these factors contribute to making this an appropriate indicator species even though it is less popular for consumption than some other species.

The goal of this screening study is to determine whether or not California lakes have unacceptably high concentrations of contaminants. Given this goal, the study is focusing on indicator species that tend to accumulate the highest concentrations of the contaminants of concern. Different contaminants tend to reach their highest concentrations in different species. Mercury biomagnifies primarily through its accumulation in muscle tissue, so top predators such as largemouth bass tend to have the highest mercury concentrations. In contrast, the organic contaminants of concern biomagnify, but primarily through accumulation in lipid. Concentrations of organics are therefore are also influenced by the lipid content of the species, with species that are higher in lipid having higher concentrations. Bottom-feeding species such as catfish and carp tend to have the highest lipid concentrations in their muscle tissue, and therefore usually have the highest concentrations of organics. Selenium also biomagnifies primarily through accumulation in muscle, but past monitoring in the San Joaquin Valley (Beckon et al. xx) suggests that bottom-feeders accumulate slightly higher concentrations, perhaps an indication of a stronger association with the benthic food web.

Consequently, this study will target two indicator species in each lake – a top predator (e.g., black bass or Sacramento pikeminnow) as a mercury indicator and a high lipid, bottom-feeding species (e.g., catfish, carp) 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. These considerations led USEPA (2000) to recommend this two species approach in their guidance document for monitoring in support of development of consumption advisories.

Some lakes, particularly high elevation lakes, may only have one abundant high trophic level species (i.e., trout). In these cases, the one species will be sampled as an indicator of all the target analytes.

Fish species are distributed unevenly across the State, with different assemblages in different regions (e.g., high Sierra Nevada, Sierra Nevada foothills, and Central Valley) and a variable distribution within each region. To cope with this, the sampling crew will have a prioritized menu of several potential target species (Table 4). Primary target species will be given the highest priority. If primary targets are not available in sufficient numbers, secondary targets have been identified. Other species will also be observed in the process of electroshocking. This "bycatch" will not be collected, but the sampling crew will record estimates of the numbers of each species observed. This information may be useful if followup studies are needed at any of the sampled lakes.

2. Locations

Lakes and reservoirs in California vary tremendously in size, from xxhundreds of small ponds less than xx10 ha to Lake Tahoe at 50,000 ha. The distribution of lake sizes of different categories is shown in Table 5. As lakes increase in size it becomes necessary to sample more than one location to obtain a representative characterization of the water body.

In sport fish sampling using an electroshocking boat, it is frequently necessary to sample over a linear course of 0.5 – 1 miles to obtain an adequate number of fish. A sampling location in this study can therefore be thought of as a circle with a diameter of 1 mile. For small lakes less than 500 ha in size, one sampling location covers a significant fraction of the surface area of the lake. An example (Lake Piru, 484 ha) is shown in Figure 4. Therefore, for lakes less than 500 ha, one location will be sampled. Since the goal of the study is to characterize human exposure, the locations will be established near centers of fishing activity.

Decisions regarding the number and placement of locations in each lake will be made in consultation with Regional Board staff with local knowledge of the lakes, especially for lakes in the large and very large categories. Criteria to be considered in determining the placement of sampling locations will include the existence of discrete centers of fishing activity, known patterns of spatial variation in contamination or other factors influencing bioaccumulation, road or boat ramp access, and possibly other factors.

As lakes increase in size, sampling of additional locations will be considered. For lakes of medium size (500 – 1000 ha), two locations will generally be sampled. Many lakes are in this size category – including 35 of the 216 (16%) popular lakes. An example of a lake in this category (Pardee Reservoir, 884 ha) is shown in Figure 5. Two locations would provide coverage of a significant portion of the surface area of a lake of this size. In some cases, upon consultation with Regional Board staff, it may even be decided that one location is adequate for a lake in this size category.

For lakes in the large category (1000 – 5000 ha), two to four locations will be sampled. A smaller percentage of lakes are in this category (22 of the 216 popular lakes, or 10%). An example of a lake in this category (Black Butte Lake, 1824 ha) is shown in Figure 6. Three locations would provide coverage of a significant portion of the surface area of a lake of this size. In some cases, upon consultation with Regional Board staff, it may even be decided that two locations are adequate for a lake in this size category. In other cases where lakes are known to have significant spatial variation in factors affecting human exposure, four locations might be sampled in a lake in this size range.

For lakes in the very large category (>5000 ha), two to four locations will be sampled. A small percentage of lakes are in this category (11 of 216 popular lakes, or 5%). An example of a lake in this category (Lake Berryessa, 6800 ha) is shown in Figure 7. Three locations would provide coverage of a significant portion of the surface area of a lake of this size. In some cases, upon consultation with Regional Board staff, it may even be decided that two locations are adequate for a lake in this size category. In other cases where lakes are known to have significant spatial variation in factors affecting human exposure, four locations might be sampled in a lake in this size range. The largest lakes, Lake Tahoe and the Salton Sea, are special cases where consultation with Regional Board staff will be particularly important.

3. Size Ranges and Compositing for Each Species

Size Ranges and Compositing

Chemical analysis of trace organics is relatively expensive ($470 per sample for PCB congeners and $504 per sample for organochlorine pesticides), and the management questions established for this survey can be addressed with good information on average concentrations, so a compositing strategy will be employed for these chemicals. These data will be used to answer the management questions listed on page 6.

Chemical analysis of mercury is much less expensive ($60 per sample), and SWAMP partners would like to answer management questions in addition to the ones listed on page 6. The additional questions relate to statistical evaluation of differences among lakes and of trends over time. The partners include the State Water Resources Control Board and some of the Regional Boards, and these partners are bringing additional funds to the table to contribute to obtaining the information needed to address the additional questions. Consequently, the sampling design for the mercury indicator species includes analysis of mercury in individual fish. For the mercury indicator species, an analysis of covariance approach will be employed, in which the size:mercury relationship will be established for each location and an ANCOVA will be performed that will allow the evaluation of differences in slope among the locations and the comparison of mean concentrations and confidence intervals at a standard length, following the approach of Tremblay (1998). Experience applying this approach in the Central Valley indicates that to provide robust regressions 10 fish spanning a broad range in size are needed (Davis et al. 2003, Melwani et al. 2007).

Specific size ranges to be targeted for each species are listed in Table 6. Black bass (including largemouth, smallmouth, and spotted bass) and Sacramento pikeminnow (included in Group 1) are the key mercury indicators. These species have a high trophic position and a strong size:mercury relationship. These species will be analyzed for mercury only, and will be analyzed individually. The numbers and sizes indicated for these species will provide the size range needed to support ANCOVA. In addition, the size range for black bass takes the legal limit for these species (305 mm, or 12 inches) into account. The goal for black bass is to have a size distribution that encompasses the standard length (350 mm) to be used in statistical comparisons. This length is near the center of the distribution of legal-sized fish encountered in past studies (Davis et al. 2003, Melwani et al. 2007).

In many high elevation lakes only trout species will be available. Past sampling of rainbow trout in the Bay-Delta watershed has found low concentrations and a weak size:mercury relationship. Therefore, for these species the ANCOVA approach will not be used. Mercury will be analyzed in individuals, but a specified size range will be targeted to control for size rather than a wide span to support a regression-based analysis. These trout will also be analyzed as composites for organics. The size ranges established for trout are based on a combination of sizes prevalent in past sampling (Melwani et al. 2007) and the 75% rule recommended by USEPA (2000) for composite samples.

Catfish, carp, bullhead, and sucker are the primary targets for high lipid bottom-feeders. These species will be analyzed for organics, selenium, and mercury. Organics are expected to be highest in these species based on past monitoring in the Toxic Substances Monitoring Program and other studies (Davis et al. 2007). Selenium is expected to be highest in these species, although the difference is not as distinct as for the organics, based on data from the Grassland Bypass Project (Beckon et al. xx). Mercury is expected to be highest in the pelagic predators, but concentrations are also expected to be above thresholds for concern in the bottom-feeders, so mercury will be analyzed in these samples as well. Samples for these species will be analyzed as composites. The size ranges established for trout are based on a combination of sizes prevalent in past sampling (Melwani et al. 2007) and the 75% rule recommended by USEPA (2000) for composite samples.

Secondary targets have been identified that will be collected if the primary targets are not available. These species would be processed for potential analysis of mercury, selenium, and organics. The samples would be analyzed as composites. The size ranges established for trout are based on a combination of sizes prevalent in past sampling (Melwani et al. 2007) and the 75% rule recommended by USEPA (2000) for composite samples.

The sampling crew will be reporting their catch back to the BOG on a weekly basis to make sure that the appropriate samples are collected and to address any unanticipated complications.

4. Compositing and Archiving Strategies

Strategies for compositing and archiving will vary somewhat for lakes of different size. The overall strategy will be described first for small lakes, followed by a discussion of the differences for larger lakes.

Small Lakes

Figure 8 illustrates the approach to be taken for the predator and bottom-feeding species. As described above, the predator species will be analyzed for mercury only and as individual fish. All samples of the predator species will be analyzed. Small lakes will be treated as one sampling location, so fish from anywhere in the lake will be counted toward meeting the targets for each size range listed in Table 6. For ANCOVA, one common regression line will be developed to describe the size:mercury relationship for the lake as a whole. Aliquots from these samples will also be archived after they are analyzed in case of any problems or other circumstances calling for reanalysis at a later time.

The bottom-feeding species will be analyzed as composites for organics, selenium, and mercury (Figure 8). It is anticipated, based on review of past data (Davis et al. 2007) that the majority of lakes will not exceed thresholds of concern for organics or selenium. Therefore, to address the management questions guiding this study in a cost-effective manner, these composite samples will be analyzed in a stepwise fashion. To answer MQ2 (305(b) assessment), a representative indication of the average concentration in the lake is needed. For a statewide screening survey, one sample per lake is adequate for this purpose. Therefore, one representative composite sample will be analyzed immediately. To answer MQ1 (303(d) listing), the State Water Board's listing policy requires a minimum of two samples to support a determination that a water body should be on the 303(d) list. Therefore, another composite sample will also be collected. However, this second composite sample will only be analyzed if the first composite sample exceeds a threshold (Tables 7 and 8). The threshold for this followup analysis (Table 8) has been designated as 75% of the threshold for concern (Table 7). The thresholds for concern (Table 7) are derived from an assessment by OEHHA (Klasing and Brodberg 2006). At concentrations below these thresholds, OEHHA strongly encourages consumption of up to 8 meals per month. At concentrations above these thresholds, OEHHA would begin to consider advising limited consumption (i.e., fewer than 8 meals per month). Considering PCBs as an example, if the first composite has a concentration of 22 ppb or higher, then the second archived composite would also be analyzed. If the concentration in the first composite is below 22 ppb, then the second composite would not be analyzed. This approach will avoid expenditure of funds on organics analysis where it is not helping to answer the management questions of interest. Aliquots from all composites will also be archived whether they are analyzed or not in case of any problems or other circumstances calling for analysis or reanalysis at a later time.

The followup analysis will be performed as quickly as possible so that the management questions can be answered as well as possible in a report to be prepared within one year of sampling. The following steps will be taken to expedite the analysis of these samples.

1. Lakes that are likely, based on existing information, to exceed thresholds for organics and selenium will be identified and sampled early in the sampling season.
2. When the lab obtains results indicating concentrations above the followup threshold, the remaining composites from that lake will be immediately put to the front of the queue for analysis.

Larger Lakes

For lakes in the medium, large, and very large categories the basic approach will be similar, with a couple of modifications. Figures 9-11 illustrate the approach. The first difference from the small lake approach is that sampling locations will be treated discretely. For the predator species, this means that 11 fish spanning a wide range of sizes will be targeted for each location to support the development of a size:mercury regression and an estimated mean concentration at standard length for each location. From these location means a lakewide mean will be calculated to answer MQ2. The location means will be used to answer MQ1.

For the bottom-feeder species, discrete composites will be prepared for each location. These composites will be homogenized and archived. Aliquots of homogenate from each location composite will be pooled to form a lakewide composite. The lakewide composite will be analyzed immediately. If the lakewide composite concentration of any of the organics or selenium exceeds a threshold for followup analyis (Table 8), then all of the discrete location composites will be analyzed. Aliquots from all composites will also be archived whether they are analyzed or not in case of any problems or other circumstances calling for analysis or reanalysis at a later time.

D. Sample Processing and Analysis

Upon collection each fish collected will be tagged with a unique ID. Several parameters will be measured in the field, including 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. Total length changes with freezing and thawing and is best noted in the field for greatest accuracy and because it is the measure fishers and wardens use to determine whether a fish is legal size. Doing fork length at the same time simplifies matters, and might help with IDs later to sort out freezer mishaps.

Whole fish will be wrapped in aluminum foil and frozen on dry ice for transportation to the laboratory, where they will be stored in freezers. Fish will be kept frozen wrapped in foil until the time of dissection. Dissection and compositing of muscle tissue samples will be performed following USEPA guidance (USEPA 2000). At the time of dissection, fish will be placed in a clean lab to thaw. After thawing, fish will cleaned by rinsing with de-ionized (DI) and ASTM Type II water, and handled only by personnel wearing polyethylene or powder-free nitrile gloves (glove type is analyte dependent). All dissection materials will be cleaned by scrubbing with Micro® detergent, rinsing with tap water, DI water, and finally ASTM Type II water.

All fish will have the skin dissected off, and only the fillet muscle tissue will be used for analysis. This is inconsistent with the guidance of USEPA (2000) that recommends that fish with scales have the scales removed and be processed with skin on, and skin is only removed from scaleless fish (e.g. catfish). The BOG is aware of this difference, but favors skin removal. Skin removal has been repeatedly used in past California monitoring. All fish (with limited exceptions) in Toxic Substances Monitoring Program, the Coastal Fish Contamination Program, and the Fish Mercury Project have also been analyzed skin-off. Processing fish with the skin on is very tedious and results in lower precision because the skin is virtually impossible to homogenize thoroughly and achieving a homogenous sample is difficult. Also, skin-on preparation actually dilutes the measured concentration of mercury because there is less mercury in skin than in muscle tissue. The most ubiquitous contaminant in fish in California that leads to most of our advisories is mercury. By doing all preparation skin-off we will be getting more homogeneous samples, better precision for all chemicals, and definitely a better measure of mercury concentrations, which are our largest concern.

Mercury will be analyzed according to EPA 7473, "Mercury in Solids and Solutions by Thermal Decomposition, Amalgamation, and Atomic Absorption Spectrophotometry" using a Direct Mercury Analyzer. Samples, blanks, and standards will be prepared using clean techniques. ASTM Type II water and analytical grade chemicals will be used for all standard preparations. A continuing calibration verification (CCV) will be performed after every 10 samples. Initial and continuing calibration verification values must be within ±20% of the true value, or the previous 10 samples must be reanalyzed. Three blanks, a standard reference material (DORM-2), as well as a method duplicate and a matrix spike pair will be run with each set of samples.

Selenium will be digested according to EPA 3052M, "Microwave Assisted Acid Digestion of Siliceous and Organically Based Matrices", modified, and analyzed according to EPA 200.8, "Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma-Mass Spectrometry". Samples, blanks, and standards will be prepared using clean techniques. ASTM Type II water and analytical grade chemicals will be used for all standard preparations. A continuing calibration verification (CCV) will be performed after every 10 samples. Initial and continuing calibration verification values must be within ±20% of the true value, or the previous 10 samples must be reanalyzed. Two blanks, a standard reference material (2976 or DORM-2), as well as a method duplicate and a matrix spike pair will be run with each set of samples.

Organochlorine pesticides and PBDEs will be analyzed according to EPA 8081AM, "Organochlorine Pesticides by Gas Chromatography" and PCBs will be analyzed according to EPA 8082M, "Polychlorinated Biphenyls (PCBs) by Gas Chromatography". Samples, blanks, and standards will be prepared using clean techniques. ASTM Type II water and analytical grade chemicals will be used for all standard preparations. A continuing calibration verification (CCV) will be performed after every 10 samples. Initial and continuing calibration verification values must be within ±25% of the true value, or the previous 10 samples must be reanalyzed. One blank, a laboratory control spike (LCS), as well as a method duplicate and a matrix spike pair will be run with each set of samples.

E. Analytes

Table 9 provides a summary of the contaminants included on the list of analytes for the study. Since the study is focused on assessing the impacts of bioaccumulation on the fishing beneficial use, the list is driven by concerns over human exposure. Contaminants were included if they were considered likely to provide information that is needed to answer the three management questions for the study (see page 6). Addressing the first two management questions (relating to information needs of the Water Boards) is the immediate priority, but providing information that builds toward addressing MQ 3 (relating to information needs of OEHHA) is a longer-term priority.

Additional discussion of the analytes is provided below. A detailed evaluation by OEHHA of which congeners and metabolites to include in the analyses is provided in Appendix 1.

Ancillary Parameters

Ancillary parameters to be measured in the lab include moisture, lipid, and age (Table 10). Age will be determined through analysis of fish scales for a subset of lakes where detailed studies of bioaccumulation factors are being conducted through a separate coordinated effort of the State Water Resources Control Board. Fish sex will not be determined as it is not considered critical for this screening study.

Mercury

Mercury is the contaminant of greatest concern with respect to bioaccumulation on a statewide basis. Based on past studies (Davis et al. 2007), mercury is expected to exceed the threshold of concern in many lakes and reservoirs. Mercury will be measured as total mercury. Nearly all of the mercury present in edible fish muscle is methylmercury, and analysis of fish tissue for total mercury provides a valid, cost-effective estimate of methylmercury concentration. Mercury will be analyzed in all samples of both the pelagic predator and bottom-feeder species because a substantial proportion of samples of each are expected to exceed the threshold of concern.

PCBs

PCBs are the contaminant of second greatest concern with respect to bioaccumulation on a statewide basis. Based on past studies (Davis et al. 2007), PCBs are expected to exceed the threshold of concern in approximately 20 – 30% of California lakes and reservoirs. PCBs will be analyzed using a congener specific method. Considerations regarding the list to be analyzed are discussed in Appendix 1. A total of 55 congeners will be analyzed. The congener data will be used to estimate concentrations on an Aroclor basis, since the thresholds for concern are expressed on an Aroclor basis (Klasing and Brodberg 2006). USEPA (2000) also recommends the use of Aroclor data for development of fish advisories. The concentrations of Aroclors 1248, 1254, and 1260 will be estimated using the method of Newman et al. (1998). PCBs will be analyzed in only the primary target bottom-feeder species, or the secondary target species if the primary targets are not available.

Legacy pesticides

Based on past studies (Davis et al. 2007), legacy pesticides are expected to exceed thresholds of concern in a very small percentage of California lakes and reservoirs. Considerations regarding the list of pesticides to be analyzed are discussed in Appendix 1. Pesticides will be analyzed in only the primary target bottom-feeder species, or the secondary target species if the primary targets are not available.

Selenium

Selenium was not included in the review of Davis et al. (2007), but based on TSMP monitoring selenium is expected to exceed the threshold of concern in a very small percentage of California lakes and reservoirs. Selenium will be measured as total selenium. Selenium will be analyzed in only the primary target bottom-feeder species, or the secondary target species if the primary targets are not available. As discussed above, data from the Grassland Bypass Project indicate that bottom-feeders accumulate slightly higher concentrations than pelagic predators (Beckon et al. 200xx). Selenium is not expected to exceed thresholds in many water bodies on a statewide basis. The 2007 sampling will be performed to confirm this hypothesis. Whether additional sampling is needed in 2008 will be decided based on the results of the 2007 sampling.

PBDEs

Few data are currently available on PBDEs in California sport fish, and a threshold of concern has not yet been established. However, a rapid increase in concentrations in the 1990s observed in San Francisco Bay and other parts of the country raised concern about these chemicals, and led to a ban on the production and sale of the penta and octa mixtures in 2006 (Oros et al. 2005). The deca mixture is still produced commercially. A threshold of concern is anticipated to be established soon by USEPA. The most important PBDE congeners with respect to bioaccumulation are PBDEs 47, 99, and 100. These congeners, and a few others, can be measured along with the PCBs at no additional cost as they can be separated using the same column and GC program as the PCBs. Estimated concentrations will be determined for PBDEs 17, 28, 47, 66, 99, and 100. These will only be estimates as the analysis will not include measurement of matrix spikes and other QA samples needed to report more accurate data. PBDEs accumulate in lipid, and will therefore be analyzed in only the primary target bottom-feeder species, or the secondary target species if the primary targets are not available. If results from this screening indicate concentrations of concern in some water bodies, then followup sampling with a quantitative method will be considered.

Dioxins and Dibenzofurans

Few data are available on dioxins and dibenzofurans in California sport fish. Perhaps the best dataset exists for San Francisco Bay, where sampling in 1994, 1997, and 2000 indicated that concentrations in high lipid species exceeded a published screening value of 0.3 TEQs (for dioxins and furans only) by five fold (Greenfield et al. 2003). However, there are no known major point sources of dioxins in the Bay Area and the concentrations measured in the Bay are comparable to those in rural areas of the U.S. OEHHA did not include dioxins in their recent evaluation of guidance tissue levels for priority contaminants due to the lack of data for dioxins in fish throughout the state (Klasing and Brodberg 2006). Given the relatively high cost of dioxin analysis and these other considerations, OEHHA recommended that dioxins not be included in this screening study (Table 9). The priority of dioxins with respect to 303(d) listing is also unclear, with inconsistencies between USEPA and the Regional Boards. However, water bodies in the San Francisco Bay-Delta do appear on the 303(d) list due to dioxin contamination, and currently Region 2 is considering developing a TMDL for dioxins. From a 303(d) perspective, therefore, dioxin analysis is considered a priority, albeit a low one (as indicated on the 303(d) list). Given the ambiguity regarding the priority of obtaining dioxin data and the high expense of the analyses, dioxins are not included on the analyte list for the statewide survey.

Organophophates, PAHs, and TBT

Past monitoring (TSMP, San Francisco Bay work – SFBRWQCB 1995) indicates that concentrations of these chemicals in sport fish are far below thresholds of concern for human exposure. Therefore, they will not be included in the present study.

Other Emerging Contaminants

Other emerging contaminants are likely to be present in California sport fish. Examples include perfluorinated chemicals, other brominated flame retardants in addition to PBDEs, and others. Thresholds do not exist for these chemicals, so advisories or 303(d) listing are not likely in the near future. However, early detection of increasing concentrations of emerging contaminants can be very valuable for managers, as evidenced by the PBDE example. Measuring emerging contaminants would not directly address the management questions guiding this study, so analysis of these chemicals is not included in the design.

F. Archiving

As described above, aliquots of homogenates of all samples analyzed will be 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 will be made and archived on a long-term basis. 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.

G. Ancillary Measures at Each Lake

Collecting information on basic water quality parameters of each lake will be helpful in understanding spatial patterns of bioaccumulation of mercury and perhaps other contaminants. This study will follow the same procedures that will be used for a national study of water quality in lakes to be conducted this summer by USEPA. That protocol calls for sampling the deepest part of a lake recording a depth profile from the surface to the bottom at every 0.5 or 1.0 meter depending on depth. Following this methodology will allow comparison of lakes sampled in this study provide a perspective of lakes to other California lakes, as well as other lakes in the surrounding states. The EPA Lakes study will be recording DO, pH, temperature, and Secchi depth. In this study, these parameters will be measured, along with electrical conductivity.

H. Timing

Sampling will be conducted from May 2007 through October 2007. Seasonal variation in body condition (Cidziel et al. 2003) and reproductive physiology are recognized as factors that could affect contaminant concentrations. However, sampling as many lakes as possible is essential to a statewide assessment, and it will take this many months to sample the 130 lakes targeted for 2007.

I. Products and Timeline

A technical report on the 2007 sampling will be drafted by June 2008 and will include a complete assessment of condition of lakes based on a randomized sampling of 50 lakes across California for use in a 305(b) report, supplemented by a thorough sampling of 80 popular lakes that will provide a sound basis for determining whether 130 lakes should be included on the 303(d) list. The report will be distributed for peer review in June 2008. The final report, incorporating revisions in response to reviewer comments, will be completed in September 2008.

It is anticipated that funding for an additional round of sampling will be available in 2008. This work would follow the same approach described in this document, but focusing on the remaining popular lakes. This sampling would begin May 2008. Preliminary results from the 2007 sampling will be evaluated to determine whether any adjustments to the design are needed.

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Table 1. Bioaccumulation monitoring assessment framework for the fishing beneficial use.

D.1. Determine the status of the fishing beneficial use throughout the State with respect to bioaccumulation of toxic pollutants

D.1.1 What are the extent and location of water bodies with sufficient evidence to indicate that the fishing beneficial use is at risk due to pollutant bioaccumulation?

D.1.2 What are the extent and location of water bodies with some evidence indicating the fishing beneficial use is at risk due to pollutant bioaccumulation?

D.1.3 What are the extent and location of water bodies with no evidence indicating the fishing beneficial use is at risk due to pollutant bioaccumulation?

D.1.4 What are the proportions of water bodies in the State and each region falling within the three categories defined in questions D.1.1, D.1.2, and D.1.3?

D.2. Assess trends in the impact of bioaccumulation on the fishing beneficial use throughout the State

D.2.1 Are water bodies improving or deteriorating with respect to the impact of bioaccumulation on the fishing beneficial use?

- D.2.1.1 Have water bodies fully supporting the fishing beneficial use become impaired?
- D.2.1.2 Has full support of the fishing beneficial use been restored for previously impaired water bodies?

D.2.2 What are the trends in proportions of water bodies falling within the three categories defined in questions D.1.1, D.1.2, and D.1.3 regionally and statewide?

D.3. Evaluate sources and pathways of bioaccumulative pollutants impacting the fishing beneficial use

D.3.1 What are the magnitude and relative importance of pollutants that bioaccumulate and indirect causes of bioaccumulation throughout each Region and the state as a whole?

D.3.2 How is the relative importance of different sources and pathways of bioaccumulative pollutants that impact the fishing beneficial use changing over time on a regional and statewide basis?

D.4. Provide the monitoring information needed to evaluate the effectiveness of management actions in reducing the impact of bioaccumulation on the fishing beneficial use

D.4.1 What are the management actions that are being employed to reduce the impact of bioaccumulation on the fishing beneficial use regionally and statewide?

D.4.2 How has the impact of bioaccumulation on the fishing beneficial use been affected by management actions regionally and statewide?

Table 2. List of popular lakes. Lakes with sampling sequence number 80 or less will be sampled in 2007.

Sampling Sequence	Name	Region	County	Area (ha)	Elevation (ft)
23	Alondra Park Lake	4	LOS ANGELES	3	55
16	Anderson Lake	2	SANTA CLARA	410	623
175	Antelope Lake	5	PLUMAS	373	5004
79	Apollo Lake	6	LOS ANGELES	2	2326
166	Barrett Lake	9	SAN DIEGO	51	1593
98	Bass Lake	5	MADERA	417	3368
8	Bear River Reservoir	5	AMADOR	67	5878
132	Beardsley	5	TUOLUMNE	282	3408
202	Benbow Lake	1	HUMBOLDT	25	367
131	Big Bear Lake	8	SAN BERNARDINO	1102	6760
66	Big Lagoon	1	HUMBOLDT	553	9
34	Big Lake	5	SHASTA	12	5850
153	Big Reservoir	5	PLACER	24	4048
125	Black Butte Lake	5	TEHAMA	1824	475
97	Blue Lakes	5	LAKE	37	1361
140	Boca Reservoir	6	NEVADA	386	5607
189	Bon Tempe Lake	2	MARIN	49	718
108	Bowman Lake	5	NEVADA	328	5560
199	Bridgeport Reservoir	6	MONO	1058	6456
122	Brite Valley Lake	5	KERN	1	5256
61	Bucks Lake	5	PLUMAS	672	5160
109	Butt Valley Reservoir	5	PLUMAS	613	4144
114	Butte Lake	5	LASSEN	80	6051
128	Calero Reservoir	2	SANTA CLARA	135	505
145	Camanche Reservoir	5	AMADOR	2994	218
37	Camp Far West Reservoir	5	YUBA	787	284
24	Caples Lake	5	ALPINE	246	7800
95	Castaic Lake	4	LOS ANGELES	923	1518
146	Castle Lake	5	SISKIYOU	20	5439
207	Cave Lake	5	MODOC	2	6640
47	Cherry Lake	5	TUOLUMNE	726	4754
32	Chesbro Reservoir	3	SANTA CLARA	80	549
173	Clear Lake	5	LAKE	16216	1328
118	Cleone Lake	1	MENDOCINO	6	26
5	Collins Lake	5	YUBA	411	1186
17	Contra Loma Reservoir	5	CONTRA COSTA	25	192
163	Convict Lake	6	MONO	70	7579
181	Copco Lake	1	SISKIYOU	314	2608
178	Courtright Reservoir	5	FRESNO	685	8185
212	Coyote Lake	2	SANTA CLARA	172	773
6	Dead Lake	1	DEL NORTE	11	36
30	Dixon Lake	9	SAN DIEGO	26	1032
107	Dodge Reservoir	6	LASSEN	204	5734
167	Don Pedro Reservoir	5	TUOLUMNE	4484	803
103	Donnells Lake	5	TUOLUMNE	174	4924
28	Donner Lake	6	NEVADA	332	5936
85	Duncan Reservoir	5	MODOC	65	4953
213	Eagle Lake	6	LASSEN	8118	5110
25	East Park Reservoir	5	COLUSA	687	1198
194	Eastman Lake	5	MADERA	712	NA
136	Echo Lake	6	EL DORADO	132	7416
62	El Capitan Lake	9	SAN DIEGO	589	773
143	Ellery Lake	6	MONO	23	9481

Table 2. List of popular lakes (continued).

Sampling Sequence	Name	Region	County	Area (ha)	Elevation (ft)
58	Elsinore, Lake	8	RIVERSIDE	984	1242
155	Evans, Lake	8	RIVERSIDE	11	783
180	Fallen Leaf Lake	6	EL DORADO	560	6379
208	Faucherie Lake	5	NEVADA	55	6134
38	Florence Lake	5	FRESNO	369	7333
177	Folsom Lake	5	PLACER	4478	468
12	French Meadows Reservoir	5	PLACER	575	5223
11	Frenchman Lake	5	PLUMAS	619	5590
43	George, Lake	6	MONO	17	9025
56	Gold Lake	5	SIERRA	198	6409
71	Grant Lake	6	MONO	421	7134
147	Gregory, Lake	6	SAN BERNARDINO	33	4551
211	Gull Lake	6	MONO	26	7618
50	Gumboot Lake	5	SISKIYOU	3	6101
65	Harry L Englebright Lake	5	YUBA	305	524
52	Hell Hole Reservoir	5	PLACER	555	4584
82	Hensley Lake	5	MADERA	600	NA
112	Hernandez Reservoir	3	SAN BENITO	254	2400
7	Hesperia Lake	6	SAN BERNARDINO	1	4675
99	Horseshoe Lake	6	MONO	20	8960
69	Howard Lake	1	MENDOCINO	9	3856
78	Hume Lake	5	FRESNO	35	5203
134	Huntington Lake	5	FRESNO	574	6951
204	Ice House Reservoir	5	EL DORADO	252	5436
44	Indian Creek Reservoir	6	ALPINE	66	5604
81	Indian Valley Reservoir	5	LAKE	1404	1479
45	Iron Canyon Reservoir	5	SHASTA	131	2666
154	Iron Gate Reservoir	1	SISKIYOU	435	2329
26	Isabella Lake	5	KERN	3120	2584
160	Jackson Meadow Reservoir	5	SIERRA	421	6038
96	Jenkinson Lake	5	EL DORADO	194	3473
127	June Lake	6	MONO	119	7620
90	Kangaroo Lake	1	SISKIYOU	8	6022
119	Ken Hahn State Recreational Ar	4	LOS ANGELES	1	NA
1	Lafayette Reservoir	2	CONTRA COSTA	46	458
165	Lake Almanor	5	PLUMAS	10044	4502
20	Lake Alpine	5	ALPINE	70	7305
129	Lake Amador	5	AMADOR	121	482
91	Lake Arrowhead	6	SAN BERNARDINO	302	5117
77	Lake Berryessa	5	NAPA	6800	NA
101	Lake Britton	5	SHASTA	411	2735
191	Lake Cachuma	3	SANTA BARBARA	1255	754
115	Lake Cahuilla	7	RIVERSIDE	48	22
55	Lake Casitas	4	VENTURA	700	519
157	Lake Chabot	2	SOLANO	19	83
27	Lake Crowley	6	MONO	1967	6768
123	Lake Davis	5	PLUMAS	1494	5777
169	Lake del Valle	2	ALAMEDA	413	747
216	Lake Havasu	7	MOHAVE	7986	451
3	Lake Hemet	8	RIVERSIDE	126	4339
214	Lake Henshaw	9	SAN DIEGO	731	2688
70	Lake Hodges	9	SAN DIEGO	166	277
102	Lake Jennings	9	SAN DIEGO	52	697

Table 2. List of popular lakes (continued).

Sampling Sequence	Name	Region	County	Area (ha)	Elevation (ft)
54	Lake Kaweah	5	TULARE	687	698
53	Lake Lagunitas	2	MARIN	9	785
215	Lake McClure	5	MARIPOSA	2267	839
116	Lake McSwain	5	MARIPOSA	123	399
149	Lake Mendocino	1	MENDOCINO	690	741
142	Lake Miramar	9	SAN DIEGO	56	716
60	Lake Nacimiento	3	SAN LUIS OBISPO	2331	806
133	Lake Natoma	5	SACRAMENTO	196	129
21	Lake Oroville	5	BUTTE	6272	901
137	Lake Pillsbury	1	LAKE	799	1820
179	Lake Piru	4	VENTURA	494	1078
86	Lake Poway	9	SAN DIEGO	25	958
164	Lake San Antonio	3	MONTEREY	2194	780
121	Lake Sonoma	1	SONOMA	962	452
124	Lake Spaulding	5	NEVADA	281	5013
198	Lake Sutherland	9	SAN DIEGO	227	2055
10	Lake Webb	5	KERN	338	294
126	Lake Wohlford	9	SAN DIEGO	90	1482
162	Lee Lake/Corona Lake	8	RIVERSIDE	27	1127
161	Lewiston Lake	1	TRINITY	290	1914
144	Lexington Reservoir	2	SANTA CLARA	129	648
159	Lily Lake	5	MODOC	3	6709
197	Little Grass Valley Reservoir	5	PLUMAS	561	5036
158	Little Oso Flaco Lake	3	SAN LUIS OBISPO	9	21
135	Littlerock Reseroir	6	LOS ANGELES	41	3260
184	Loch Lomond Reservoir	3	SANTA CRUZ	71	573
80	Loon Lake	5	EL DORADO	399	6381
106	Lopez Lake	3	SAN LUIS OBISPO	374	478
64	Los Banos Reservoir	5	MERCED	276	333
68	Lower Bear River Reservoir	5	AMADOR	294	5819
100	Lower Blue Lake	5	ALPINE	65	8057
182	Lower Otay Reservoir	9	SAN DIEGO	425	494
87	Lundy Lake	6	MONO	41	7805
151	Mamie, Lake	6	MONO	7	8894
188	Mammoth Pool Reservoir	5	MADERA	486	3333
59	Mary, Lake	6	MONO	35	8963
74	McCumber Reservoir	5	SHASTA	23	4061
141	Medicine Lake	5	SISKIYOU	173	6679
138	Millerton Lake	5	MADERA	1512	563
63	Modesto Reservoir	5	STANISLAUS	795	212
110	Morena Reservoir	9	SAN DIEGO	42	2955
117	New Bullards Bar Reservoir	5	YUBA	1613	1908
89	New Hogan Lake	5	CALAVERAS	1287	681
92	New Melones Lake	5	CALAVERAS	726	1091
105	Nicasio Lake	2	MARIN	335	168
130	North Battle Creek Reservoir	5	SHASTA	31	5581
104	O'Neill Forebay	5	MERCED	912	229
192	Packer Lake	5	SIERRA	5	6227
170	Paradise Lake	5	BUTTE	61	2546
73	Pardee Reservoir	5	AMADOR	884	575
168	Parker Dam	7	SAN BERNARDINO	0	472
203	Perris Reservoir	8	RIVERSIDE	770	1567
42	Pine Flat Lake	5	FRESNO	2100	954
36	Pinecrest	5	TUOLUMNE	120	5619
88	Pinto Lake	3	SANTA CRUZ	47	114

Table 2. List of popular lakes (continued).

Sampling Sequence	Name	Region	County	Area (ha)	Elevation (ft)
13	Plaskett Lake	1	GLENN	2	5951
83	Pleasant Valley Reservoir	6	INYO	40	4393
187	Prado Park Lake	8	RIVERSIDE	9	487
84	Prosser Creek Reservoir	6	NEVADA	262	5745
51	Puddingstone Reservoir	4	LOS ANGELES	98	941
39	Pyramid Lake	4	LOS ANGELES	590	2581
75	Ramer Lake	7	IMPERIAL	63	-174
29	Reservoir C	5	MODOC	8	4943
139	Rock Creek Lake	6	INYO	22	9698
201	Rollins Reservoir	5	NEVADA	313	2172
193	Ruth Lake	1	TRINITY	431	2656
94	Sabrina, Lake	6	INYO	78	9131
183	Saddlebag Lake	6	MONO	113	10068
76	Salt Springs Reservoir	5	AMADOR	362	3954
171	Salton Sea	7	RIVERSIDE	94403	-231
200	San Luis Reservoir	5	MERCED	5208	555
205	San Pablo Reservoir	2	CONTRA COSTA	317	318
14	San Vicente Reservoir	9	SAN DIEGO	428	652
67	Santa Fe Reservoir	4	LOS ANGELES	424	NA
210	Santiago Reservoir/Irvine Lake	8	ORANGE	235	794
206	Santo Margarita Lake	3	SAN LUIS OBISPO	301	1305
49	Scotts Flat Reservoir	5	NEVADA	267	3071
113	Shadow Cliffs Reservoir	2	ALAMEDA	27	352
18	Shasta Lake	5	SHASTA	11037	1077
150	Shaver Lake	5	FRESNO	905	5372
120	Silver Lake	5	AMADOR	212	7264
15	Silver Lake	6	MONO	44	7230
2	Silver Lake	5	SHASTA	10	6580
35	Silverwood Lake	6	SAN BERNARDINO	364	3375
186	Siskiyou Lake	5	SISKIYOU	172	3185
93	Soulejoule Lake	2	MARIN	20	258
190	South Lake	6	INYO	68	9771
172	Spicer Meadow Reservoir	5	ALPINE	67	6433
9	Spring Lake	1	SONOMA	29	293
176	Stampede Reservoir	6	SIERRA	1370	5952
48	Stevens Creek Reservoir	2	SANTA CLARA	37	NA
41	Stony Gorge Reservoir	5	GLENN	571	842
174	Success Lake	5	TULARE	1006	656
46	Sweetwater Reservoir	9	SAN DIEGO	372	242
40	Tahoe, Lake	6	WASHOE	49692	6231
148	Tioga Lake	6	MONO	27	9643
196	Topaz Lake	6	DOUGLAS	775	5009
209	Trinity Lake	1	TRINITY	6497	2374
111	Tulloch Reservoir	5	CALAVERAS	401	511
4	Turlock Lake	5	STANISLAUS	1286	242
195	Twin Lakes	6	MONO	5	8559
156	Union Valley Reservoir	5	EL DORADO	976	4844
152	Upper Blue Lake	5	ALPINE	118	8138
72	Uvas Reservoir	3	SANTA CLARA	81	463
31	Virginia Lakes	6	MONO	10	9810
57	Whiskeytown Lake	5	SHASTA	1258	1213
19	Wiest Lake	7	IMPERIAL	17	-162
22	Wishon Reservoir	5	FRESNO	400	6583
185	Woodward Reservoir	5	STANISLAUS	718	212
33	Yosemite Lake	5	SAN JOAQUIN	2	11

Table 3. List of other lakes.

NAME	Region	Sampling Sequence	Area (ha)	Elevation (	Sampleabl
Rubicon Reservoir	5	2	34	6548	N
NA	3	4	28	534	?
Lower Klamath Lake	1	5	33	4081	?
Reservoir F	1	7	162	4963	?
NA	5	9	8	154	?
Merritt, Lake	2	10	58	0	?
Little Egg Lake	5	11	23	4258	?
NA	6	13	16	9856	N
Marysville Lake	5	14	13	162	?
Warren Lake	6	16	44	3956	N
NA	5	17	5	697	N
Long Lake	5	19	27	5338	N
NA	3	20	7	432	N
NA	1	21	25	2529	?
NA	1	23	6	4559	N
NA	5	25	48	8661	N
NA	5	26	17	27	N
NA	5	28	5	11188	N
NA	5	30	5	52	?
Pine Flat Lake	5	32	222	954	Y
Kunkle Reservoir	5	33	7	1443	?
Las Virgenes Reservoir	4	36	50	1028	?
Marsh in Fresno Slough	5	40	6	160	Y
Lobdell Lake	6	41	13	9252	Y
Guest Lake	5	44	7	10193	N
Lake of the Pines	5	45	87	1511	Y
Buena Vista Lagoon	9	47	29	12	Y
Lower Klamath Lake	1	49	276	4081	?
West Valley Reservoir	5	51	377	4763	Y
NA	5	53	10	3874	Y
NA	6	55	5	5565	N
NA	5	56	5	11223	N
Dog Lake	5	57	11	9173	N
Discovery Bay	5	58	35	0	Y
NA	5	60	8	10857	N
Milton Reservoir	5	61	16	5726	?
Loveland Reservoir	9	63	170	1357	Y
Fontanillis Lake	6	66	11	8287	N
NA	6	67	6	4445	?
NA	3	68	6	54	N
Whitehorse Flat Reservoir	5	69	825	4387	?
Sage Lake	1	71	28	4577	?
NA	5	73	48	138	?
Graven Reservoir	5	75	68	5202	?
Virginia, Lake	5	77	29	10342	N
San Gabriel Reservoir	4	79	215	1455	?
NA	5	80	5	11390	N
NA	5	81	44	351	Y
NA	6	83	52	5696	N

Table 3. List of other lakes (continued).

NAME	Region	Sampling Sequence	Area (ha)	Elevation (	Sampleabl
NA	5	85	16	161	N
Hog Lake	5	87	23	4924	?
NA	5	89	6	9156	N
NA	5	90	7	-3	?
Ferguson Lake	7	91	197	191	Y
NA	5	92	11	11240	N
NA	6	93	38	6464	N
NA	5	94	6	56	N
Horseshoe Lake	5	97	41	6540	N
Brenda Reservoir	5	100	59	273	Y
NA	5	101	21	7531	N
Baseball Reservoir	1	103	63	5256	?
Sphinx Lakes	5	104	11	10517	N
NA	5	105	5	9816	N
NA	5	106	21	14	?
Evolution Lake	5	108	24	10860	N
Stump Meadow Lake	5	109	120	4264	?
Vail Lake	9	111	101	1400	Y
NA	1	113	60	4081	?
Lower Crystal Springs Reservoir	2	114	231	287	?
Mendiboure Reservoir	6	115	21	5981	?
Tamarack Lake	5	120	8	9219	N
Emeric Lake	5	121	12	9340	N
Calaveras Reservoir	2	122	608	768	?
NA	5	124	11	9533	N
Fuller Lake	5	125	26	5345	?
Lake Henne	2	126	6	1812	?
Mirror Lake	1	129	6	6609	N
Susie Lake	6	130	16	7767	N
NA	2	132	10	313	?
Crum Reservoir	5	133	11	3585	?
NA	1	135	4	4671	N
Upper Twin Lakes at Bridgeport	6	137	116	7096	Y
Upper San Leandro Reservoir	2	138	310	463	?
Graves Reservoir	5	139	22	4419	?
NA	5	140	7	9603	N
Mott Lake	5	141	7	10072	N
Ponderosa Reservoir	5	142	39	961	?
NA	5	144	11	11525	N
Hamilton Dam	5	145	6	803	?
NA	4	148	188	1518	Y
NA	1	151	56	4754	?
Hetch Hetchy Reservoir	5	153	745	3799	Y
Gene Wash Reservoir	7	155	82	737	?
Upper Indian Lake	5	156	5	10472	N
NA	5	157	4	7100	N
Soda Lake	3	160	1063	1912	?
Buckhorn Lake	5	161	8	4781	N
NA	5	164	24	258	?

Table 3. List of other lakes (continued).

NAME	Region	Sampling Sequence	Area (ha)	Elevation (	Sampleabl
Griener Reservoir	5	167	19	4819	N
NA	5	168	11	11545	N
Waugh Lake	6	169	67	9446	N
NA	5	172	19	10236	N
NA	5	173	10	1570	Y
NA	5	176	6	278	N
NA	1	177	4	4470	N
Moon Lake	5	179	1069	5518	?
NA	5	180	8	865	?
NA	5	181	6	1154	?
Juniper Lake	5	183	37	5605	N
Erin Lake	5	184	10	11647	N
Tenaya Lake	5	185	69	8152	?
Lower Blue Lake	5	186	14	1365	?
Haiwee Reservoir	6	187	443	3749	?
NA	5	188	12	12050	N
Star Lake	6	189	9	9098	N
Abbotts Lagoon	2	190	86	33	N
Cliff Lake	1	193	23	6111	N
Lake Madigan	2	194	35	1370	N
Crater Lake	5	195	10	6871	N
NA	3	196	5	295	N
Toad Lake	5	197	10	6938	?
Dry Lake	1	199	96	4143	N
NA	5	200	33	75	N
NA	5	201	60	8897	N
NA	5	202	6	59	?
Three Finger Lake	7	203	29	219	?
NA	5	204	20	11150	N
NA	6	205	5	9408	N
NA	5	206	18	62	?
Green Island Lake	5	209	5	6102	N
NA	6	211	153	5594	?
NA	4	212	7	887	?
NA	5	213	5	285	?
Whitney Reservoir	1	215	107	4687	?
NA	5	217	13	9822	N
NA	5	218	33	1	?
Vee Lake	5	220	22	11165	N
Independence Lake	6	221	276	6946	?
Upper Letts Lake	5	222	14	4484	?
NA	6	227	22	5839	N
NA	5	228	7	98	?
Lake Eleanor	5	229	417	4661	?
Goose Lake	5	231	37626	4704	Y
NA	6	232	6	12184	N
Beck Lakes	5	233	11	9806	N
NA	5	234	9	21	N
Davis Lake	5	236	45	11074	N

Table 3. List of other lakes (continued).

NAME	Region	Sampling Sequence	Area (ha)	Elevation (	Sampleabl
Horseshoe Lake	5	238	8	28	?
Glaser Lakes	1	241	13	4090	?
NA	5	244	26	105	?
Preston Reservoir	5	245	7	359	?
Holbrook Reservoir	5	247	46	5370	?
NA	5	248	5	4654	?
Iron Lakes	5	249	6	8230	N
NA	1	250	14	14	N
Salt Lake	6	251	329	1056	?
Rae Lakes	5	252	25	10541	N
Scotts Lake	6	253	10	8021	N
Lower Bucks Lake	5	254	51	5029	?
NA	5	256	171	221	?
Dead Horse Reservoir	5	259	196	5020	?
NA	5	260	18	85	?
Cecil Lake	5	261	9	10880	N
NA	5	262	13	130	?
Walnut Canyon Reservoir	8	263	16	816	Y
North Lake	6	264	5	9263	?
NA	5	265	6	522	?
Lake Hennessey	2	266	297	318	Y
NA	3	268	7	162	?
Freeway Lake	1	269	16	2709	N
Lone Pine Lake	1	271	33	4553	?
NA	5	272	53	550	N
NA	5	273	18	8808	N
NA	7	275	33	156	?
Upper Lamarck Lake	6	276	15	10922	N
NA	6	279	92	2817	Y
Wilson Lake	5	281	40	5274	?
Shugru Reservoir	6	283	11	4186	?
Malibu Lake	4	284	16	721	Y
Lake Ramona	5	285	7	45	?
South Mountain Reservoir	1	287	94	5091	?
NA	5	288	7	165	?
NA	6	289	5	6989	N
NA	5	292	5	12024	N
Lake Combie	5	293	147	1614	Y
Washington, Lake	5	294	10	11	?
NA	9	295	46	107	?
NA	1	297	362	4081	?
Briones Reservoir	2	298	232	503	?
Patterson Lake	6	299	9	9017	N
NA	5	301	17	302	?
NA	6	303	44	5291	N
NA	5	304	18	10728	N
NA	5	305	5	11519	N
Cherry Flat Reservoir	2	306	10	1701	?
High Lake	6	307	5	11485	N

Table 3. List of other lakes (continued).

NAME	Region	Sampling Sequence	Area (ha)	Elevation (	Sampleabl
Jackson Lake	5	309	21	6587	?
Amel Lake	5	310	29	1029	?
Big Laguna Lake	9	311	7	5427	N
Essex Pond	1	313	9	59	?
Half Moon Lake	6	314	9	8142	N
NA	6	315	13	4002	?
Schwan Lagoon	3	316	10	13	?
NA	5	317	16	3318	?
NA	2	318	11	43	?
Harvey Lake	1	319	7	4738	?
NA	5	320	9	80	?
NA	5	321	11	208	N
White Reservoir	5	323	11	4804	?
John's River	5	324	7	413	?
Pika Lake	5	325	8	10535	N
Thermalito Afterbay	5	326	1564	139	Y
NA	5	328	6	11268	N
Spring Creek Reservoir	5	329	38	797	?
NA	1	330	5	373	N
McCoy Flat Reservoir	6	331	576	5548	?
Fairmont Reservoir	6	332	58	3034	N
NA	5	333	10	75	?
NA	1	335	15	4660	N
NA	5	337	21	7352	N
NA	2	338	25	0	?
Payne Lake	5	340	13	11225	N
NA	6	341	9	6579	N
NA	5	342	8	54	?
NA	3	344	4	1082	?
Summit Lake	5	345	5	6678	?
Hartson Lake	6	347	197	3992	?
NA	5	349	25	7708	N
NA	5	352	7	10439	N
Sadler Lake	5	353	6	9367	N
NA	6	355	70	1892	?
NA	5	356	9	11811	N
NA	5	357	5	247	?
NA	5	358	12	12	?
NA	9	359	17	1336	N
Tule Lake	1	361	1319	4035	?
Pilarcitos Lake	2	362	39	700	?
NA	6	363	6	6016	?

Table 4. Target species and their characteristics.

	Foraging Type		Trophic Level	Distribution			
Species	Water column	Bottom feeder		Low Eleva-tion	Foothills	High Elevation	Priority for Collection
Largemouth bass	X		4	**X**	**X**		**A**
Smallmouth bass	X		4	X	**X**		**A**
Spotted bass	X		4	X	**X**		**A**
Sacramento pikeminnow	X		4	X	X		B
White catfish		X	4	X	X		**A**
Brown bullhead		X	3	X			B
Channel catfish		X	4	**X**	**X**		**A**
Carp		X	3	**X**	**X**		**A**
Sacramento sucker		X	3	X	X		B
Tilapia		X	3				B
Bluegill	X		3	**X**	**X**		B
Green sunfish	X		3	**X**	**X**		B
Crappie	X		3/4	X	X		B
Redear sunfish	X		3	**X**	**X**		B
Rainbow trout	X		3/4	X	X	**X**	**A**
Brown trout	X		3		X	X	**A**
Brook trout	X		3			X	**A**
Kokanee	X		3	?	X	X	B

Trophic levels are the hierarchical strata of a food web characterized by organisms that are the same number of steps removed from the primary producers. The USEPA's 1997 Mercury Study Report to Congress used the following criteria to designate trophic levels based on an organism's feeding habits:

Trophic level 1: Phytoplankton.
Trophic level 2: Zooplankton and benthic invertebrates.
Trophic level 3: Organisms that consume zooplankton, benthic invertebrates, and TL2 organisms.
Trophic level 4: Organisms that consume trophic level 3 organisms.

X widely abundant X less widely abundant “A” primary target for collection “B” secondary target for collection

Table 5 Frequency distribution of lake sizes.

Xx Need from Don Stevens

Table 6. Target species, size ranges, and processing instructions.

	Process as Individuals and/or Composites	Process for Organics	Numbers and Size Ranges (mm)
Primary Targets: stay on location until one of these targets from both Group 1 and 2 is obtained			
Group 1) Predator			
Black bass	I		2X(200-249), 2X(250-304), 5X(305-407), 2X(>407)
Sacramento pikeminnow	I		3X(200-300), 3X(300-400), 3X(400-500)
Rainbow trout	I and C	X	5X(300-400)
Brown trout	I and C	X	5X(300-400)
Brook trout	I and C	X	5X(300-400)
Group 2) Bottom feeder			
White catfish	C	X	5X(229-305)
Channel catfish	C	X	5X(375-500)
Common carp	C	X	5X(450-600)
Brown bullhead	C		5X(262-350)
Sacramento sucker	C	X	5X(375-500)
Secondary Targets: collect these if primary targets are not available			
Bluegill	C	X	5X(127-170)
Redear sunfish	C	X	5X(165-220)
Black crappie	C	X	5X(187-250)
Tilapia	C		??
Green sunfish	C		??
Kokanee			??

Table 7. Thresholds for concern for pollutants included in the survey. Thresholds are from Klasing and Brodberg (2006), and correspond to a concentration at which OEHHA would begin to consider advising limited consumption (i.e., fewer than 8 meals per month). Exceeding these thresholds will be considered an indication of impairment.

Pollutant	**Threshold for concern (ppb)**
Methylmercury[1]	120
PCBs[2]	30
DDTs[3]	830
Dieldrin[4]	24
Chlordanes[5]	300
Selenium[6]	3,930
PBDEs	Not available

[1] Estimated by total mercury measurements in fish. Threshold for sensitive populations (i.e., women of childbearing age and children 17 and under), based on non-cancer risk and a reference dose of $1X10^{-4}$ mg/kg-day.
[2] Threshold based on non-cancer risk and a reference dose of $2X10^{-5}$ mg/kg-day.
[3] Threshold based on non-cancer risk and a reference dose of $5X10^{-4}$ mg/kg-day.
[4] Threshold based on cancer risk and a slope factor of 16 $(mg/kg/day)^{-1}$.
[5] Threshold based on cancer risk and a slope factor of 1.3 $(mg/kg/day)^{-1}$.
[6] Threshold for consumers who do not take selenium supplements in excess of the RDA, based on non-cancer risk and a reference dose of $5X10^{-3}$ mg/kg-day.

Table 8. Thresholds for triggering followup analysis of archived composite samples. Triggers are 75% of the threshold for concern.

Pollutant	**Threshold for followup analysis (ppb)**
Methylmercury[1]	90
PCBs	22
DDTs	622
Dieldrin	18
Chlordanes	225
Selenium	2,947
PBDEs	Not available

[1] Estimated by total mercury measurements in fish.

Table 9. Summary of analytes included in the study. +/- indicates whether an analyte is a priority for a given management question.

Analyte	**303(d) and 305(b) (MQs 1 and 2) (Water Boards)**	**Fish Advisories (MQ 3) (OEHHA)**	**Included in Screening Study?**
Methylmercury[1]	+	+	All samples
PCBs	+	+	Bottom-feeder only
DDTs	+	+	Bottom-feeder only
Dieldrin	+	+	Bottom-feeder only
Aldrin	+	+	Bottom-feeder only
Chlordanes	+	+	Bottom-feeder only
Selenium	+	+	Bottom-feeder only
PBDEs	+	+	Bottom-feeder only
Dioxins	+	-	Not included – low priority for OEHHA and expensive
Organophosphates	-	-	Not included – low concern in sport fish
PAHs	-	-	Not included – low concern in sport fish
TBT	-	-	Not included – low concern in sport fish

[1] Measured as total mercury.

Table 10. Parameters to be measured.

FISH ATTRIBUTES

1. Total length
2. Fork length
3. Weight
4. Moisture
5. Lipid content
6. Sex
7. Age

METALS AND METALLOIDS

1. Total mercury
2. Total selenium

Table 10. Parameters to be measured (continued).

PESTICIDES

Chlordanes

1. Chlordane, cis-
2. Chlordane, trans-
3. Heptachlor
4. Heptachlor epoxide
5. Nonachlor, cis-
6. Nonachlor, trans-
7. Oxychlordane

DDTs

1. DDD(o,p')
2. DDD(p,p')
3. DDE(o,p')
4. DDE(p,p')
5. DDMU(p,p')
6. DDT(o,p')
7. DDT(p,p')

Cyclodienes

1. Aldrin
2. Dieldrin
3. Endrin

HCHs

1. HCH, alpha
2. HCH, beta
3. HCH, gamma

Others

1. Dacthal
2. Endosulfan I
3. Hexachlorobenzene
4. Methoxychlor
5. Mirex
6. Oxadiazon
7. Tedion

Table 10. Parameters to be measured (continued).

PCBs

1. PCB 008
2. PCB 018
3. PCB 027
4. PCB 028
5. PCB 029
6. PCB 031
7. PCB 033
8. PCB 044
9. PCB 049
10. PCB 052
11. PCB 056
12. PCB 060
13. PCB 064
14. PCB 066
15. PCB 070
16. PCB 074
17. PCB 087
18. PCB 095
19. PCB 097
20. PCB 099
21. PCB 101
22. PCB 105
23. PCB 110
24. PCB 114
25. PCB 118
26. PCB 126
27. PCB 128
28. PCB 132
29. PCB 137
30. PCB 138
31. PCB 141
32. PCB 146
33. PCB 149
34. PCB 151
35. PCB 153
36. PCB 156
37. PCB 157
38. PCB 158
39. PCB 169
40. PCB 170
41. PCB 174
42. PCB 177

43. PCB 180
44. PCB 183
45. PCB 187
46. PCB 189
47. PCB 194
48. PCB 195
49. PCB 198
50. PCB 199
51. PCB 200
52. PCB 201
53. PCB 203
54. PCB 206
55. PCB 209

Calculated Values

1. PCB Aroclor 1248
2. PCB Aroclor 1254
3. PCB Aroclor 1260

Table 10. Parameters to be measured (continued).

PBDEs (these would be estimated values obtained along with PCB congeners at no additional cost without matrix spikes and lab control solutions)

1. PBDE 017
2. PBDE 028
3. PBDE 047
4. PBDE 066
5. PBDE 100
6. PBDE 099

Figure 1. Locations of the 216 popular lakes. Water Board regional boundaries also shown.

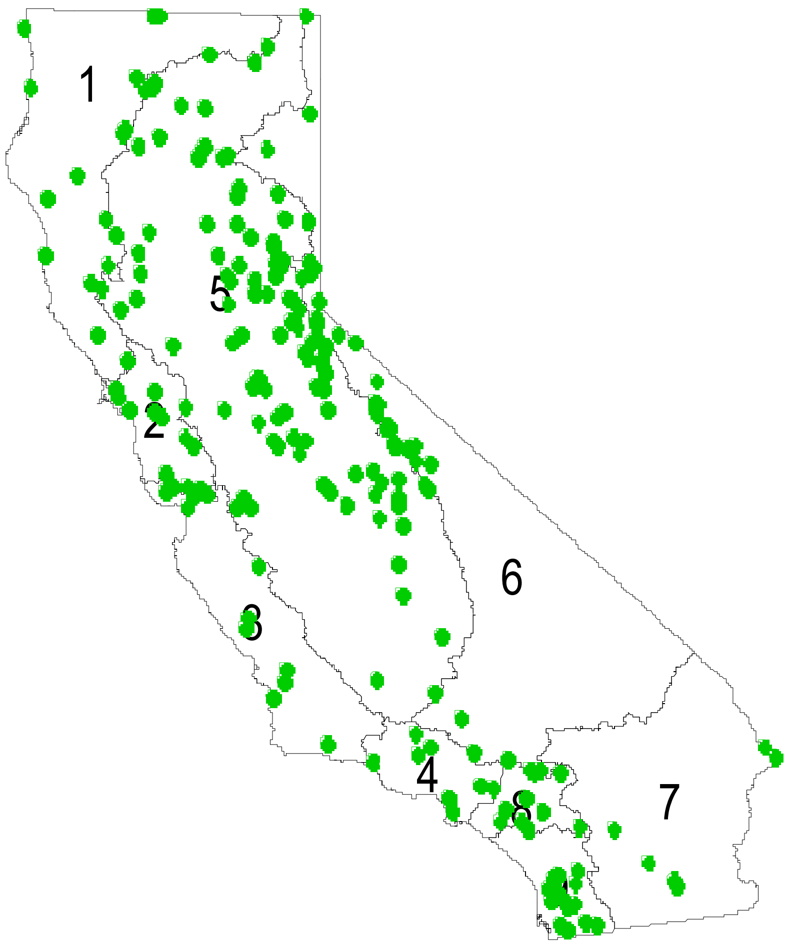


Figure 2. Locations of the popular lakes to be sampled in 2007.

Xx need from Don Stevens

Figure 3. Inclusion probability variation with size of the lake.

Xx Need from Don Stevens

Figure 4. A representative small lake – Lake Piru in Ventura County. The area of the lake is 484 ha. The width of the lake (line shown in the figure) is 2.2 miles. One sampling location is representative of a relatively large fraction of the area of the lake, and is considered to provide an adequate sample of the lake. Diameter of circle shown is 1 mile.

Figure 5. A representative medium lake – Pardee Reservoir in Amador County. The area of the lake is 884 ha. The width of the lake is 4 miles. Two sampling locations are representative of a relatively large fraction of the area of the lake, and are considered to provide an adequate sample of the lake. Diameter of circles shown is 1 mile. Locations shown are hypothetical.

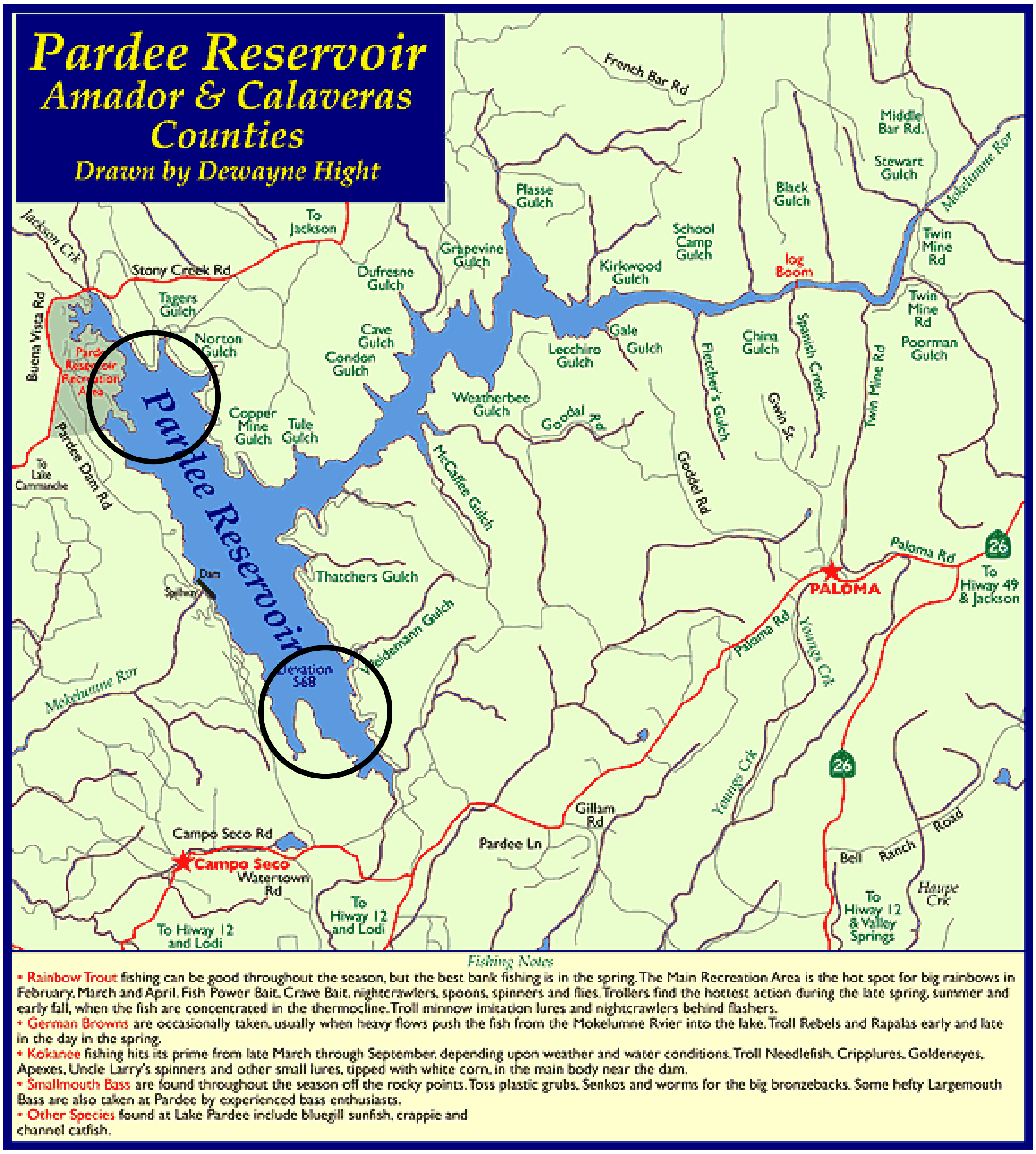


Figure 6. A representative large lake – Black Butte Lake in Tehama County. The area of the lake is 1824 ha. The width of the lake (line drawn on map) is 5 miles. Two to four sampling locations would be needed to provide an adequate sample of the lake. Diameter of circles shown is 1 mile. Locations shown are hypothetical.

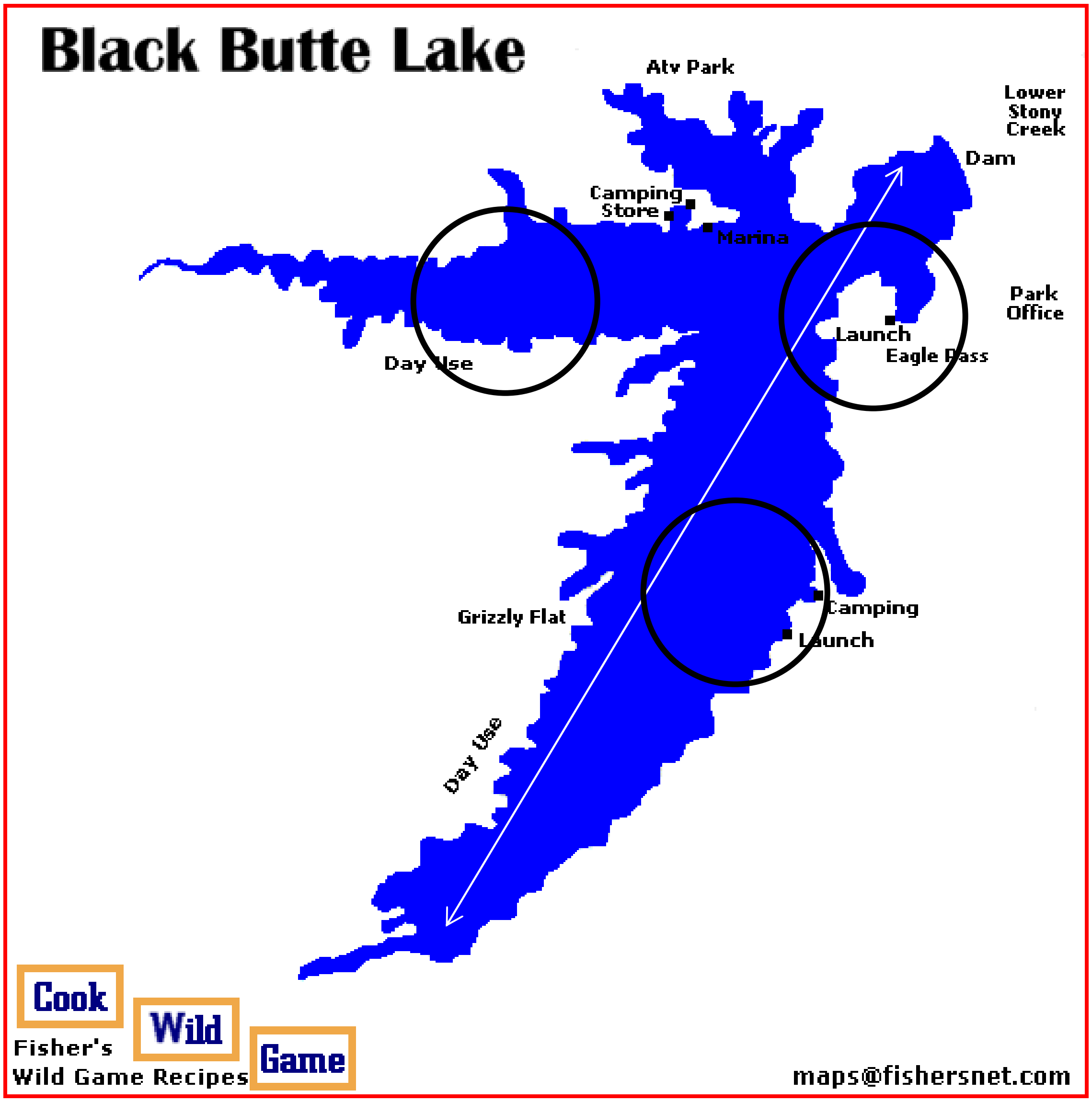


Figure 7. A representative very large lake – Lake Berryessa in Napa County. The area of the lake is 6800 ha. The width of the lake (line drawn on map) is 13 miles. Two to four sampling locations would be needed to provide an adequate sample of the lake. Diameter of circles shown is 1 mile. Locations shown are hypothetical.

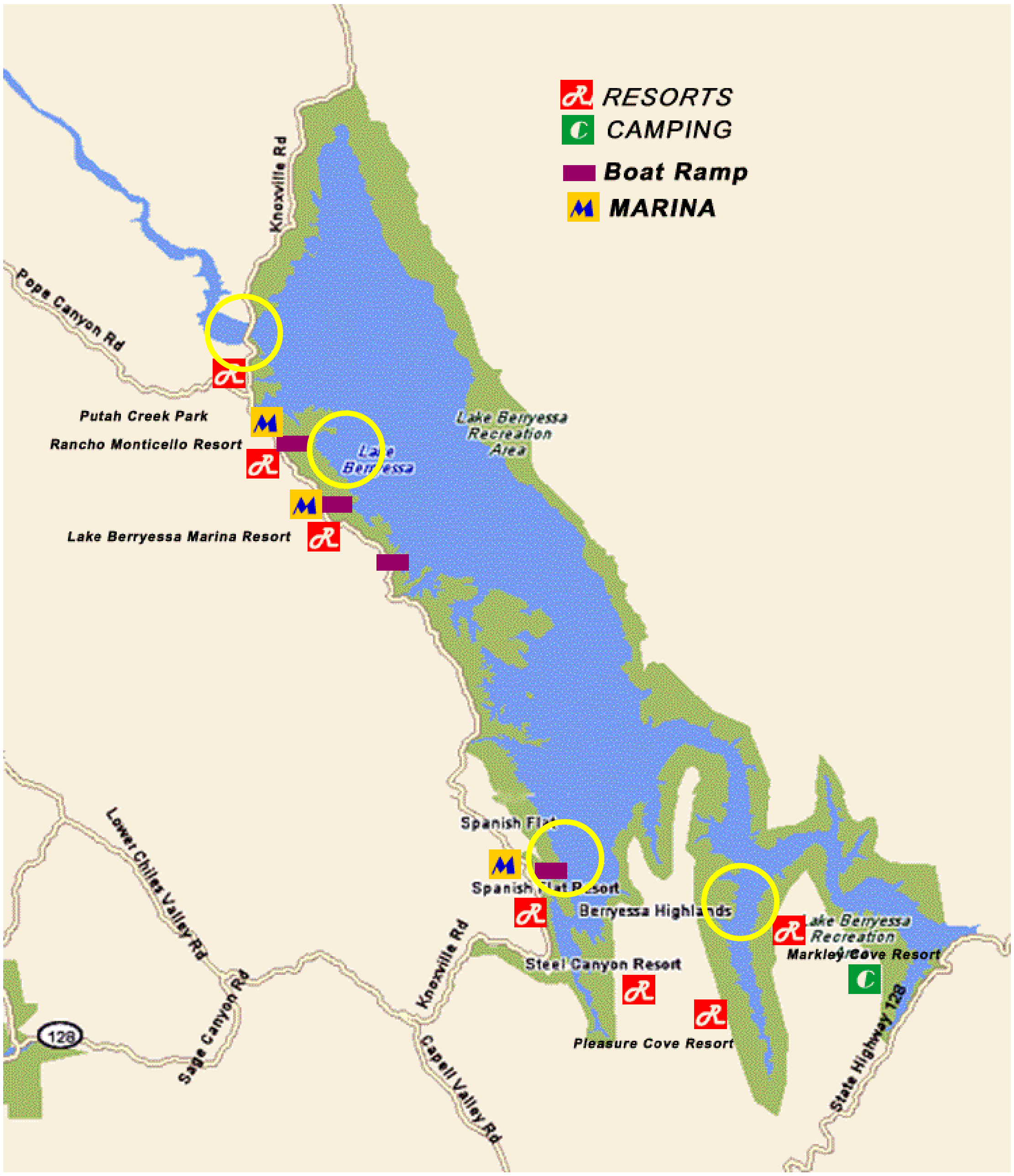


Figure 8. Sampling strategy for small lakes.

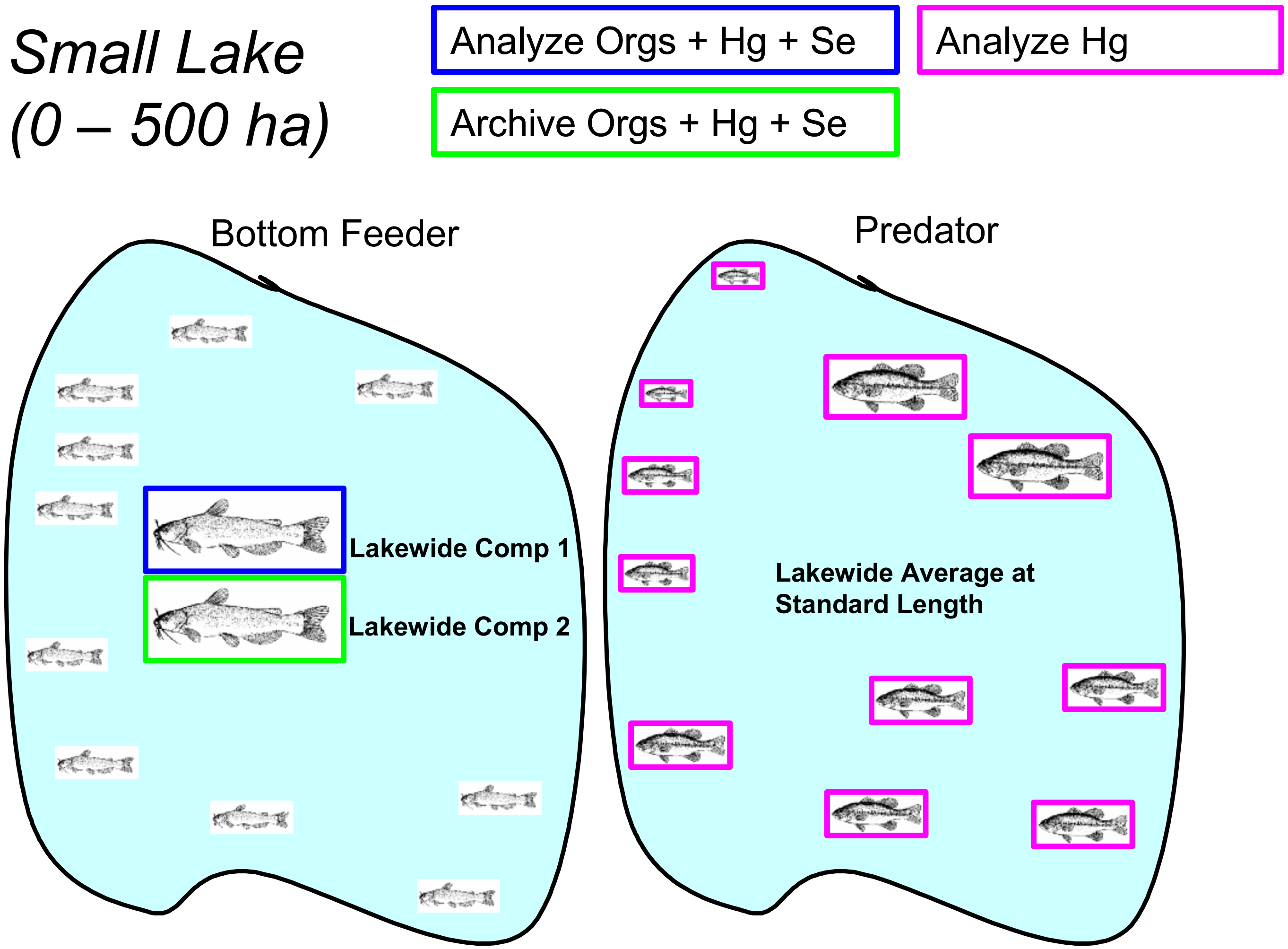


Figure 9. Sampling strategy for medium lakes.

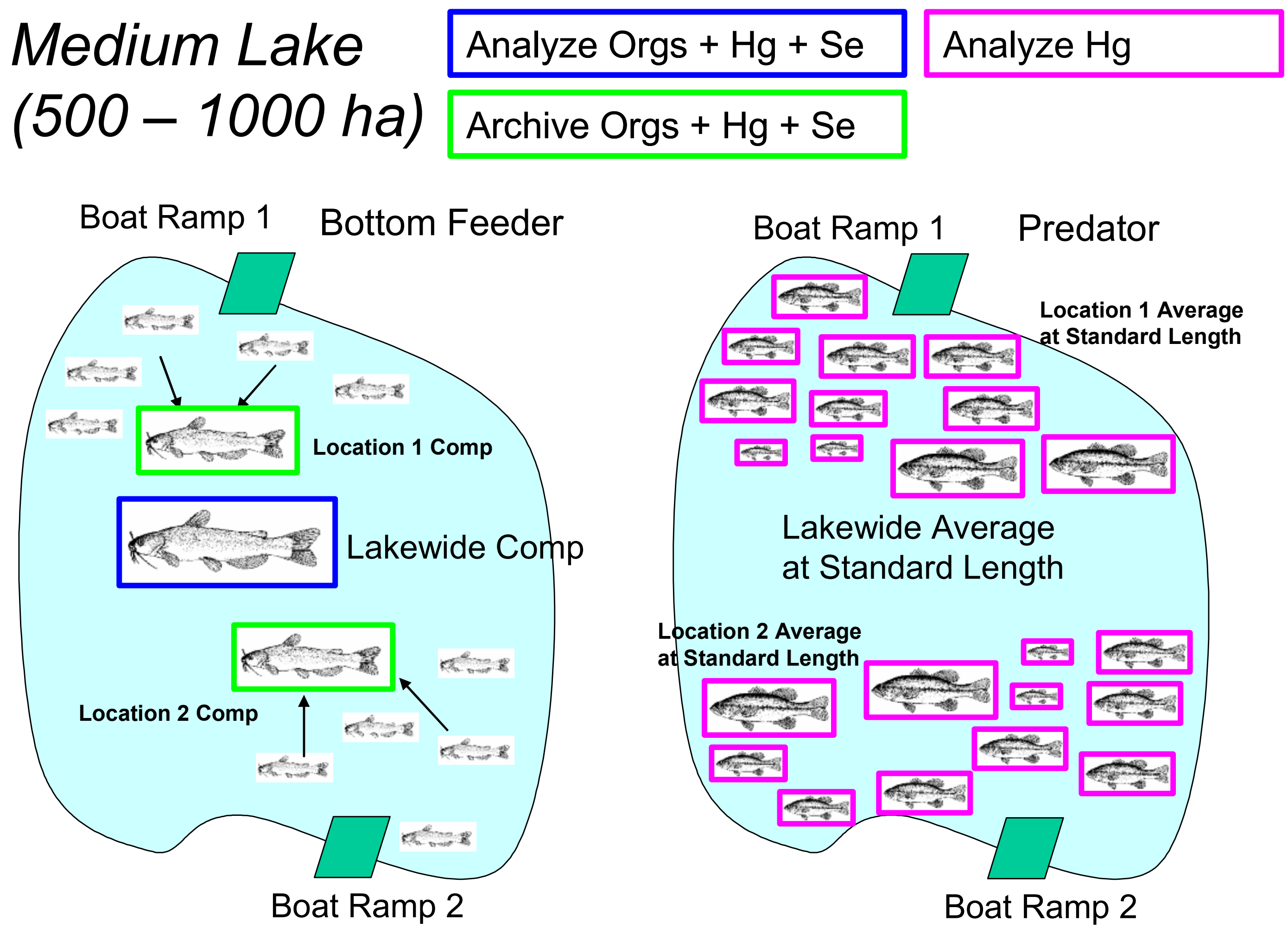
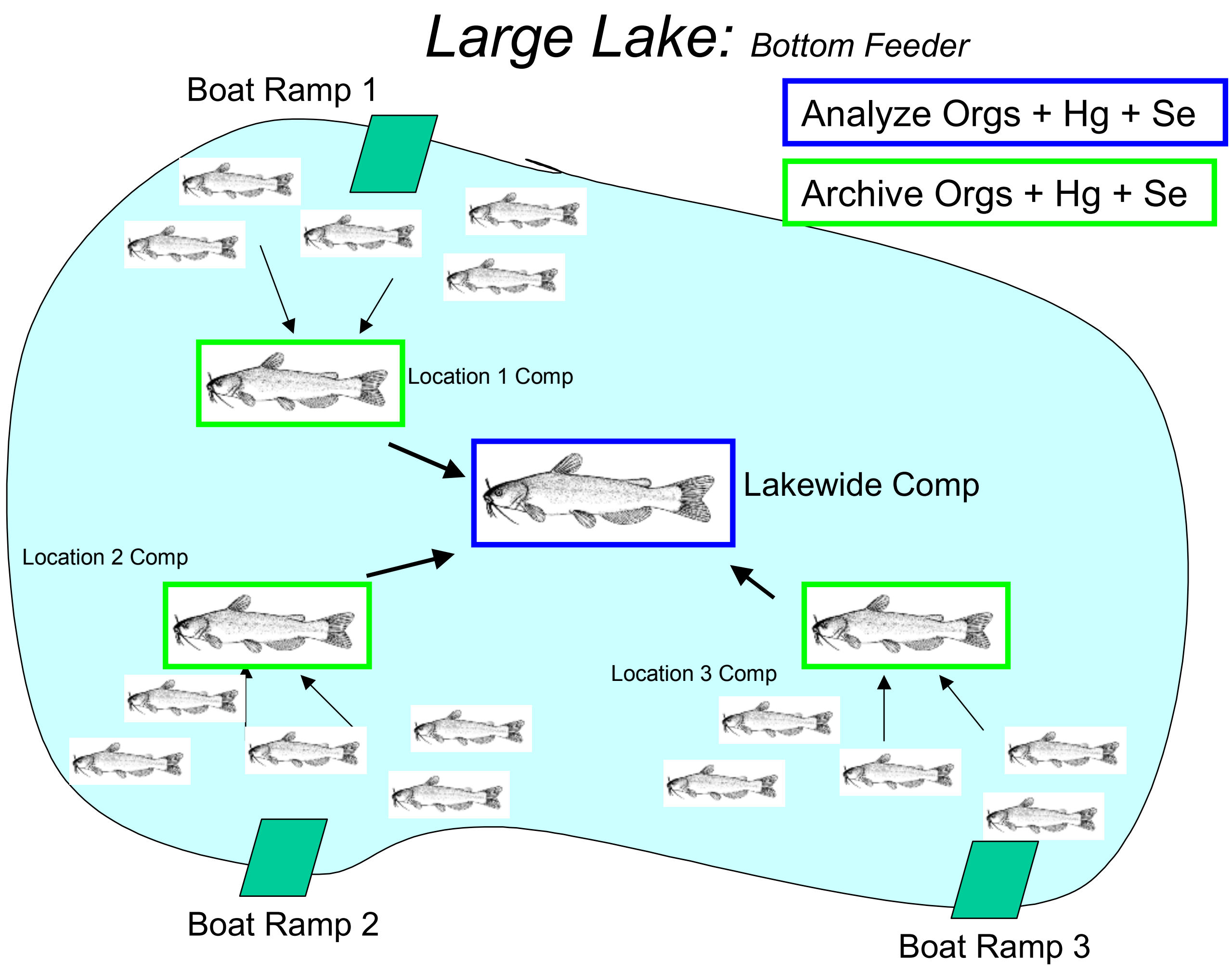


Figure 10. Sampling strategy for large lakes: bottom feeder.



1 Figure 11. Sampling strategy for large lakes: predator.