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Recommendations for a Bioaccumulation Monitoring and Human Health Risk Reduction Program for California

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PREFACE

This report was written for the State Water Resources Control Board's Surface Water Ambient Monitoring Program (SWAMP) as a step toward the development of an improved bioaccumulation monitoring program for California. SWAMP contracted with SFEI to produce two reports toward this goal.

The first report was to provide a review of bioaccumulation monitoring data generated under three historic State Board programs (the Toxic Substances Monitoring Program, the State Mussel Watch Program, and the Coastal Fish Contamination Program) and other major bioaccumulation studies since 1970. That report was drafted, revised in response to comments from stakeholders and peer reviewers, finalized in October 2007, and will be published by SWAMP in 2008 (Davis et al. 2008. Bioaccumulation of Pollutants in California Waters: A Review of Historic Data and Assessment of Impacts on Fishing and Aquatic Life. California State Water Resources Control Board, Sacramento, CA).

This is the second report. The goal of this report was to recommend an organizational structure, process, and preliminary design for a statewide bioaccumulation monitoring and risk reduction program for California. The report was intended to provide a starting point for the collaborative group process that is needed. In order to facilitate discussion and illustrate how the concepts described in this report would translate into a monitoring and risk reduction program, a *preliminary* design of a program was presented. It was anticipated that the stakeholder and peer review processes described in the preceding section would lead to a final design that differs from the preliminary design proposed in this report.

In response to uncertainty about future funding, this report illustrates what the program could look like at three different levels of funding: $500,000 per year; $1.5 million per year; and $3.3 million per year. The two lower levels of funding were based on possible scenarios for the FY 2006 budget. The highest level of funding is proposed as an ideal scenario, where the amount of funding allocated to the program is commensurate with the task of monitoring and reducing risks from bioaccumulation in a state as large and diverse as California.

In 2006, a Bioaccumulation Oversight Group (BOG), a subcommittee of the SWAMP Roundtable, was formed to plan and provide oversight for SWAMP bioaccumulation studies. Plans for bioaccumulation monitoring rapidly became more focused and, with input from BOG members, advanced beyond the preliminary considerations presented in this report. A long-term strategy was devised for performing statewide sampling by sequentially covering major water body types one by one. The first two years of sampling under the new program are focused on a survey of lakes and reservoirs across the state. A sampling plan for this lakes survey was developed and peer-reviewed (Bioaccumulation Oversight Group, 2008). The lakes sampling plan and the long-term plan in development by the BOG supersede this report.

The present report was reviewed by some BOG members, but not revised in response to review comments because of the developments described above. This report therefore solely represents the perspective of the author. Nevertheless, the SWAMP considered it appropriate for SFEI to publish the report in its present form. The report documents the rationale for some of the elements of the design that was chosen and the design process that was followed by the BOG, and also contains ideas that may be useful if SWAMP is able to invest more substantial funding in bioaccumulation monitoring in the future. If a strategy for funding the full integrated monitoring program can be found, California could create an excellent foundation for evaluating long-term progress in restoring the fishing and aquatic life beneficial uses, and in a 10 year period could achieve a significant reduction of risks and impacts to the health of Californians from consumption of contaminated fish.

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BACKGROUND

Bioaccumulation of pollutants in many California water bodies is of a sufficient magnitude to cause concern for effects on the health of humans and wildlife and is having a significant and widespread impact on the fishing and aquatic life beneficial uses. Bioaccumulation monitoring will be a crucial element of adaptive management strategies to reduce these health risks and impacts on beneficial uses. This report was written for the Surface Water Ambient Monitoring Progjram (SWAMP) as a first step toward the development of an improved bioaccumulation monitoring program for California. This document provides recommendations for a process for developing a Statewide program and a preliminary vision of what the program could include.

Bioaccumulation monitoring offers many advantages over monitoring of water or sediment. TMDLs for many contaminants of present concern (such as mercury and PCBs) are increasingly emphasizing the use of tissue targets. Bioaccumulation monitoring is therefore an essential indicator of the status of the fishing and aquatic life beneficial uses.

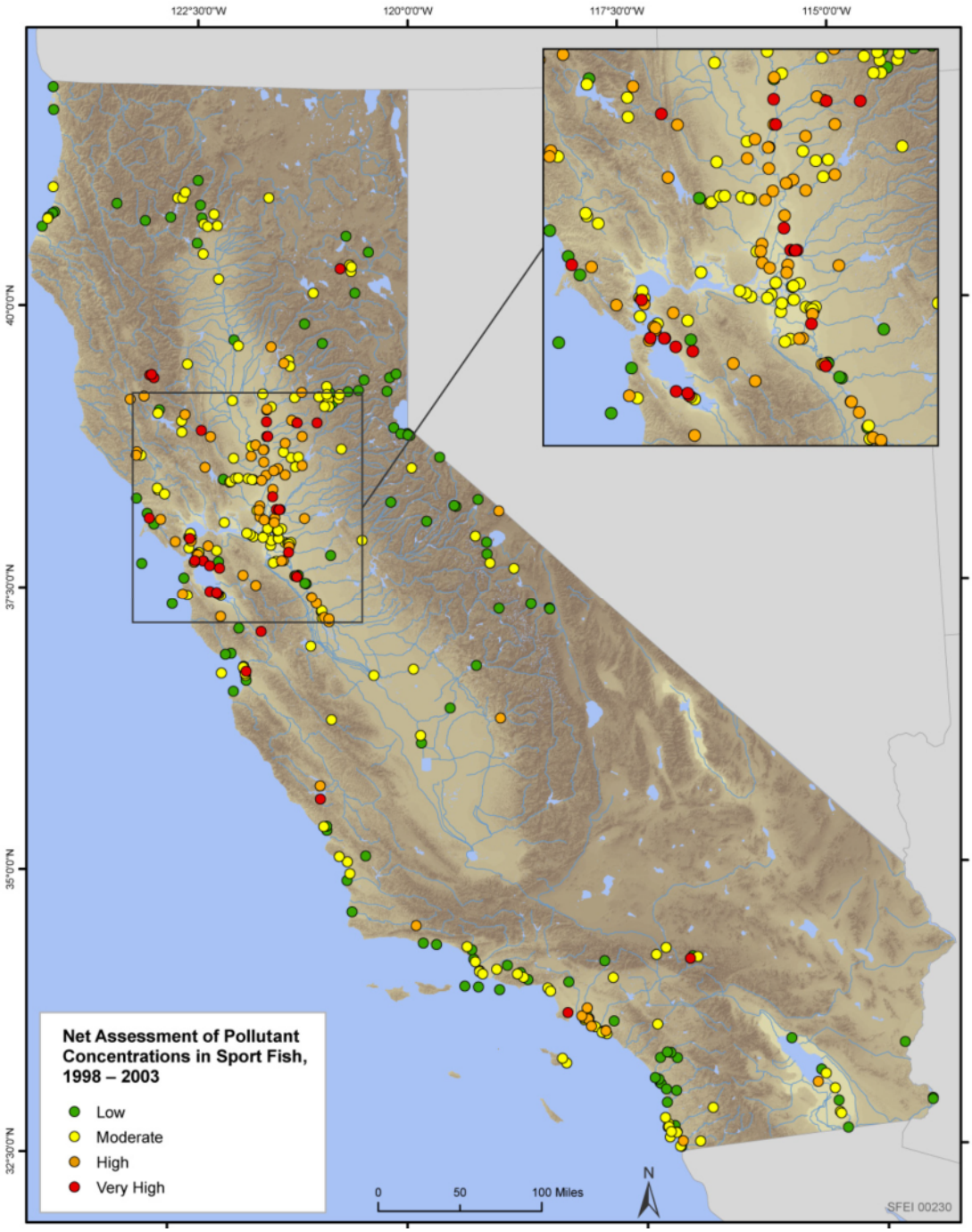
ADDRESSING THE BIOACCUMULATION PROBLEM

For bioaccumulative pollutants in California, the cause of the beneficial use impacts can be defined as *biotic exposure to bioaccumulative pollutants*. The goal for water quality managers can be defined as *to reduce biotic exposure to bioaccumulative pollutants below thresholds for concern*. The ultimate solution to the bioaccumulation problem is to reduce pollutant sources and concentrations in water and sediment of our aquatic ecosystems. This solution would reduce exposure to all species, including sensitive wildlife species and humans. Bioaccumulation monitoring will be an essential part of adaptive management strategies to achieve this goal. However, contamination of our watersheds and aquatic ecosystems is so pervasive that, even with serious cleanup actions, concentrations of some toxic chemicals in fish are likely to remain above thresholds of concern for at least 50 to 100 years.

While managers work toward the long-term cleanup of the ecosystem, bioaccumulation monitoring can also provide a foundation for an alternative approach to significantly reducing human exposure to bioaccumulative pollutants in a much shorter time-frame. This alternative approach involves thorough monitoring, development of sound consumption advice, and effectively communicating the advice to anglers. Consumption advisories have been issued for some of the State's water bodies (Figure 1). However, consumption advice presently exists for only a small percentage of areas that need it. The most recent monitoring data indicate that most sampled locations are impacted by pollutants (Figure 2). On the other hand, concentrations in some places and some species are lower, and with an

Figure 1. Consumption advisories in California as of January 2006.

Figure 2. Bioaccumulative pollutants are currently having a widespread impact on the fishing beneficial use in California. Dot colors indicate degree of net impact at each location sampled. Based on concentrations of several chemicals (mercury, PCBs, DDTs, dieldrin, and chlordanes) from analysis of edible tissue in a variety of species from 1998 – 2003.



awareness of this information the public can more fully enjoy the health benefits of consuming clean fish.

With a foundation of solid monitoring information, consumption advice can be developed that steers anglers toward fish species and fishing locations that are relatively low in chemical concentrations. In the near-term, this is the best available approach to reducing human exposure to pollutants in Central Valley waterways while promoting the fishing beneficial use. Groups with relatively high rates of fish consumption will benefit the most from this project, including disadvantaged communities with their higher proportion of subsistence fishing.

This document proposes a program that combines long-term bioaccumulation monitoring with a near-term effort to reduce human health risks associated with sport fish consumption. The basic elements of this program would include: 1) stakeholder involvement, 2) monitoring bioaccumulation in sport fish and other indicator species, 3) advisory development, and 4) communication of risks back to stakeholders (Figure 3). The program would address environmental justice concerns by facilitating participation of community-based organizations and placing a high priority on communicating risks to disadvantaged populations. Sport fish monitoring would be closely integrated with stakeholder involvement, advisory development, and risk communication. With this program of integrated monitoring and risk communication, human exposure to bioaccumulative pollutants in California could be significantly reduced in the next 10 years.

RECOMMENDATIONS FOR A BIOACCUMULATION MONITORING AND RISK REDUCTION PROGRAM FOR CALIFORNIA

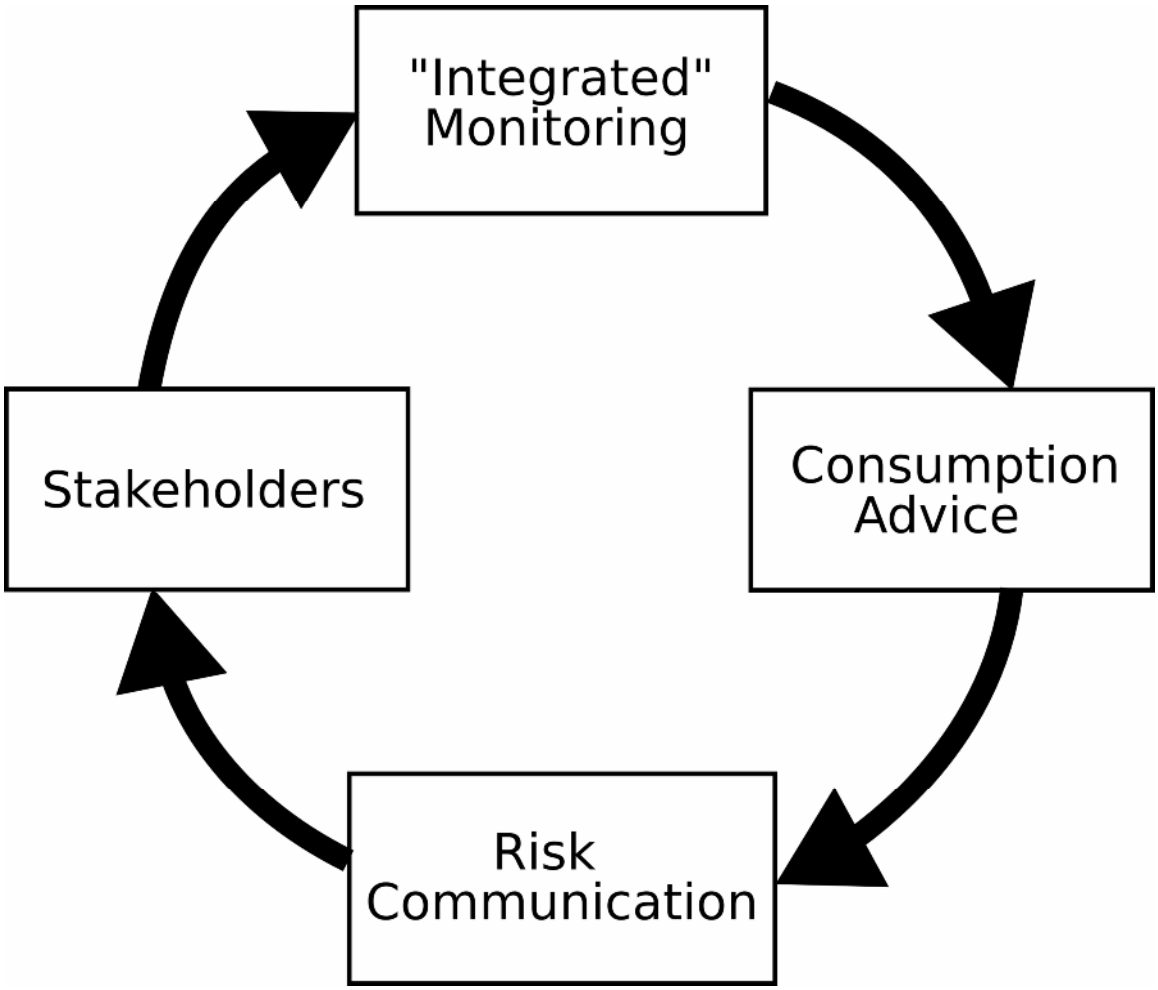
This report describes a recommended organizational structure, process, and preliminary design of a statewide bioaccumulation monitoring and risk reduction program for California. The report is intended to provide a starting point for the collaborative group process that is needed.

Organizational and Procedural Elements of the Program

SWAMP would be the funding agency and would have the ultimate decision-making authority over program activities. The other groups involved would include a Stakeholder Committee, a Peer Review Panel, and contractors to implement the program.

Effective monitoring depends upon a clear understanding of the needs of the end-users of the information. The end-users of the information generated by a statewide bioaccumulation monitoring program would include organizations involved in protecting water quality, habitat restoration, resource management, and protecting human health. The State and Regional Boards, through the SWAMP, would be the principal funder of the program, and therefore would have the ultimate authority for making decisions on the design and implementation of the program. However, a consensus-based approach that

Figure 3. "Integrated" sport fish monitoring combines stakeholder involvement, monitoring, development of consumption advice, and risk communication with the goal of achieving near-term reductions in human exposure in a manner that incorporates environmental justice principles.



includes all of the stakeholders would be optimal in guiding the program. With this type of approach, all of the stakeholders have a voice in guiding a truly collaborative program. Inclusion of community-based organizations (CBOs) as stakeholders in this manner is a fundamental requirement for incorporating environmental justice principles. The CBOs can be tremendously valuable partners in monitoring and risk communication. In addition to end-users of monitoring information, the Stakeholder Committee can also provide a hub for coordinating bioaccumulation monitoring with other monitoring, research, and restoration activities in California. Given the limited budget available for bioaccumulation monitoring, and the enormous challenge of characterizing status and trends in bioaccumulation across the entire State, coordination will be essential to achieving SWAMP's bioaccumulation monitoring goals and objectives.

The proposed level of investment and technical effort calls for a high caliber of peer review. Internal peer review should be provided by technical representatives of: the funding agency (the State Board and Regional Boards), other agencies that contribute funds or in-kind services, and stakeholder groups. External peer review for a program of this magnitude should be obtained from a panel of experts with national or international recognition as authorities in their fields.

A Preliminary Recommendation for the Design of the Program

In order to facilitate discussion and illustrate how the concepts described in this report would translate into a monitoring and risk reduction program, a *preliminary* design of a program is presented. The stakeholder and peer review processes described in the preceding section will certainly lead to a final design that differs from the preliminary design proposed in this report, perhaps substantially. After the program is established, it will also be essential that it continue to evolve in response to changing management priorities and advances in understanding.

In response to uncertainty about available funding, this report illustrates what the program could look like at three different levels of funding: $500,000 per year; $1.5 million per year; and $3.3 million per year. The two lower levels of funding were based on possible scenarios for the FY 2006 budget. The highest level of funding is proposed as an ideal scenario, where the amount of funding allocated to the program is commensurate with the task of monitoring and reducing risks from bioaccumulation in a state as large and diverse as California.

The Full Program

At the full level of funding ($3.3 million per year), the program could adequately address all of the objectives and assessment questions set forth for the program, including both those that have already been articulated and those that have not yet been articulated relating to advisory development, risk communication, and environmental justice. At this level the program would include:

1. A sport fish monitoring program that is integrated with advisory development and risk communication and addresses environmental justice issues through funded participation of representatives of affected communities.
2. A stepwise program for developing consumption advice that would result in complete coverage of the State in a 10 year period.
3. Risk communication efforts integrated into the program that could reduce human health risks significantly in a 10 year period without necessarily reducing fishing or fish consumption (through directing anglers to less contaminated fish species and locations).
4. Monitoring of sport fish at 70 sites per year, integrated into a Statewide randomized design, in one of ten Focal Areas established to facilitate stakeholder involvement, advisory development, and risk communication.
5. Monitoring of sport fish at 35 sites per year with a Statewide randomized design that would determine the status of the fishing beneficial use throughout the State without bias to known impairment. After 5 years the precision of estimates of the areas or miles of each category of water body (large rivers, lakes, coastal waters, and bays and estuaries) falling into each designated level of support of the fishing beneficial use would be better than ± 14%.
6. Monitoring of sport fish at 35 targeted sites per year to be used in assessment of long-term trends and effectiveness of management actions.
7. Monitoring of bivalves at 5 targeted sites per year to supplement bivalve monitoring performed by other programs.
8. Monitoring of small fish at 50 targeted sites per year to be used in assessment of long-term trends in food web mercury, sources and pathways of mercury, and effectiveness of actions to manage mercury contamination.
9. Monitoring of bird eggs at 15 targeted sites once every three years to provide information on regional long-term trends in bioaccumulative contaminants, including emerging contaminants and expensive analytes such as dioxins.
10. A $300,000 allotment for pilot and special studies.

The full funding scenario includes a budget and activities that would be needed for a program that fully addresses the objectives and assessment questions set forth by SWAMP and the goal of achieving a near-term reduction of human exposure to bioaccumulative pollutants. The budget and some of the activities proposed may be beyond the scope of the SWAMP, and this is a topic that should be carefully considered by the Roundtable. It may be possible for other agencies with interests in or mandates for water quality management and protection of human health to contribute resources to the program. It also appears that it will be possible to accomplish some of the monitoring through coordination with other national and regional monitoring programs.

If a strategy for funding the full program can be found, the State could create an excellent foundation for evaluating long-term progress in restoring the fishing and aquatic life beneficial uses, and in a 10 year period could achieve a significant reduction of risks and impacts to the health of Californians from consumption of contaminated fish.

A $1.5 Million Program

At a $1.5 million level of funding the program could address a subset of the objectives and assessment questions established for the program. At this level the program would include:

1. Monitoring of sport fish at 40 sites per year, integrated into a Statewide randomized design, in one of ten Focal Areas established to facilitate stakeholder involvement, advisory development, and risk communication (however, the stakeholder involvement, advisory development, and risk communication tasks would not be funded).
2. Monitoring of sport fish at 35 sites per year with a Statewide randomized design that would determine the status of the fishing beneficial use throughout the State without bias to known impairment. After 5 years the precision of estimates of the areas or miles of each category of water body (large rivers, lakes, coastal waters, and bays and estuaries) falling into each designated level of support of the fishing beneficial use would be better than ± 14%.
3. Monitoring of sport fish at 35 targeted sites per year to be used in assessment of long-term trends and effectiveness of management actions.
4. Monitoring of small fish at 25 targeted sites per year to be used in assessment of long-term trends in food web mercury, sources and pathways of mercury, and effectiveness of actions to manage mercury contamination.
5. Monitoring of bird eggs at 10 targeted sites once every three years to provide information on regional long-term trends in bioaccumulative contaminants, including emerging contaminants and expensive analytes such as dioxins.
6. A $70,000 allotment for pilot and special studies.

At this level of funding it would not be possible to include the advisory development program, risk communication, an environmental justice component, or bivalve monitoring. The number of sites sampled for sport fish, small fish, and bird eggs would be reduced, diminishing the value of the program in answering all of the program Objectives. The allotment for pilot and special studies would also be reduced.

A $0.5 Million Program

At a $0.5 million level of funding the program could address a very small subset of the objectives and assessment questions established for the program. At this level the program would include:

1. Monitoring of sport fish at 40 targeted sites per year to be used in assessment of long-term trends and effectiveness of management actions.

At this level of funding it would not be possible to include the advisory development program, risk communication, an environmental justice component, bivalve monitoring, small fish monitoring, or bird egg monitoring. No funds would be available for pilot and special studies. Funding for peer review and archiving would be reduced.

I. INTRODUCTION

A. BACKGROUND

Bioaccumulation of pollutants in many California water bodies is of a sufficient magnitude to cause concern for possible effects on the health of humans and wildlife and is having a significant and widespread impact on the fishing and aquatic life beneficial uses (Davis et al. 2006). Bioaccumulation monitoring will be a crucial element of adaptive management strategies to reduce these health risks and impacts on beneficial uses.

This report was written for the Surface Water Ambient Monitoring Progjram (SWAMP) as a first step toward the development of an improved bioaccumulation monitoring program for California. From the late 1970s through the 1990s, the California State Water Resources Control Board (State Board) maintained two significant long-term Statewide bioaccumulation monitoring programs: the Toxic Substances Monitoring Program (TSMP) and the State Mussel Watch Program (SMWP). The TSMP employed a uniform approach for monitoring pollutants in fish and invertebrates in freshwater and estuarine habitats (SWRCB 1986, Rasmussen 1995, 1997). The State Mussel Watch Program (SMWP) was initiated in 1977 to provide information on long-term trends in water quality in coastal marine waters and to identify specific areas with elevated concentrations (Hayes et al. 1985, Hayes and Phillips 1986, Rasmussen 2000). These two programs were very successful in many ways. The SMWP was instrumental in gaining widespread international acceptance of bivalve monitoring as a tool in aquatic environments (Phillips 1988). Over the years, both of these programs yielded a wealth of information on water quality in California. Many instances of severe contamination were identified, leading to cleanup actions and fish advisories to reduce exposure of humans and wildlife. In addition, many relatively uncontaminated areas were identified. These programs have documented the successful management of many pollutants that posed serious threats to wildlife and human health in the 1970s and 1980s. These programs were instituted just in time to document the rapid improvements in water quality that resulted from bans on PCBs and legacy pesticides, reductions in metals due to wastewater treatment, and other improvements.

In 2000, the SWRCB, responding to a bill passed by the California legislature, developed a plan to restructure their existing water quality monitoring programs (including TSMP and SMWP) and create a Surface Water Ambient Monitoring Program (SWAMP) for water quality that addresses all hydrologic units of the State using consistent and objective monitoring, sampling and analytical methods; consistent data quality assurance protocols; and centralized data management (SWRCB 2000). Sampling under the three monitoring programs ended in 2003, as SWAMP began to take shape.

In 2004 the State Board established a contract with the San Francisco Estuary Institute to perform a comprehensive review of historic bioaccumulation monitoring data for the State and, based on the findings of the review, formulate a recommendation for an

improved Statewide bioaccumulation monitoring program. Two reports are in preparation to accomplish these goals. The first, providing a review of historic data was drafted and distributed for review in March 2006 (Davis et al. 2006).

Davis et al. (2006) concluded that the dataset generated by the State Board bioaccumulation monitoring programs has several limitations when viewed from the perspective of current management questions and priorities:

- many areas have not been sampled adequately;
- the distribution of sampling locations has varied over time;
- most of the sampling has not been tailored to the development of consumption advice;
- long-term time series for detecting trends in sport fish or other wildlife contamination are lacking; and
- much of the sampling has been biased toward characterization of polluted areas.

Davis et al. (2006) further concluded that a sampling design with spatial randomization would be better suited to answering SWAMP assessment questions. Such a design would allow for an unbiased overall assessment of the condition of California water bodies. A randomized design could also be augmented by targeted sampling for long-term trends in particular locations, allowing for the continuation of valuable time series or for the initiation of new ones.

This document is a draft of the second report, providing recommendations for a process for developing a Statewide program and a preliminary vision of what the program could include.

B. THE VALUE OF BIOACCUMULATION MONITORING

Bioaccumulation monitoring offers several advantages over monitoring of water or sediment, including:

- measuring the degree to which pollutants are actually entering the food web, which for some pollutants (such as mercury) can be quite different from the total concentrations present in water and sediment;
- yielding a strong signal of contamination, since many pollutants reach concentrations that are much higher and easier to measure in biota than in water and sediment;
- providing an integrative measure of pollutant concentrations over time and a cost-effective tool for obtaining information on average concentrations; and
- especially for fish, providing information that is directly linked to the impacts of pollutants on human and wildlife health.

Many pollutants currently of concern are highly bioaccumulative, including mercury, PCBs, legacy pesticides, selenium, dioxins, and PBDEs. Most of these actually "biomagnify", reaching higher and higher concentrations with each step up the food chain. As water and sediment contamination does not reliably correlate with bioaccumulation and health risks to humans and wildlife, TMDLs for these chemicals are

increasingly emphasizing the use of tissue targets. Bioaccumulation monitoring is therefore an essential indicator of the status of the fishing and aquatic life beneficial uses.

C. ADDRESSING THE BIOACCUMULATION PROBLEM

Wiener et al. (2003) developed a valuable conceptual framework for linking mercury science with adaptive management and restoration in the Bay-Delta watershed. They pointed out that clear definition of a problem affecting ecosystem or human health is an essential first step in an adaptive management process. For mercury, they defined the primary problem in the Bay-Delta and other aquatic ecosystems as *biotic exposure to methylmercury*, and stated that the overall challenge to scientists and managers involved with ecological restoration in the Bay-Delta ecosystem is *to avoid increasing – and to eventually decrease – biotic exposure to methylmercury*.

A similar problem definition, expanded to include all of California and multiple pollutants, can be applied to the bioaccumulation problem for the State as a whole. For bioaccumulative pollutants in California, the problem can be defined as *biotic exposure to bioaccumulative pollutants*. The goal for water quality managers can be defined as *to reduce biotic exposure to bioaccumulative pollutants below thresholds for concern*.

The ultimate solution to the bioaccumulation problem is to reduce pollutant sources and concentrations in water and sediment of our aquatic ecosystems. This solution would reduce exposure to all species, including sensitive wildlife species and humans. Bioaccumulation monitoring will be an essential part of adaptive management strategies to achieve this goal – a vital performance measure to gauge progress and evaluate the effectiveness of management actions. However, contamination of our watersheds and aquatic ecosystems is so pervasive that, even with serious cleanup actions, concentrations of some toxic chemicals in fish are likely to remain above thresholds of concern for at least 50 to 100 years. Furthermore, some activities planned for the near future (e.g., large scale wetland restoration, which may increase methylmercury concentrations at a regional scale) have the potential to exacerbate the existing problem.

While managers work toward the long-term cleanup of the ecosystem, bioaccumulation monitoring can also provide a foundation for an alternative approach to significantly reducing human exposure to bioaccumulative pollutants in a much shorter time-frame. This alternative approach involves thorough monitoring, development of sound consumption advice, and effectively communicating the advice to anglers.

Consumption advisories have been issued for some of the State's water bodies (Figure 1). However, consumption advice presently exists for only a small percentage of areas that need it. The most recent monitoring data indicate that most sampled locations are impacted by pollutant bioaccumulation (Figure 2). Of the 67% of locations with impacts, some are in areas presently under advisories, but many are not. In addition, it is likely that many areas that have not been sampled in recent years and are not under advisories also do not fully support the fishing beneficial use. On the other hand,

concentrations in some places and some species are lower, and with an awareness of this information the public can more fully enjoy the health benefits of consuming clean fish.

With a foundation of solid monitoring information, consumption advice can be developed that steers anglers toward fish species and fishing locations that are relatively low in chemical concentrations. In the near-term, this is the best available approach to reducing human exposure to pollutants in Central Valley waterways while promoting the fishing beneficial use. Groups with relatively high rates of fish consumption will benefit the most from this project, including disadvantaged communities with their higher proportion of subsistence fishing.

This document proposes a program that combines long-term bioaccumulation monitoring with a near-term effort to reduce human health risks associated with sport fish consumption. The basic elements of this program would include: 1) stakeholder involvement, 2) monitoring bioaccumulation in sport fish and other indicator species, 3) advisory development, and 4) communication of risks back to stakeholders (Figure 3). The program would address environmental justice concerns by facilitating participation of community-based organizations and placing a high priority on communicating risks to disadvantaged populations. Sport fish monitoring would be closely integrated with stakeholder involvement, advisory development, and risk communication. With this program of integrated monitoring and risk communication, human exposure to bioaccumulative pollutants in California could be significantly reduced in the next 10 years.

II. RECOMMENDATIONS FOR A BIOACCUMULATION MONITORING AND RISK REDUCTION PROGRAM

A. OVERVIEW

The best way to develop an informative and relevant monitoring program is through a collaborative process that includes input from the environmental managers that will use the information generated to make management decisions, the stakeholders that will be affected by the decisions made, and scientists that know how to obtain reliable information on the condition of the environment. In order to retain its value over time, a monitoring program must adapt to changes in management priorities and technical advances in understanding or technology. The key ingredient of an adaptive monitoring program is active and continuous dialogue among managers, stakeholders, and scientists with an interest in the resource being monitored. Both the establishment and maintenance of a monitoring program therefore depend on an organizational structure that facilitates the collaboration of managers, stakeholders, and scientists. Development of a multifaceted program for monitoring and communicating human and wildlife health risks due to bioaccumulation for an area as large and diverse as California calls for the collaboration and insight of a large, engaged gathering of representatives of many government agencies, stakeholder groups, and scientific disciplines.

This report describes a recommended organizational structure, process, and preliminary design of a statewide bioaccumulation monitoring and risk reduction program for California. The report is intended to provide a starting point for the collaborative group process that is needed. As soon as the stakeholders are convened it is anticipated that improvements will begin to be made to the plan suggested in this report.

The recommendations regarding the organizational structure and process are similar to those offered in the CALFED document "Mercury Strategy for the Bay-Delta Ecosystem: A Unifying Framework for Science, Adaptive Management, and Ecological Restoration" (Wiener et al. 2003). Mercury contamination is one of the highest priority water quality issues in the State, so this document is highly relevant to the topic of future bioaccumulation monitoring in California. Bioaccumulation monitoring, focusing on sport fish and small fish, was a cornerstone of the adaptive management approach prescribed by Wiener et al. (2003). The recommendations for organizational structure, process, and technical approach offered in this report are completely consistent with the recommendations of Wiener et al. (2003) for development of a monitoring program for mercury in fish in the Bay-Delta watershed.

A CALFED-funded project, the Fish Mercury Project (FMP) (Davis et al. 2005), is being conducted to implement the bioaccumulation monitoring recommendations of Wiener et al. (2003). The FMP is combining monitoring of mercury in fish in the Bay-Delta watershed with advisory development, risk communication, and stakeholder involvement. The recommendations contained in this report are informed by the lessons learned so far in the FMP. Incorporating community-based organizations and environmental justice concerns into a monitoring program has been a novel aspect of the

FMP and a topic in particular where much has been learned. While the FMP is a multifaceted and significant project in itself, a bioaccumulation monitoring program for multiple contaminants throughout California will be an even larger enterprise, requiring even more coordination and planning.

Lessons learned from the Regional Monitoring Program for Water Quality in the San Francisco Estuary (RMP) (Davis et al. 2006) are another strong influence on the recommendations in this report. The RMP has been in place since 1993 and is still considered by stakeholders to be a successful and valuable program. A primary reason for the success of the RMP is that it has undergone a substantial amount of adaptation over the past 13 years, and along the way has evolved an effective organizational structure and procedural framework for flexibly responding to changing management needs and technical advances. The Mercury Strategy cites the RMP as good model for an adaptive monitoring program. In addition, the RMP is a multifaceted water quality monitoring program that has demonstrated many of the elements of a comprehensive bioaccumulation monitoring program: sport fish, bivalves, avian eggs, small fish, marine mammals, and food web studies.

B. ORGANIZATIONAL AND PROCEDURAL ELEMENTS OF THE STATEWIDE BIOACCUMULATION MONITORING AND RISK REDUCTION PROGRAM

The basic organizational structure of the proposed program is shown in Figure 4. SWAMP would be the funding agency and would have the ultimate decision-making authority over activities of the other groups. The other groups involved would include a Stakeholder Committee, a Peer Review Panel, and contractors to implement the program. Since the program calls for tasks associated with several diverse disciplines, it will likely require a multidisciplinary team of several contractors. The membership and roles of the Stakeholder Committee and Peer Review Panel are described further below.

Stakeholder Committee

Groups to be Included

Effective monitoring depends upon a clear understanding of the needs of the end-users of the information. The end-users of the information generated by a statewide bioaccumulation monitoring program would include organizations involved in:

1) protecting water quality,
2) habitat restoration (due to the possible influence on bioaccumulation of mercury and possibly other pollutants),
3) resource (i.e., water and fisheries) management,
4) protecting human health, and
5) communicating information on health risks to affected communities.

For water quality managers and habitat managers bioaccumulation monitoring will provide a performance measure of environmental condition that is essential to adaptive management of pollution remediation and habitat restoration. Resource managers need monitoring information to understand the condition of the habitats and populations they

are protecting. Organizations involved in protecting human health need reliable and relevant monitoring information in order to craft messages that are effective in encouraging fish consumers to make healthier choices.

In order to optimize the value of the monitoring program, it is essential that representatives of these categories of organizations actively participate in the planning, implementation, and communication phases of the program. This participation is needed not only at the inception of the program, but for as long as the program continues. The information needs of end-users are not static – priorities can change considerably due to political developments and as knowledge increases.

More specifically, the following groups should be targeted for inclusion in planning for the Statewide program:

- water quality management agencies - the State Board, the Regional Boards, and USEPA;
- resource management agencies - the California Bay-Delta Authority, California Department of Fish and Game, U.S. Bureau of Reclamation, Army Corps of Engineers, Department of Water Resources, U.S. Fish and Wildlife Service, National Marine Fisheries Service;
- health agencies - Office of Environmental Health Hazard Assessment, Department of Health Services, and county health departments;
- community-based organizations - tribal groups such as International Indian Treaty Council, community groups such as Eco Village, West County Toxics Coalition, LULAC Todos Unidos, and United Cambodian Families, and watershed groups such as the Sacramento River Watershed Program;
- fishing organizations - e.g., United Anglers, Federation of Fly Fishers
- environmental organizations - e.g., Baykeeper/Deltakeeper; Clean Water Action;
- organizations involved in bioaccumulation monitoring – including the U.S. Geological Survey, University of California, and many agencies already listed above.

Examples of groups from each of the different sectors are provided, based on the Steering Committee roster for the Fish Mercury Project.

The State and Regional Boards, through the SWAMP, would be the principal funder of the program, and therefore would have the ultimate authority for making decisions on the design and implementation of the program. If other collaborating organizations can bring additional resources to the table, they should share in this ultimate decision-making authority. However, a consensus-based approach that includes all of the stakeholders would be optimal in guiding the program. The FMP has been able to implement this type of approach, with the CBDA as the sole funder and ultimate decision-maker, but the diverse membership of the FMP Steering Committee all having input on project activities. With this type of approach, all of the stakeholders have a voice in guiding a truly collaborative program.

Environmental Justice

Environmental justice is a high priority among water quality and resource management agencies. Bioaccumulation monitoring, more specifically sport fish monitoring, is a topic that is strongly associated with environmental justice concerns. The FMP has served as a pilot effort to incorporate environmental justice principles into a bioaccumulation monitoring project. Inclusion of community-based organizations (CBOs) as stakeholders is a fundamental requirement for incorporating environmental justice principles. The CBOs can be tremendously valuable partners in monitoring and risk communication. They can provide important input to sampling designs, including information on popular species and fishing locations. CBOs also represent one of the most effective channels for communicating information back to their constituencies, which in many cases include disadvantaged populations that disproportionately bear the environmental injustice of fish contamination. Unlike agency representatives, CBO representatives generally do not receive wages or travel expenses when attending committee meetings. A lesson learned from discussions within the FMP is that really incorporating environmental justice into a fish monitoring and risk communication program would require involving CBOs in planning and execution of the entire project and providing funding for stakeholder participation in program planning and collaboration on activities that build local capacity for risk communication.

Coordination

In addition to end-users of monitoring information, the Stakeholder Committee can also provide a hub for coordinating bioaccumulation monitoring with other monitoring, research, and restoration activities in California. Given the limited budget available for bioaccumulation monitoring, and the enormous challenge of characterizing status and trends in bioaccumulation across the entire State, coordination will be essential to achieving SWAMP's bioaccumulation monitoring goals and objectives. Examples of monitoring programs to coordinate with include regional programs such as the Regional Monitoring Program (SFEI 2005) and the Sacramento River Watershed Program (SRWP 2005), State programs such as the mussel watch monitoring being conducted and national programs such as NOAA's National Status and Trends Program and the proposed National Water Quality Monitoring Network for U.S. Coastal Waters and their Tributaries (Spooner and Mallard 2006). The National Monitoring Network in particular should be tracked closely as it could represent a significant investment of resources in monitoring coastal waters and tributaries, and a significant augmentation of monitoring efforts in California. Another national effort to coordinate with is USEPA's upcoming National Lakes Survey (http://www.epa.gov/owow/lakes/lakessurvey/).

In coordinating SWAMP bioaccumulation monitoring with these other programs, several elements should be covered, including:

- Sampling design (to avoid duplication and maximize cost-effectiveness);
- Quality assurance (to promote generation of directly comparable data across the State);
- Sharing of results and information, including recent, unpublished findings; and

- Reporting of available data from the various programs.

Initial Tasks for the Stakeholder Committee

At the beginning of the program, decisions will have to be made on how to proceed with setting up the organizational structure and the initial steps in development of the monitoring program. The SWAMP Roundtable, perhaps with a small number of key additions (e.g., OEHHA), could serve as a Preliminary Stakeholder Committee for these early decisions until the full Committee can be established. Early decisions to be made include the scope of the program (e.g., Should SWAMP bioaccumulation monitoring be integrated with risk reduction efforts? Should the program emphasize environmental justice?) and mechanisms for funding each program element (e.g., Should risk reduction be funded with the SWAMP bioaccumulation budget or could it be funded through other channels?). The outcome of these decisions should then be articulated as goals and objectives for the bioaccumulation monitoring program. The Preliminary Stakeholder Committee should also select contractors for implementing the program. Selecting contractors early on in the planning process will be necessary to organize stakeholder participation and to begin the planning and sampling design process.

Objectives and assessment questions for the SWAMP bioaccumulation element have already been developed (Table 1). These serve well in providing a focus for the sampling design of the bioaccumulation monitoring program. The preliminary sampling designs proposed later in this report are specifically intended to address these objectives and questions. A fundamental first step in developing the monitoring program will be to thoroughly scrutinize this framework and ensure that these are precisely the questions that the monitoring program should answer.

However, if monitoring is to be integrated with advisory development, risk communication, and environmental justice the objectives framework for SWAMP bioaccumulation monitoring will need to be augmented. The present objectives do not say anything about these topics. The Steering Committee and Review Panel for the Fish Mercury Project developed a set of goals and objectives that encompass risk communication and environmental justice (Table 2) (Davis et al. 2005), and can serve as a relevant example in considering how to incorporate these topics into the SWAMP objectives framework.

Once the objectives framework is established and the sampling designs have taken shape, data quality objectives should be established. A Quality Assurance Program Plan should be developed that explicitly ties data quality objectives to the objectives and assessment questions being addressed by the program.

The full Stakeholder Committee should be established as early as possible to allow time for stakeholder input and planning and then for sampling to begin as early as possible. Tasks that the Stakeholder Committee should complete before sampling can begin include:

- Obtain general agreement on objectives and assessment questions;

- Identify long-term bioaccumulation monitoring plans of other programs in California and develop plans for coordination;
- Identify region for first year sampling and risk communication;
- Provide fishing activity information for areas they are familiar with;
- Develop targeted sampling designs (sites and frequencies for sport fish, bivalves, small fish, and avian eggs);
- Review Draft QAPP;
- Review Final QAPP;
- Review Draft Sampling and Analysis Workplan; and
- Review Final Sampling and Analysis Workplan.

It is anticipated that the planning process leading up to the start of sampling will take approximately one year (Table 3). This will include time for the Stakeholder Committee to complete these tasks and for contractors to perform the work need to develop a probabilistic sampling frame for the sport fish element (this latter topic is described further below).

Peer Review Panel

Peer review is an essential element of any scientific endeavor. The monitoring program proposed in this document would be a considerable effort, with an extensive and multifaceted scope and a significant investment of resources to be sustained over a long period of time. This level of investment and technical effort calls for a high caliber of peer review. Two types of peer review – internal and external – will be needed for the success of the program.

Internal peer review should be provided by technical representatives of: the funding agency (the State Board and Regional Boards), other agencies that contribute funds or in-kind services, and stakeholder groups. The SWAMP Roundtable would the nucleus of an internal peer review group. These internal peer reviewers would provide technical oversight that is combined with an understanding of how the information generated by the program will be used in decision-making at the State and regional levels.

External peer review for a program of this magnitude should be obtained from a panel of experts with national or international recognition as authorities in their fields. These reviewers would be able to ensure that the technical elements of the program meet appropriately high standards, and would bring a perspective based on lessons learned from monitoring in other parts of the country or the world. The panel should be comprised of individuals with areas of expertise that specifically correspond to the major elements of the program, including sport fish monitoring, general bioaccumulation monitoring (bivalves, small fish, avian eggs, invertebrates such as sand crabs), risk communication, and statistics and sampling design. Expertise on the panel should cover all of the pollutants being monitored.

It would be ideal for this panel to help guide the program from its earliest formative stages. The planned peer review of this report could be the first task for the

panel. The report should then be revised to reflect panel input. Other tasks for the panel during the startup phase of the program would include:

- Review objectives and assessment questions;
- Review development of the probabilistic and targeted sampling designs;
- Review Draft QAPP;
- Review Final QAPP;
- Review Draft Sampling and Analysis Workplan; and
- Review Final Sampling and Analysis Workplan.

C. A PRELIMINARY RECOMMENDATION FOR THE DESIGN OF A BIOACCUMULATION MONITORING AND RISK REDUCTION PROGRAM FOR CALIFORNIA

A Preliminary Design

In order to facilitate discussion and illustrate how the concepts described in this report would translate into a monitoring and risk reduction program, a *preliminary* design of a program is presented. The stakeholder and peer review processes described in the preceding section will certainly lead to a final design that differs from the preliminary design proposed in this report, perhaps substantially. After the program is established, it will be essential that it continue to evolve in response to changing management priorities and advances in understanding. However, the preliminary proposed design is based on lessons learned from other major monitoring programs and is intended to provide a reasonable starting point.

Designs for Different Funding Scenarios

Uncertainty regarding the annual availability of funding is one of the primary challenges to be faced in implementing the program. In response to this uncertainty, this report illustrates what the program could look like at three different levels of funding: $500,000 per year; $1.5 million per year; and $3.3 million per year (Tables 4a and b). The two lower levels of funding were based on possible scenarios for the FY 2006 budget. The highest level of funding is proposed as an ideal scenario, where the amount of funding allocated to the program is commensurate with the task of monitoring and reducing risks from bioaccumulation in a state as large and diverse as California.

The RMP and FMP provide useful frames of reference. The RMP for San Francisco Bay is a $3 million per year program, that monitors water, sediment, toxicity, and bioaccumulation in sport fish, bivalves, bird eggs, and small fish. The FMP is a three-year $4.5 million project (or $1.5 million per year) that is performing monitoring of mercury (no other chemicals) in sport fish and small fish, advisory development, stakeholder involvement, and risk communication in a sizable area - the portion of the Bay-Delta watershed below major dams and above San Pablo Bay. Comparison to these programs indicates that a budget of $3.3 million is reasonable for a program to monitor bioaccumulation of all chemicals of concern in a suite of indicators across the entire state.

General Structure of the Program

The proposed monitoring and risk reduction program would include the following tasks (in descending order of share of the annual budget):

- Sampling and analysis for the core monitoring program;
- Project management;
- Advisory development;
- Risk communication;
- CBO participation and risk communication;
- Pilot and Special Studies;
- Peer review; and
- Archiving.

A proposed design for sampling and analysis in the core monitoring program is described further below, with detail provided for each of the four elements of the program (sport fish, bivalves, small fish, and bird eggs). In this section, brief descriptions of the other elements of the program are provided.

Project Management

Project management includes many tasks: contracting; coordination of the Stakeholder Committee, Peer Review Panel, and contractors; quality assurance; data management; data synthesis; and reporting. Project management including these tasks in the RMP accounts for about 30% of the total RMP budget. In this proposed program, some of these tasks can be partially covered by broader SWAMP activities (QA and data management), so project management is allocated 20 – 22% of the total budget (Table 5). Reporting of the data is a crucial task. A suite of communication products including peer-reviewed technical reports, an annual report that is accessible to a nontechnical audience, an annual meeting for presentation of results, and an actively maintained website would be valuable.

Advisory Development

Sound consumption advice is the centerpiece of any strategy to promote fishing while reducing exposure to toxic chemicals. Information developed through the proposed bioaccumulation monitoring program could be used to communicate to the public the health risks of pollutant exposure from fish consumption, steps that can be taken to reduce exposure, the health benefits of eating relatively "clean" fish, species and locations with high concentrations of pollutants, and species and locations with low concentrations of pollutants. Developing sound consumption advice depends on 1) knowing where people fish and what they catch and eat and 2) recent and appropriate monitoring data.

Consumption advice is currently in place for some parts of California, but there are many areas where advisories are not in place. In some of these areas there is reason to suspect that advice may be needed, and in others there is simply a lack of information and it is not known whether or not advice is likely to be needed. The FMP is developing

advice for a large portion of the Central Valley, but this advice is incomplete because it is based primarily on a dataset that contains extensive mercury information but a limited amount of information on other contaminants. Developing advice for all of the areas where it is needed should be a high priority for SWAMP.

In order to facilitate advisory development it is recommended that some of the sites to be covered each year be concentrated in a "focal area". This approach would create manageable geographic areas to target for organizing CBO participation, gathering fishing activity information, developing advice with associated public comment, and communicating risk information back to the fish-consuming public. To illustrate, in year 1, planning for the first year of sampling would occur and Focal Area #1 would be selected. This should be an area that is a high priority for advisory development. Then, also in year 1, CBOs for this Focal Area would be identified and a concentrated effort would be made to gather fishing activity information from stakeholders and other sources. With this information in hand, the sampling plan for Focal Area #1 would be developed and sampling would be performed in year 2. Sampling results from year 2 would be available in year 3. With these data available, consumption advice for Focal Area #1 could be drafted, finalized after public comment, and then used in risk communication activities within the Focal Area. This same sequence of steps could be followed in subsequent years of the program.

Following this approach, with the highest level of funding ($3.3 million per year), it would be possible to provide thorough coverage of the State – including a detailed Statewide sampling, advisories in most of the areas where they are needed, and a sustained effort at risk communication over much of California – in approximately a 10 year period. For a general visual comparison, the FMP, SRWP, and Central Valley Regional Board together sampled 70 sites in the Central Valley in 2005 (Figure 5). If the State were divided into 10 Focal Areas, an initial estimate is that 70 sites per Focal Area could provide adequate coverage of each, and over a 10 year period would lead to a reasonably good coverage of the State as a whole.

OEHHA is the agency whose mandate is to issue advice to minimize public health risks from consumption of sport fish. Some of this activity therefore falls within the scope of their existing budget. However, if the full-scale program is implemented, it will include an ambitious 10-year program of data gathering and advisory development that would demand additional resources for their increased level of activity. Consequently, the budget for the full-scale program includes an estimated amount of funds for "advisory development" (Tables 4a and 5).

Risk Communication and CBO and County Health Agency Participation

Once consumption advice is developed, enhancing the fishing beneficial use in the near-term depends on effectively communicating the advice to the public. A primary emphasis of this element should be building local capacity for communicating risks associated with fish consumption. Stakeholder participation in all phases of this project (from the initial stages on) would facilitate establishing relationships with additional

stakeholder groups and local health agencies, refining communication products, and training community members to deliver messages to target audiences. A train-the-trainer approach would be effective in building local capacity for addressing risk communication needs within the affected communities. A central component of the risk communication activities would be the development of collaborative projects with stakeholders. Stakeholders have credibility in their communities and are well-positioned to conduct culturally and linguistically appropriate activities that can reach target populations. In addition, risk communication contractors could conduct risk communication activities with guidance from the stakeholders, which may include multi-media campaigns, community events or programs, peer counseling, written materials, signs, demonstrations, interactive exhibits, and others.

The preliminary budget at the full funding level allocates 9% of the program budget to "risk communication" (Tables 4a and 5). This category would fund a risk communication contractor to coordinate CBO participation, gather fishing activity information from CBOs and other organizations, and perform risk communication activities. The preliminary budget at the full funding level also allocates 9% of the program budget to "CBOs and county health agencies" (Tables 4a and 5). This category would fund participation of CBOs and county health agency representatives in the planning process for the program and in implementing risk communication initiatives.

Detailed plans for tasks to be carried out under this category would be developed with guidance from the Stakeholder Committee and Review Panel.

Pilot and Special Studies

A long-term monitoring program must maintain a high degree of consistency from year to year in order to effectively document trends through time. However, a monitoring program should be adaptive if it is to maintain its relevance and value. One mechanism that allows for adaptation is to allocate a portion of the annual budget to pilot and special studies. A pilot study is a monitoring study conducted on a trial basis in order to determine whether it is suitable for inclusion in long-term monitoring. A special study is a study that helps improve monitoring measurements or the interpretation of monitoring data, or that serves to meet program objectives through activities other than monitoring. Pilot and special studies constitute a mechanism for responding quickly to new information or concerns, assessing new technical approaches, investigating particular questions that have defined endpoints, and evaluating new directions for status and trends monitoring. In the RMP, approximately $500,000 per year (compared to $1.5 million per year for status and trends monitoring) is allocated to pilot and special studies, and these studies have led to many refinements of status and trends monitoring and advances in understanding of contaminant dynamics in San Francisco Bay (Davis et al. 2006).

Some examples of studies that could be considered for inclusion in the program on a trial basis are already apparent. The techniques for these studies in some cases are already reasonably well-established. What needs to be discussed by the committees

guiding the program are the relative priority of these potential elements, the portion of the budget that they could be allocated, and the design for a Statewide pilot study. Two examples of monitoring approaches or topics that should be considered for pilot studies are described briefly below.

- Sand crabs. Dugan et al. (2005) conducted a study of bioaccumulation of multiple contaminants in sand crabs (*Emerita analogai*) at 19 locations along the Central Coast. This species is an indicator for exposed sandy beach environments, a habitat that has not previously been routinely monitored. The crabs are an indicator of spatial and temporal trends, and risks to predators. The study demonstrated that crabs are a sensitive indicator for many chemicals, including petroleum hydrocarbons, chlorinated hydrocarbons, and metals.
- Marine mammals. Several studies of marine mammals in San Francisco Bay and along the Central Coast suggest that PCBs and other chemicals are elevated in some individuals and may be high enough to have adverse impacts (Nakata et al. 1998, O'Shea et al. 1998, Bacon et al. 1999, She et al. 2002, Kannan et al. 2004, Neale 2004, Neale et al. 2005). Marine mammals accumulate high concentrations of many pollutants due to their high trophic position and high rates of fish consumption. Monitoring of this species could be valuable for evaluating long-term trends in coastal areas and risks to the seals.

The program should also solicit ideas from participants and other interested parties for additional elements to be considered for the program. A fair and transparent process should be established for soliciting these ideas and selecting studies for funding – the RMP has developed a good model for such a process.

In the full funding scenario, $300,000 (9% of the total budget) is allocated to pilot and special studies. In the $1.5 million scenario, $70,000 (5%) of the total budget is allocated to these studies.

Peer Review

The role and activities of an external peer review panel were described above. Input from members of such a panel would be tremendously valuable and the members should receive an appropriate level of compensation for their contributions. Peer review is needed for the program at any of the funding levels. For the full and mid-level programs, a panel of five members with each receiving $10,000 per year is estimated. At the $0.5 million level, the program would be simpler, so the budget assumes a three member panel.

Archiving

The program should have a systematic and carefully considered archiving strategy. In the short-term, archived samples provide an important insurance policy in the event of mishaps in the processing and analysis of samples. In the long-term, analysis of properly archived samples also provides a very powerful approach for evaluating trends in emerging contaminants or applying improved analytical techniques to

characterize trends in any pollutant of interest (e.g., Turle et al. 1991; Odsjo et al. 1997; Bignert et al. 1999, 2005; Hebert et al. 1999; Braune et al. 2001; Norstrom et al. 2002; Holmstrom et al. 2005; Olafsdottir et al. 2005). Avian eggs would be particularly valuable because of the compositing approach to be employed in the sampling design (with a large number of individuals represented by a small number of samples at each location), the high concentrations in the tissue, the ample masses available, and the regional and food web integration provided by these apex predators.

Sweden's national bioaccumulation monitoring program has included an extensive archiving component, and the archives have been effectively used to determine trends of many emerging contaminants. Bioaccumulation monitoring in Sweden is continuing time series that began in the 1960s, with annual sampling of bird (guillemot) eggs, mussels, and several species of fish (Bignert et al. 2005). The existence of archived bird eggs has allowed the characterization of long-term trends in emerging contaminants such as PBDEs, hexabromocyclododecane (HBCD – a brominated flame retardant used as a PBDE replacement), and PFOS (Sellstrom et al. 2003; Holmstrom et al. 2005).

The archives should be maintained following protocols developed by the international specimen banking community, as recently described at the International Specimen Bank Symposium in Charleston, South Carolina in November 2005. Samples should be kept at -80 deg C if possible to allow for potential analysis of less persistent chemicals and prevent degradation of the sample matrix (Nordic Council of Ministers 1995; deBoer and Smedes 1997; Holmstrom et al. 2005). Multiple aliquots of each composite sample can be archived to allow easy retrieval and repeat analysis of each sample if necessary.

Archiving samples is labor intensive and requires funding for maintaining reliable freezer space. The budget for the proposed program includes $20,000 per year for archiving at the two higher funding levels, and $15,000 per year at the lowest funding level.

The Core Monitoring Program

General Features of the Design

Addressing the multiple objectives of the SWAMP across the variety of habitats of interest calls for a monitoring program with a suite of bioaccumulation indicators. The design proposed in this document is built on the assumption that evaluating support of the fishing beneficial use is a top priority. This emphasis is due to several factors: 1) human health risks are often driven by cancer endpoints that translate to conservative cleanup targets that protect both humans and wildlife; 2) with a adequate sport fish monitoring the opportunity exists to achieve significant near-term reductions in human health risk through development and communication of consumption advice, and 3) a high degree of societal concern about human health risks.

The SWAMP Objectives seek unbiased Statewide assessments of status of both the fishing and aquatic life beneficial uses. Obtaining this type of assessment requires a considerable investment of resources into a randomized statewide sampling effort, and it would be prohibitively expensive to accomplish this for both beneficial uses. Given the perceived higher priority of assessing the fishing beneficial use, the proposed design only includes this type of effort for the fishing beneficial use.

Given these considerations, most of the monitoring budget in the proposed program is allocated toward sport fish monitoring. For each of the three overall levels of funding considered, sport fish monitoring is allocated 83% or more of the budget (Table 6).

Sport Fish

Goals, Objectives, and Assessment Questions

Sport fish sampling would be performed to address the SWAMP objectives and assessment questions relating to support of the fishing beneficial use (Objectives D1, D2, D3, and D4, and associated assessment questions).

The sport fish work would also address the as yet unarticulated goals and objectives relating to the development of consumption advice, risk communication, and environmental justice. The integrated monitoring approach described previously would provide the mechanism for addressing these goals and objectives.

Addressing the multiple objectives and assessment questions developed by SWAMP calls for a monitoring program that combines spatially randomized sampling with targeted sampling. Objective D1 and its associated management questions (Table 1) call for determining "the status of the fishing beneficial use throughout the State without bias to known impairment". A randomized design is the best way to meet this objective. Complete coverage of all fishing locations throughout the State with a targeted sport fish sampling program would be prohibitively expensive. A more realistic and cost-effective approach is to sample a representative subset of these locations and make inferences about unsampled locations. Random sampling provides a sure way to obtain a representative sample, and therefore a robust basis for inferring the characteristics of the population as a whole. Random sampling also is the best way, perhaps the only way, to obtain a truly unbiased sample. A random sampling design is well-suited to answering all of the assessment questions associated with Objective D1 in a cost-effective and unbiased manner.

Objective D2 is to "assess trends in the fishing beneficial use throughout the State". The assessment questions under this objective ask whether support of the fishing beneficial use is generally improving or deteriorating for the State as a whole, and whether specific classes of water bodies are improving or deteriorating. A randomized design provides some information on trends, and can incorporate a limited amount of revisiting of sites (a "rotating panel" design) to obtain more information on trends

(Stevens 2005). However, another powerful way to assess trends is to repeatedly sample selected locations in a consistent manner for a long period of time. An advantage of this latter approach is that it can build on time series that have been created for some locations in the State. A hybrid sampling design that combines the unbiased Statewide coverage of random sampling with the trend detection power of targeted sampling would be appropriate for addressing Objective D2.

Objective D3 is to "evaluate sources and pathways of factors impacting the fishing beneficial use." The spatial distribution of contaminant concentrations in sport fish across the landscape is a valuable indicator of important sources and pathways. Spatially randomized sampling is an effective way of systematically obtaining information on the spatial distribution of contamination. This information can then be compared to the spatial distribution of land use (e.g., urban land use, historic mines) and discharge locations to provide a general assessment of the importance of different sources and pathways. Targeted sampling can also be of value of there is a particular interest in monitoring the influence of a specific source or pathway. The combination of random sampling supplemented by targeted sampling of selected locations will address this objective effectively.

Objective D4 is to "evaluate the effectiveness of management actions in improving the fishing beneficial use." Categories of management action to evaluate include remediation, source control, and pollution prevention, on both a regional and statewide basis. Trend assessment is the tool to be used to evaluate the reductions in pollutant concentrations that result from management actions. The same approach described for Objective D2 therefore applies for this Objective, with a greater emphasis on targeted sampling of locations that are expected to respond to management actions.

An overall approach to addressing these objectives and assessment questions should therefore combine random and targeted sampling. The precise proportion of the total sampling effort allocated to each depends on the relative priorities of these objectives and the amount of funding that is available. The relative priorities will have to be worked out through Roundtable discussions. The influence of different levels of funding on the mix of random and targeted sampling is discussed further below.

If the Roundtable does decide to include goals or objectives relating to advisory development and environmental justice, a hybrid design with a combination of random and targeted sampling would also address these well. As described further below, a random sampling scheme could have a weighting scheme that samples locations in proportion to selected variables, such as the amount of fishing activity or the spatial distribution of groups with relatively high consumption rates. The random scheme should therefore cover most of the important fishing areas and areas with environmental justice concerns. If it turns out that high priority locations are not covered in the random scheme, these locations could be covered through targeted sampling.

A Hybrid Monitoring Design to Meet Multiple Objectives

A hybrid sampling design that combines random and targeted sampling will be the best way to meet the multiple objectives of the program. Water and sediment sampling in the RMP provides a California example of a hybrid design that combines spatially randomized sampling using a GRTS framework with targeted sampling (Lowe et al. 2005). In the early years of the RMP, all samples were collected using targeted, fixed station designs. In response to a peer review of the Program, a shift was made in 2002 to a design that is primarily focused on randomized sampling, with a small amount of the total effort still allocated to fixed station sampling. The shift to randomized sampling was made to provide better coverage of the different habitats within the Bay and to provide unbiased estimates of average concentrations. Some of the historic fixed stations were retained in order to obtain information on long-term trends by extending the time series that had been established and achieving the better temporal trend detection provided by fixed station sampling. This same basic approach is proposed for SWAMP bioaccumulation monitoring, though with more of an equal emphasis on random and targeted sampling.

Habitats to be covered with both random and targeted sport fish monitoring could include bays and estuaries, coastal waters, lakes, large rivers, and possibly wadeable streams. Fishing activity assessments should evaluate the amount of fish consumption that occurs through fishing of wadeable streams. Wetlands could also be included if fishing activity assessment identifies locations with significant sport fishing.

Randomized Sampling

In the Statewide bioaccumulation monitoring program, we would like to answer the assessment question about the proportion of water bodies in the State and each region falling within the different levels of support of the fishing beneficial use, and how these proportions change over time. Actually sampling all of the water bodies in California would be prohibitively expensive. Randomized sampling would provide an excellent, practical, and completely unbiased approach to inferring the condition of all water bodies in the State from a limited sample of the whole population.

The method of choice for developing an array of randomized monitoring locations is the generalized random tessellation-stratified (GRTS) approach developed for U.S. EPA's Environmental Monitoring and Assessment Program (Overton et al. 1991, Stevens and Olsen 2004, Theobald et al. in review). 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. The GRTS approach also offers several other advantages. The framework for GRTS sampling and data analysis has been developed over a long period of time by for the EMAP, and a large body of documentation and technical support is available (e.g., http://www.epa.gov/nheerl/arm/). GRTS designs are being used by many national, state, and regional programs, which add to the infrastructure available for support and also provide opportunities for coordination. Two significant upcoming opportunities for coordination through GRTS sampling

include the National Lakes Survey (http://www.epa.gov/owow/lakes/lakessurvey/) and the National Monitoring Network (Spooner and Mallard 2006). Coordination with these programs may result in reduced costs for SWAMP. Other advantages of the GRTS approach relative to other alternatives for random sampling include a combination of low variance in estimates of means and other statistics, quantitative estimates of variance, simplicity and ease of implementation, and cost-effectiveness (Theobald et al. in review).

Another valuable feature of a GRTS sampling frame is its flexibility. One aspect of this flexibility is that sampling effort can be focused on subpopulations of interest, and the overall design will still retain its integrity as a random sample of the entire population. In the GRTS design, the variable weighting of different subpopulations is achieved by assigning varying probabilities of being sampled to each one. The key characteristic that allows this to remain a random sample is that all locations within a study area have some known, non-zero chance of being selected. One kind of subpopulation of interest is water bodies with a high magnitude of expected risk. Expected risk is a function of consumption rates and degree of contamination. Objectives and assessment questions related to the fishing beneficial use require better information for water bodies with a large amount of expected risk. On the other hand, it does not make sense to allocate a large amount of sampling effort to water bodies with little fishing activity or very clean fish. Focusing SWAMP sport fish sampling on water bodies with higher expected risk will provide a more reliable assessment of the fishing beneficial use and a more rigorous basis for consumption advice. An important step in the development of the random sampling frame will be to compile available information on fishing activity across the State. For many areas, there is probably limited quantitative information on fishing activity. An outcome of the compilation of fishing activity information may be identification of areas where better information is needed. In spite of the present lack of information, it should be possible for each region to rank its water bodies according to their amount of fishing activity. This ranking will direct sampling effort to where it is most needed. Including this weighting would provide a way of incorporating environmental justice into the sampling design, as this weighting would ensure adequate sampling in water bodies that are fished by groups that have high consumption rates for cultural or socioeconomic reasons or for disadvantaged groups fishing in contaminated water bodies. A spatial statistical model would provide an effective way of summarizing contaminant concentration data for use in calculating expected risk.

Another variable that should also be considered for use in weighting the sampling effort is the extent of existing information. In the near-term, areas with high fishing activity that have not been sampled recently may be a higher priority for sampling. A systematic and quantitative way of characterizing the density of existing information across the State would be to develop spatial statistical models for contaminants of greatest concern. These models would provide estimates of average concentrations and the uncertainty of those estimates across the State. The areas with high fishing activity and the greatest uncertainty would be the highest priorities for sampling. Another benefit of these spatial models would be that they provide a way of incorporating the information

gained through future targeted sampling into the Statewide assessments that will be primarily based on random sampling.

Once the variables to be used in defining inclusion probabilities have been selected, the process of developing a sampling design can include examining the effect of different weighting scenarios, and selecting the one that is best suited to answering the program's assessment questions.

Another important aspect of the flexibility of a GRTS design is the ability to respond to unforeseen events, such as discoveries made in monitoring (e.g., finding unexpectedly high concentrations in a water body that call for follow-up sampling), fluctuations in budgets, or changing management priorities. The GRTS pool of sampling points can be established such that any of these scenarios can be addressed. In anticipation of selected water bodies needing follow-up sampling, an excess of points for each water body would be created that could be used if needed. Using these points in follow-up sampling would still contribute to a spatially-balanced, probability-based assessment of contamination at the local, regional, and Statewide level. Similarly, if changes in priorities or budgets call for increased sampling in a particular region, some of the excess of points created in the development of the design could be used and still retain their value in contributing to probability-based regional and statewide assessments. On the other hand, if funding becomes limited one year, the pool of sampling points could be used at a slower pace and still contribute to probability-based regional and statewide assessments.

In summary, a GRTS design offers the distinct advantages of random sampling (thorough, representative, and unbiased characterization of all water bodies) and also has the flexibility to provide, to a large extent, some of the principal advantages of a targeted design (sampling specific areas of interest, responding to discoveries or changing budgets and priorities). A GRTS design that is weighted by fishing activity, information density, and expected risk would likely sample most of the locations that managers would want to have sampled. In a hybrid design, important gaps in sampling left by a GRTS design could be filled by targeted sampling.

The focal area approach described previously that would facilitate stakeholder involvement, advisory development, and risk communication could be implemented within a GRTS framework. To illustrate how this might work, in the full funding scenario (Table 4a), a total of approximately 140 random and targeted sites could be sampled each year. Seventy of these sites could be allocated toward GRTS sampling of a focal area, 35 could be allocated toward GRTS sampling of the rest of the State to provide data needed for statewide assessment, and 35 could be allocated toward targeted sampling to answer questions about trends, sources and pathways, and effectiveness of management actions.

Targeted Sampling

Targeted sampling would be of value in addressing questions under Objectives D2, D3, and D4, regarding assessing trends, sources and pathways of contamination, and the effectiveness of management actions. Targeted sampling could also be of value in addressing goals or objectives relating to advisory development or environmental justice, supplementing the coverage provided by GRTS sampling.

Targeted sampling for trend assessment could include selection of key sites for repeated sampling on a regular basis. This type of sampling is the most powerful way to detect long-term trends, as the influence of spatial and seasonal variation is removed from the long-term trend signal. One of the major shortcomings of the historic database on bioaccumulation in California sport fish is the lack of long-term time series and conclusive information on trends (Davis et al. 2006). In selecting sites for trend assessment, consideration should be given to continuing historic time series at some locations. In other cases new long-term trend monitoring sites may also be desired.

For sport fish, annual sampling may not be the most cost-effective approach for assessment of long-term trends. For mercury (the primary contaminant of concern in sport fish on a Statewide basis) sport fish gradually accumulate this contaminant over the course of their lives, so the concentrations at a given location would not be expected to vary in direct proportion to annual changes in mercury in the food web. For this reason, the Review Panel for the Fish Mercury Project recommended biennial sampling in that three-year project rather than annual sampling. In the RMP, a similar rationale is the basis for conducting sport fish sampling on a triennial basis, with the additional consideration of the relatively slow anticipated rates of decline of organic contaminants of concern. Visiting long-term trend monitoring sites on a biennial or triennial basis should be considered as a way of extending trend monitoring to more locations. If rapid change is expected in a particular location due to a management action then more frequent sampling should be considered.

The locations for targeted sampling could be selected based on priorities of the nine Regional Boards, with some consideration given to consistency among regions and fitting into a Statewide assessment framework.

Annual Sampling Activity Within Each Region with the Proposed Design

This section provides a brief description of what the proposed design would look like at the regional level at the full level of funding. The State would be divided into 10 Focal Areas, each containing a roughly equivalent amount of expected risk. These Focal Areas would not necessarily correspond to the boundaries of the nine Regional Boards. Each Focal Area would be sampled intensively (70 random samples in one year) once every 10 years. In addition to this, in each year 35 samples would be collected across the entire State using the GRTS sites. These would be divided among the Regions in proportion to the amount of expected risk in each Region. So, on average, each region might have approximately four sites sampled each year as part of the Statewide random

sampling. Finally, each Region would also have approximately 4 sites each year to use in targeted sampling for trend analysis, investigation of sources and pathways, or monitoring the effectiveness of management actions.

Combining Random and Targeted Sampling for Regional and Statewide Assessments

Spatial statistical models were discussed previously as a tool for summarizing data from historical targeted sampling designs in order to characterize the density of information and the expected risk across the State. Another important benefit of these spatial models would be that they provide a way of incorporating the information gained through future targeted sampling into the Statewide assessments that will be largely based on random sampling. This is important because a significant proportion of future sampling, becoming greater for lower levels of funding, will be allocated toward targeted sampling. Spatial statistical models would allow the use of the combined random and targeted data in predicting concentrations at unsampled locations, predicting average concentrations and other statistics for units of varying spatial scale across the landscape, and estimating relationships between contaminant concentrations in fish and other covariates such as land use or discharge locations (Ver Hoef et al. Accepted). Spatial statistical models should therefore be developed in the startup phase of the program and then maintained into the future. Each contaminant will need its own model. A cost-effective approach would be to prioritize the list of contaminants and only develop models for those of the highest priority.

Bivalves

Bivalves are an excellent tool for long-term trends and spatial patterns in contaminant concentrations in aquatic food webs. Long-term monitoring of contaminants in bivalves at coastal locations by the State Mussel Watch Program and the RMP has yielded excellent documentation of the significant declines that have occurred in many cases, and has identified some areas where recovery is progressing more slowly (Davis et al. 2006). Bivalve monitoring should continue to be a part of California's bioaccumulation monitoring program, with particular value in supplementing the other bioaccumulation indicators (sport fish, small fish, and bird eggs) by providing a powerful tool for evaluating site-specific, long-term trends in coastal waters. However, it does not appear to be necessary to allocate significant SWAMP funds to bivalve monitoring. Existing programs appear to provide for an appropriate amount of bivalve monitoring relative to the other proposed elements of the Statewide bioaccumulation monitoring program.

Phillips (1988) provided a very thorough discussion of the positive attributes that make bivalves one of the best indicators of spatial and temporal trends in bioaccumulation. Bivalve molluscs have been more frequently employed as spatial and temporal trend indicators of contaminants in aquatic environments than have species of any other family or phylum, and the available literature on their use for such purposes is considerable. Extensive studies of the uptake, sequestration, and excretion of contaminants in bivalves have provided a firm basis for the evaluation of the usefulness

of bivalves as indicators of contamination in aquatic ecosystems. The blue mussel, *Mytilus edulis*, has been sampled extensively by various programs in California and is probably the species most widely used for bioaccumulation monitoring worldwide.

Two programs that have conducted extensive sampling in California, NOAA's Mussel Watch Project (part of the National Status and Trends Program) (http://www8.nos.noaa.gov/cit/nsandt/download/mw_monitoring.aspx) and the California State Mussel Watch Program (Hayes et al. 1985, Hayes and Phillips 1986, Rasmussen 2000) were instrumental in gaining widespread international acceptance of this technique as a monitoring tool in aquatic environments. The State Mussel Watch Program yielded a wealth of useful information on water quality in California. Many instances of severe contamination were identified, leading to cleanup actions to reduce exposure of humans and wildlife. In addition, many relatively uncontaminated areas were identified. The State Mussel Watch Program documented the successful management of many pollutants that posed serious threats to wildlife and human health in the 1970s and 1980s. The SMWP was instituted just in time to document the rapid improvements in water quality that resulted from bans on PCBs and legacy pesticides, reductions in metals due to wastewater treatment, and other improvements (Stephenson et al. 1995, Davis et al. 2006).

Three significant bivalve monitoring efforts are currently in place with funding from sources other than the SWAMP. First, NOAA's Mussel Watch is the longest continuous contaminant monitoring program in U.S. coastal waters, and continues to analyze contaminant trends in bivalve tissue collected at over 280 coastal sites nationwide, including 41 sites in California. Sampling is currently performed on a biennial basis. This program samples resident mussels and oysters and measures concentrations of trace elements, organochlorine pesticides, PCBs, PAHs, and TBT. Second, the RMP is conducting annual sampling of organic contaminants in transplanted mussels (9 sites) and resident clams (2 sites) in San Francisco Bay (SFEI 2005). This monitoring is continuing to build on the time series for the Bay established in the 1980s by the SMWP. Third, mussel monitoring is continuing at 15 coastal sites with funding derived from an endowment resulting from a legal settlement between PGE and the State Water Board. This is annual sampling that will continue into the foreseeable future. Together, these three programs are providing for bivalve monitoring at 67 sites along the California coast.

These continuing long-term programs are providing a degree of coverage for bivalve monitoring that is appropriate relative to the scopes proposed for the other bioaccumulation indicators in this report and commensurate with the SWAMP assessment questions to be answered. This monitoring will address objectives and assessment questions related to evaluating long-term trends, sources and pathways, and effectiveness of management actions for both the aquatic life and fishing beneficial uses. The monitoring will not directly address impacts to these beneficial uses, but will provide information that is highly indicative of temporal and spatial trends in these impacts.

The budget proposed for the full funding level includes a small amount of funding ($18,000 per year) for sampling an additional five sites to cover any high priority sites that are missed by the other programs.

Small Fish

Introduction

Small "biosentinel" fish represent the best tool for monitoring spatial and temporal variation in mercury concentrations in aquatic food webs (Wiener et al. 2003). Biosentinel fish monitoring is therefore one of the primary elements of the CALFED Mercury Strategy, and the key monitoring "performance measure" recommended for gauging methylmercury contamination of the Bay-Delta ecosystem during restoration. Since mercury is the contaminant of greatest concern on a Statewide basis, this tool would make a valuable addition to a Statewide bioaccumulation monitoring program in support of adaptive management of mercury contamination. Small fish monitoring is also of value in assessing impacts of other contaminants on piscivorous wildlife. Small fish monitoring would be a small component (up to 10% in the full funding scenario) (Table 6) of the annual sampling and analysis budget for the proposed program.

Many factors can influence the bioaccumulation of methylmercury in long-lived biota of upper trophic levels such as sport fish, interfering with the detection and interpretation of patterns in mercury concentrations. In contrast, small whole fish have been widely and successfully used as indicators of mercury contamination in aquatic food webs (e.g., Frost et al. 1999, Slotton et al. 2003, Tetra Tech 2005, Wiener et al. in press). Perhaps the best time series generated by the Toxic Substances Monitoring Program was for red shiner, a small fish species, from San Diego Creek at Michelson Drive, where significant declines in many contaminants were documented. A biosentinel species should possess certain key attributes (Wiener et al. 2003). It should be spatially widespread and abundant throughout much of the ecosystem. Ecotoxicological relevance is enhanced if the biosentinel is important in the food-web transfer of methylmercury in the studied ecosystem. The biosentinel should exhibit limited variation in diet and trophic position; in other words, variation in mercury concentrations in the biosentinel should result largely from variation in processes influencing the abundance of methylmercury in the aquatic ecosystem, rather than to differences in diet or trophic position. Small fish generally also have constricted home ranges. Small fish with these attributes provide a responsive, integrative measure of bioaccumulation that can in turn be linked to mercury in large fish and wildlife, as well as to underlying measures of net methylmercury production and presence. Biosentinel fish species can provide information on fine-scale trends in space (i.e., specific restoration or cleanup sites) and in time (i.e., seasonal or interannual variation).

Two current projects are implementing significant small fish mercury monitoring efforts. The FMP (Davis et al. 2005) is a CALFED-funded project that is conducting extensive small fish biosentinel monitoring (in addition to the sport fish sampling described above) in the Bay-Delta watershed in response to the recommendations of the

Mercury Strategy. A set of index sites has been established to track interannual trends and possible regional-scale impacts of restoration projects. Localized monitoring of numerous wetland restoration projects is also being performed in order to assess effects on mercury on a local scale. Over 50 sites have been sampled since the Project began in 2005. The RMP also began a pilot study on small fish mercury monitoring in 2005. The goals of this pilot study are to characterize food-web mercury at finer spatial and temporal scales than RMP sport fish studies and to assess local and regional trends in bioaccumulation of mercury related to the extensive wetland restoration occurring in San Francisco Bay. A suite of species is being sampled to provide complete coverage of eight sites spanning a range of salinities.

Small fish are also valuable indicators for other contaminants. Small fish are important prey items for a variety of wildlife species, making them useful indicators of exposure and risk to these species. One prominent California example of a study using small fish for this purpose was a major survey of the sanddab guild performed by the Southern California Bight Regional Monitoring Project (Allen et al. 2002). Tissue targets and monitoring of PCBs in small fish are being considered for the PCB TMDL for San Francisco Bay. In response, the RMP is considering augmenting the Small Fish Pilot Study to allow it to include analysis of organic contaminants of concern. The small fish element proposed in this document does not include analysis of organics, although this could be added in selected instances if deemed appropriate.

Goals, Objectives, and Assessment Questions

Small fish monitoring would address SWAMP objectives and assessment questions relating to support of both the aquatic life and fishing beneficial uses. Small fish would provide a valuable complement to trend monitoring in sport fish and avian eggs, covering finer temporal and spatial scales than the other two indicators. This trend information would be relevant to both the fishing and aquatic life beneficial uses. Small fish monitoring would also provide a tool for assessing health risks to piscivorous wildlife, and would therefore for many contaminants be a valuable indicator of impairment of the aquatic life beneficial use.

Small fish monitoring would specifically address objectives A1, A2, A3, A4, D2, D3, and D4. Objective A1 is to "determine the status of aquatic life use support throughout the State without bias to known impairment". Small fish monitoring as proposed in this document would partially address this objective. The monitoring proposed would consist of a limited, targeted sampling effort that would provide information on the aquatic life beneficial use (specifically, risks to piscivorous wildlife) for only the high priority water bodies that are sampled. A complete, unbiased survey of this indicator across the entire State would be prohibitively expensive.

Small fish monitoring would also be valuable in assessing objectives A2 ("assess trends in support of the aquatic life beneficial use throughout the State") and the related objective A4 ("evaluate effectiveness of management actions improving the aquatic life beneficial use"), and the parallel objectives D2 and D4 pertaining to the fishing beneficial

use. Small fish monitoring does not directly address the fishing beneficial use, but small fish bioaccumulation is closely correlated with sport fish bioaccumulation, so the information it can provide on temporal trends is an accurate indicator of temporal trends in sport fish. Trend monitoring is the principal tool for evaluating the effectiveness of management actions. Small fish monitoring is an excellent indicator of interannual and long-term trends in mercury contamination, and would provide valuable information for the water bodies where the sampling is conducted. The sampling would not cover the entire State as called for in Objectives A2 and D2. Small fish monitoring would be a sensitive tool for evaluating the effectiveness of management actions at both a local and a regional scale (assessment questions A.4.1 and D.4.1).

In addition, small fish monitoring would be valuable in assessing objective A3 ("evaluate sources and pathways of factors impacting the aquatic life beneficial use") and the parallel objective D3 pertaining to the fishing beneficial use. As accurate indicators of spatial variation from the local scale up to the regional and Statewide scales, small fish would be a useful tool for identifying sources and pathways of mercury to aquatic food webs.

Sampling Design

The proposed budgets would allow for small fish monitoring at a limited number of sites (50 sites for the full budget and 25 sites for the $1.5 million budget). Targeted sites that are a high priority for assessment of risks to piscivorous wildlife and fine-scale temporal and spatial trends in mercury would be selected. Habitats to be covered with small fish monitoring could include all of the categories established by the SWAMP (wetlands, bays and estuaries, coastal waters, lakes, large rivers, and wadeable streams). Small fish would be particularly valuable for wetlands where the other indicators (sport fish, avian eggs, and bivalves) will not be sampled. Wetlands that serve as important wildlife habitat should be considered a high priority for small fish monitoring. Other factors to be considered in site selection include proximity to sources of methylmercury and the need for information on local trends in a given water body. Habitat restoration projects or sites of mercury remediation would be prime candidates for small fish monitoring. Maintaining time series established by the FMP to evaluate local and regional impacts of restoration and remediation in the Bay-Delta watershed should be considered.

Small fish monitoring is a powerful tool for evaluating interannual variation and shorter-term trends. This sampling would therefore be most useful in situations where changes in mercury cycling over the course of a few years are anticipated, such as restoration and remediation sites. Small fish monitoring would provide the quickest possible answer to questions of the impacts of management actions. The proposed budgets include sampling of small fish on an annual basis.

The proposed budgets assume that mercury would be the only analyte. Small fish are also a useful indicator of wildlife exposure to other contaminants. In some situations it may therefore be valuable to also analyze additional chemicals.

Risks to wildlife could be evaluated by comparison of measured concentrations to TMDL targets and published thresholds for effects on piscivorous species such as marine mammals, birds, and predatory fish species.

Bird Eggs

Introduction

Avian egg monitoring has proven to be a highly effective tool for assessment of risks to birds and long-term trends in persistent, bioaccumulative contaminants in aquatic ecosystems. The combination of avian egg monitoring with a long-term archiving program has proven to be particularly effective, allowing for retrospective studies of emerging contaminants as well as reanalysis of conventional contaminants with improved analytical methods. The specific type of monitoring proposed is of the eggs of piscivorous, colonial waterbirds, where large numbers of eggs can be easily collected and the species have a strong connection to the aquatic ecosystems of interest. Egg monitoring is proposed as a small component (up to 6% in the full budget scenario) of the annual sampling and analysis budget.

Two avian egg monitoring programs provide especially good demonstrations of the value of this tool: the Canadian Wildlife Service's Great Lakes Herring Gull Monitoring Program and the National Swedish Contaminant Monitoring Program. The Herring Gull Program has provided annual measurements of contaminants since 1974 (Hebert et al. 1999). This monitoring has yielded valuable information on long-term temporal trends and spatial patterns in many contaminants. Many chemicals previously undetected in Great Lakes upper trophic level biota were identified through this Program, including mirex, photomirex, polynuclear aromatic hydrocarbons, chlorobenzenes, and dioxins. Analysis of PBDEs in archived herring gull eggs has provided one of the best available time series documenting the exponential increase of these chemicals in aquatic ecosystems worldwide (Norstrom et al. 2002; Hites 2004). The Herring Gull Program has yielded information on contaminant sources and fate in the Great Lakes, provided a means to assess progress in controlling contaminant inputs, allowed detailed examination of the factors (e.g., changes in food web structure) that regulate contaminant levels in this species, and identified other stressors (e.g., dietary deficiencies) that may affect the success of Great Lakes herring gull populations.

The Swedes have long been at the forefront of bioaccumulation monitoring, from the first discovery of PCBs in environmental samples in 1966 by Jensen (1972) to the first reports of PBDEs in wild fish (Andersson et al. 1981) and bird eggs and seal blubber (Jansson et al. 1987). Bioaccumulation monitoring in Sweden continues to the present with annual sampling of guillemot eggs, mussels, and several species of fish (Bignert et al. 2005). Supported by an extensive specimen banking program, this work is continuing time series that began in the 1960s. The existence of archived bird eggs has allowed the characterization of long-term trends in emerging contaminants such as PBDEs, hexabromocyclododecane (HBCD – a brominated flame retardant used as a PBDE

replacement), and PFOS (Sellstrom et al. 2003; Holmstrom et al. 2005). Long-term trends have also been established for conventional pollutants such as PCBs and mercury.

The RMP has recently completed a pilot study on cormorant egg monitoring in San Francisco Bay (Davis et al. 2006). The pilot study, even with small sample sizes, detected significant spatial variation among regions for several contaminants (PCBs, Hg, and dioxins). Cormorant egg monitoring offers a high yield of information on long-term trends and regional patterns in conventional and emerging pollutants for the lowest possible cost. Piscivorous bird eggs are the best tool for tracking long-term trends in bioaccumulative emerging pollutants and expensive analytes such as dioxins. Composite samples of cormorant eggs would provide an excellent matrix for archiving and retrospective studies of long-term trends. With feedback from external reviewers, the RMP is currently evaluating whether to include cormorant egg monitoring in the Program on a long-term basis with a triennial sampling frequency.

Goals, Objectives, and Assessment Questions

Avian egg monitoring would address SWAMP objectives and assessment questions relating to support of the aquatic life and fishing beneficial uses. Due to their functioning as integrators of the food web and over time and space, avian eggs would provide a valuable complement to trend monitoring in bivalves and sport fish for conventional pollutants, and would make a unique contribution as a trend indicator for expensive analytes such as dioxins and emerging contaminants. This trend information would be relevant to both the fishing and aquatic life beneficial uses. Avian egg monitoring would also provide a tool for directly assessing health risks to the birds themselves, and would therefore for many contaminants be a sensitive indicator of impairment of the aquatic life beneficial use.

Specifically, avian egg monitoring would address objectives A1, A2, A4, D2, and D4. Objective A1 is to "determine the status of aquatic life use support throughout the State without bias to known impairment". Egg monitoring as proposed in this document would partially address this objective. The monitoring proposed would consist of a very limited, targeted sampling effort that would provide information on the aquatic life beneficial use for only the high priority water bodies that are sampled. A complete, unbiased survey of this indicator across the entire State would be prohibitively expensive.

Avian egg monitoring would also be valuable in assessing objectives A2 ("assess trends in support of the aquatic life beneficial use throughout the State") and the related objective A4 ("evaluate effectiveness of management actions improving the aquatic life beneficial use"). Trend monitoring is the principal tool for evaluating the effectiveness of management actions. Egg monitoring is an excellent indicator of long-term trends, and would provide valuable information for the water bodies where the sampling is conducted. The sampling would not cover the entire State as requested in Objective A2. Egg monitoring would be a sensitive tool for evaluating the effectiveness of management actions at a regional scale (assessment question A.4.1).

The trend information yielded by egg monitoring would augment trend information obtained from sport fish and bivalve monitoring to contribute to addressing objectives D2 ("assess trends in the fishing beneficial use throughout the State") and D4 ("evaluate the effectiveness of management actions in improving the fishing beneficial use").

Sampling Design

The proposed budgets would allow for egg monitoring at a small number of sites (15 sites for the full budget and 10 sites for the $1.5 million budget). Targeted sites that are a high priority for assessment of regional trends in emerging contaminants would be selected. Habitats to be covered with bird egg monitoring could include bays and estuaries, coastal waters, and lakes. Other factors to be considered in site selection include the presence and accessibility of colonies, proximity to sources of emerging contaminants, the need for information on regional trends in a given water body, the importance of a water body as wildlife habitat, and the magnitude of concern for impacts on aquatic life in a given water body. Coastal bays and estuaries, such as Humboldt Bay and the Southern California Bight, would be prime candidates for this type of monitoring. San Francisco Bay is another water body that would benefit from this type of monitoring, but this may be covered by the RMP. Inland water bodies with colonial water bird populations such as Clear Lake could also benefit from this type of monitoring.

In considering this tool, the RMP has performed analyses of power to detect long-term trends with different sampling frequencies. These analyses indicate that sampling every third year with three replicate composite samples yields only slightly less power than a design with annual sampling with two replicates. The triennial design is less than half as expensive as the annual design, making it a preferable option. This same triennial design should be appropriate for other water bodies in the State.

In addition to being a valuable tool for the conventional list of pollutants of concern, this monitoring element is recommended specifically as a tool for early detection and assessment of trends in emerging contaminants. The analyte list would therefore include chemicals that would not be included in routine analysis of the sport fish samples, such as: dioxins, PFOS, and potentially other emerging contaminants. These analyses are relatively expensive. For some analytes it will likely be necessary to employ methods that have not been routinely used in past monitoring. The budget scenarios include this longer analyte list.

Assessment of health risks to the birds themselves could be performed through comparison to published thresholds for effects on avian embryos, where these are available.

Program Design at Different Levels of Funding

Deciding on the elements to include in the annual bioaccumulation monitoring program at different levels of funding will be a challenging prioritization exercise for the committees guiding the program. To initiate the discussion, preliminary recommendations for designs are presented and explained below.

Key variables affecting the overall budget for each design include the number of sites to be sampled, the number of samples to be collected at each site, and the analyte list for each indicator. All of these variables are summarized in Table 4. These aspects of the design will also require thorough discussion and prioritization.

The Full Program

At the full level of funding ($3.3 million per year), the program could adequately address all of the objectives and assessment questions discussed in this report, including both those that have already been articulated (Objectives 1 – 4 for the fishing beneficial use and Objectives 2 – 4 for the aquatic life beneficial use) and those that have not yet been articulated relating to advisory development, risk communication, and environmental justice. At this level the program would include:

1. A sport fish monitoring program that is integrated with advisory development and risk communication and addresses environmental justice issues through funded participation of representatives of affected communities.
2. A stepwise program for developing consumption advice that would result in complete coverage of the State in a 10 year period.
3. Risk communication efforts integrated into the program that could reduce human health risks significantly in a 10 year period without necessarily reducing fishing or fish consumption (through directing anglers to less contaminated fish species and locations).
4. Monitoring of sport fish at 70 sites per year, integrated into a Statewide randomized design, in one of ten Focal Areas established to facilitate stakeholder involvement, advisory development, and risk communication.
5. Monitoring of sport fish at 35 sites per year with a Statewide randomized design that would determine the status of the fishing beneficial use throughout the State without bias to known impairment. After 5 years the precision of estimates of the areas or miles of each category of water body (large rivers, lakes, coastal waters, and bays and estuaries) falling into each designated level of support of the fishing beneficial use would be better than ± 14%.
6. Monitoring of sport fish at 35 targeted sites per year to be used in assessment of long-term trends and effectiveness of management actions.
7. Monitoring of bivalves at 5 targeted sites per year to supplement bivalve monitoring performed by other programs.
8. Monitoring of small fish at 50 targeted sites per year to be used in assessment of long-term trends in food web mercury, sources and pathways of mercury, and effectiveness of actions to manage mercury contamination.

9. Monitoring of bird eggs at 15 targeted sites once every three years to provide information on regional long-term trends in bioaccumulative contaminants, including emerging contaminants and expensive analytes such as dioxins.
10. A $300,000 allotment for pilot and special studies.

Without a randomized Statewide sampling effort, Objective 1 for the aquatic life beneficial use would not be fully addressed.

A $1.5 Million Program

At a $1.5 million level of funding the program could address a subset of the objectives and assessment questions discussed in this report, including Objectives 1 – 4 for the fishing beneficial use and Objectives 2 – 4 for the aquatic life beneficial use). At this level the program would include:

1. Monitoring of sport fish at 40 sites per year, integrated into a Statewide randomized design, in one of ten Focal Areas established to facilitate stakeholder involvement, advisory development, and risk communication (however, the stakeholder involvement, advisory development, and risk communication tasks would not be funded).
2. Monitoring of sport fish at 35 sites per year with a Statewide randomized design that would determine the status of the fishing beneficial use throughout the State without bias to known impairment. After 5 years the precision of estimates of the areas or miles of each category of water body (large rivers, lakes, coastal waters, and bays and estuaries) falling into each designated level of support of the fishing beneficial use would be better than ± 14%.
3. Monitoring of sport fish at 35 targeted sites per year to be used in assessment of long-term trends and effectiveness of management actions.
4. Monitoring of small fish at 25 targeted sites per year to be used in assessment of long-term trends in food web mercury, sources and pathways of mercury, and effectiveness of actions to manage mercury contamination.
5. Monitoring of bird eggs at 10 targeted sites once every three years to provide information on regional long-term trends in bioaccumulative contaminants, including emerging contaminants and expensive analytes such as dioxins.
6. A $70,000 allotment for pilot and special studies.

At this level of funding it would not be possible to include the advisory development program, risk communication, an environmental justice component, or bivalve monitoring. The number of sites sampled for sport fish, small fish, and bird eggs would be reduced, diminishing the value of the program in answering all of the program Objectives. The allotment for pilot and special studies would also be reduced.

A $0.5 Million Program

At a $0.5 million level of funding the program could address a very small subset of the objectives and assessment questions discussed in this report – Objectives 2 and 4 for the fishing beneficial use. At this level the program would include:

1. Monitoring of sport fish at 40 targeted sites per year to be used in assessment of long-term trends and effectiveness of management actions.

At this level of funding it would not be possible to include the advisory development program, risk communication, an environmental justice component, bivalve monitoring, small fish monitoring, or bird egg monitoring. No funds would be available for pilot and special studies. Funding for peer review and archiving would be reduced.

Timeline for Developing and Implementing the Program

Table 3 outlines a timeline for developing and implementing the program. Steps required for the full program are shown. Steps related to stakeholder involvement, advisory development, and risk communication could be omitted at the two lower levels of funding.

It is anticipated that approximately one year would be needed for planning and developing the sampling design for the long-term program. Tasks to be completed during this startup phase would include scoping, committee formation, developing probabilistic and targeted sampling designs, gathering information and coordinating in preparation for sampling Focal Area #1, and writing plans for sampling and analysis and a QAPP. After this startup phase, routine annual monitoring would begin in year 2, with an annual cycle of planning, implementation, and reporting for the different elements of the program.

Funding of the Program

The full funding scenario includes a budget and activities that would be needed for a program that fully addresses the objectives and assessment questions set forth by SWAMP and the goal of achieving a near-term reduction of human exposure to bioaccumulative pollutants. The budget and some of the activities proposed may be beyond the scope of the SWAMP, and this is a topic that should be carefully considered by the Roundtable. It may be possible for other agencies with interests in or mandates for water quality management and protection of human health to contribute resources to the program. It also appears that it will be possible to accomplish some of the monitoring through coordination with other national and regional monitoring programs.

If a strategy for funding the full program can be found, the State could create an excellent foundation for evaluating long-term progress in restoring the fishing and aquatic life beneficial uses, and in a 10 year period could achieve a significant reduction of risks and impacts to the health of Californians from consumption of contaminated fish.

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Table 1. Draft objectives and assessment questions for the SWAMP that pertain to bioaccumulation monitoring.

FISHING BENEFICIAL USE SUPPORT

D.1. Determine the status of the fishing beneficial use throughout the State without bias to known impairment

D.1.1 What is the extent and location of water bodies not supporting any fishing beneficial use?

D.1.2 What is the extent and location of water bodies partially supporting the fishing beneficial use?

D.1.3 What is the extent and location of water bodies fully supporting the fishing beneficial use?

D.1.4 What is the proportion of water bodies in the State and each region falling within the three levels of support of the fishing beneficial use?

D.2. Assess trends in the fishing beneficial use throughout the State

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

D.2.2 Have water bodies fully supporting the fishing beneficial use become impaired?

D.2.3 Has full support of the fishing beneficial use been restored to previously impaired water bodies?

D3. Evaluate sources and pathways of factors impacting the fishing beneficial use

D3.1 What is the relative importance of different pollutant sources and pathways in terms of impact on the fishing beneficial use on a regional and statewide basis?

D4. Evaluate the effectiveness of management actions in improving the fishing beneficial use

D4.1 How is the fishing beneficial use affected by remediation, source control, or pollution prevention actions and policies regionally and statewide?

AQUATIC LIFE BENEFICIAL USE SUPPORT

A.1. Determine the status of aquatic life use support throughout the State without bias to known impairment

A.1.1 What is the extent and location of water bodies with limited support of the aquatic life beneficial use?

A.1.3 What is the extent and location of water bodies fully supporting the aquatic life beneficial use?

A.1.4. What is the proportion of water bodies in the State and each region in each level of support of the aquatic life beneficial use?

A.2. Assess trends in support of the aquatic life beneficial use throughout the State

A.2.1 Are water bodies improving or deteriorating with respect to the fishing beneficial use?

A.2.2 Have water bodies fully supporting the aquatic life beneficial use become impaired?

A.2.3 Has full support of the aquatic life beneficial use been restored to previously impaired water bodies?

A.3. Evaluate sources and pathways of factors impacting the aquatic life beneficial use

A.3.3 What is the relative importance of different pollutant sources and pathways in terms of impact on the aquatic life beneficial use?

A.4. Evaluate effectiveness of management actions improving the aquatic life beneficial use

A.4.1 How is the aquatic life beneficial use affected by remediation, source control, or pollution prevention actions and policies regionally and statewide?

Table 2. Goals and objectives of the Fish Mercury Project (Davis et al. 2005).

Project Goals

1) Protect human health in the short term by characterizing mercury concentrations in fish, developing safe consumption guidelines, and reducing exposure through risk communication based on environmental justice principles

2) Through food web monitoring, determine how habitat restoration and mercury clean-up actions affect methylmercury accumulation in the food web

3) Establish an organizational and technical foundation for cost-effective and scientifically defensible fish mercury monitoring that meets the identified needs of end users

4) Coordinate with the major ongoing science, management, and risk communication efforts to achieve efficiencies of scale and scope

Project Objectives

1) Characterize spatial and temporal trends in mercury in fishery resources

2) Demonstrate the use of biosentinel species to link ecosystem restoration, contaminant clean-up, and other landscape changes with spatial and temporal patterns in food web mercury

3) Assess health risks of consuming contaminated fish and communicate these risks to appropriate target audiences based on environmental justice principles

4) Establish a Steering Committee and stakeholder advisory groups to facilitate:

a) stakeholder input into the monitoring and risk communication activities based on environmental justice principles, and
b) coordination with other major science, management, and outreach/communication efforts

Table 3. Proposed timeline for initiating and implementing the bioaccumulation monitoring program at the full funding level.

	YEAR 1				**YEAR 2**				**YEAR 3**			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Establish Organizational Structure												
Convene Preliminary Stakeholder Committee (RT + ?) - initial decisions on scope and funding strategy	X											
Convene Peer Review Panel	X											
Review and revise recommendations report	X											
Obtain initial agreement on goals and objectives	X											
Develop workplan for the monitoring program	X											
Select contractors to design and implement the program	X											
Convene and sustain Stakeholder Committee		X	X	X	X	X	X	X	X	X	X	X
Obtain agreement on objectives and assessment questions		X										
Identify long-term bioaccumulation monitoring plans of other programs in California and develop plans for coordination		X										
Identify Focal Area #1 for first year sampling			X									
Solicit CBO participation in Focal Area #1			X									
Interim Monitoring Measures												
Identify and sample targeted sites for long-term time series - sport fish	X											
Fill fishing activity information gaps for Focal Area #1				X								
Develop Probabilistic Sampling Frame												
Compile fishing activity information		X	X									
Develop spatial statistical models to summarize historic data and define data gaps and estimate expected risk across the State		X	X									
Obtain GIS layers needed for sampling frame: base maps, land use, fishing activity, historic data, discharge locations		X	X									
Draw Probabilistic Sampling Points				X								
Develop Targeted Sampling Designs (Sites, Frequencies)												
Sport Fish				X								
Bivalves			X									
Small Fish			X									
Avian Eggs			X									
Document Plans for Year 1 Sampling and Analysis												
Draft QAPP				X								
Final QAPP				X								
Draft Sampling and Analysis Workplan				X								
Final Sampling and Analysis Workplan				X								
BEGIN SAMPLING YEAR 1 AND FOCAL AREA #1					X							
Develop and Communicate Consumption Advice												
Develop consumption advice for Focal Area #1									X	X		
Conduct risk communication activies in Focal Area #1											X	X
Identify Focal Area #2 for second year sampling					X							
Solicit CBO participation in Focal Area #2					X							
Fill fishing activity information gaps for Focal Area #2						X	X					

Table 4a. Preliminary estimate of budgets for the bioaccumulation monitoring program at different levels of funding, part 1. Breakdowns of the sampling and analysis costs for each indicator are shown in italics. For sport fish, the per sample costs for "PBDEs" and "PCBs and OCPs" have been reduced to reflect an assumption that PBDEs will only be analyzed in 50% of samples and OCPs in 25% of samples.

		$0.5 M per year	$1.5 M per year	Full Program
PROGRAM TOTALS	TOTAL COST	$ 488,450	$ 1,507,863	$ 3,277,393
	PEER REVIEW	$ 30,000	$ 50,000	$ 50,000
	ARCHIVING	$ 15,000	$ 20,000	$ 20,000
	CORE MONITORING: SAMPLING AND ANALYSIS	$ 345,760	$ 1,066,290	$ 1,374,910
	PILOT AND SPECIAL STUDIES	$ -	$ 70,000	$ 300,000
	PROJECT MANAGEMENT	$ 97,690	$ 301,573	$ 732,483
	RISK COMMUNICATION	$ -	$ -	$ 300,000
	CBOS AND COUNTY HEALTH AGENCIES	$ -	$ -	$ 300,000
	ADVISORY DEVELOPMENT	$ -	$ -	$ 200,000
MISCELLANEOUS ITEMS	MISCELLANEOUS TOTAL	$ 56,250	$ 175,000	$ 462,500
	PEER REVIEW	$ 30,000	$ 50,000	$ 50,000
	ARCHIVING	$ 15,000	$ 20,000	$ 20,000
	PILOT AND SPECIAL STUDIES	$ -	$ 70,000	$ 300,000
	PROJECT MANAGEMENT: MISC TASKS	$ 11,250	$ 35,000	$ 92,500
SPORT FISH	SPORT FISH TOTAL	$ 432,200	$ 1,188,550	$ 2,522,208
	Sampling and analysis of fish	$ 345,760	$ 950,840	$ 1,140,160
	Advisory Development (OEHHA)			$ 200,000
	CBO Planning and Risk Communication			$ 300,000
	Risk Communication			$ 300,000
	PROJECT MANAGEMENT: SPORT FISH TASKS	$ 86,440	$ 237,710	$ 582,048
	Total Analytical Cost per Sample	*$ 1,236*	*$ 1,236*	*$ 1,236*
	Mercury	*144*	*144*	*144*
	PCBs and OCPs	*625*	*625*	*625*
	PBDE	*237*	*237*	*237*
	Se	*120*	*120*	*120*
	Dissection and Homogenization	*110*	*110*	*110*
	TOTAL SAMPLING COST	*$ 148,000*	*$ 407,000*	*$ 448,000*
	Sampling Cost per site	*$ 3,700*	*$ 3,700*	*$ 3,200*
	# of Samples per Site	*4*	*4*	*4*
	# of Sites	*40*	*110*	*140*
	Total # Samples	*160*	*440*	*560*
	TOTAL ANALYSIS COST	*$ 197,760*	*$ 543,840*	*$ 692,160*
BIVALVES	BIVALVES TOTAL	$ -	$ -	$ 18,072
	Sampling and analysis	$ -	$ -	$ 15,060
	PROJECT MANAGEMENT: BIVALVE TASKS	$ -	$ -	$ 3,012
	Total Analytical Cost per Sample	*$ 1,512*	*$ 1,512*	*$ 1,512*
	PCBs and OCPs	*988*	*988*	*988*
	PBDE	*474*	*474*	*474*
	Dissection and Homogenization	*50*	*50*	*50*
	TOTAL SAMPLING COST	*$ -*	*$ -*	*$ 7,500*
	Sampling Cost per site	*$ 1,500*	*$ 1,500*	*$ 1,500*
	# of Samples per Site	*-*	*-*	*1*
	# of Sites	*-*	*-*	*5*
	Total # Samples	*-*	*-*	*5*
	TOTAL ANALYSIS COST	*$ -*	*$ -*	*$ 7,560*

Table 4b. Preliminary estimate of budgets for the bioaccumulation monitoring program at different levels of funding, part 2. Breakdowns of the sampling and analysis costs for each indicator are shown in italics.

SMALL FISH	SMALL FISH TOTAL	$ -	$ 86,750	$ 173,500
	Sampling and analysis of fish	$ -	$ 69,400	$ 138,800
	PROJECT MANAGEMENT: SMALL FISH TASKS	$ -	$ 17,350	$ 34,700
	Total Analytical Cost per Sample	*$ 194*	*$ 194*	*$ 194*
	Mercury	*144*	*144*	*144*
	Dissection and Homogenization	*50*	*50*	*50*
	TOTAL SAMPLING COST	*$ -*	*$ 50,000*	*$ 100,000*
	Sampling Cost per site	*$ 2,000*	*$ 2,000*	*$ 2,000*
	# of Samples per Site	*-*	*4*	*4*
	# of Sites	*-*	*25*	*50*
	Total # Samples	*-*	*100*	*200*
	TOTAL ANALYSIS COST	*$ -*	*$ 19,400*	*$ 38,800*

BIRD EGGS	BIRD EGGS TOTAL PER YEAR	$ -	$ 57,563	$ 101,113
	Sampling and analysis per year	$ -	$ 46,050	$ 80,890
	PROJECT MANAGEMENT: BIRD EGG TASKS	$ -	$ 11,513	$ 20,223
	YEARS BETWEEN SAMPLING	*3*	*3*	*3*
	Total Analytical Cost per Sample	*$ 4,726*	*$ 4,726*	*$ 4,726*
	Mercury	*144*	*144*	*144*
	PCBs and OCPs	*988*	*988*	*988*
	PBDE	*474*	*474*	*474*
	Se	*120*	*120*	*120*
	Dioxins	*1500*	*1500*	*1500*
	PFOS	*500*	*500*	*500*
	Other Emerging Contaminants	*500*	*500*	*500*
	Egg Processing and Homogenization	*500*	*500*	*500*
	TOTAL SAMPLING COST	*$ -*	*$ 20,000*	*$ 30,000*
	Sampling and Analysis Cost per site	*$ 2,000*	*$ 2,000*	*$ 2,000*
	# of Samples per Site	*3*	*3*	*3*
	# of Sites	*-*	*10*	*15*
	Total # Samples	*-*	*25*	*45*
	TOTAL ANALYSIS COST	*$ -*	*$ 118,150*	*$ 212,670*

Table 5. Percentages of the budget allocated to major subtasks under each of the funding scenarios.

	$0.5 M per year	$1.5 M per year	Full Program
PEER REVIEW	6%	3%	2%
ARCHIVING	3%	1%	1%
CORE MONITORING: SAMPLING AND ANALYSIS	71%	71%	42%
PILOT AND SPECIAL STUDIES	0%	5%	9%
PROJECT MANAGEMENT	20%	20%	22%
RISK COMMUNICATION	0%	0%	9%
CBOS AND COUNTY HEALTH AGENCIES	0%	0%	9%
ADVISORY DEVELOPMENT	0%	0%	6%

Table 6. Allocations of the overall budget for sampling and analysis among the different bioaccumulation indicators.

	$0.5 M per year	$1.5 M per year	Full Program
CORE MONITORING: SAMPLING AND ANALYSIS	$ 345,760	$ 1,066,290	$ 1,374,910
SPORT FISH	$ 345,760	$ 950,840	$ 1,140,160
BIVALVES	$ -	$ -	$ 15,060
SMALL FISH	$ -	$ 69,400	$ 138,800
BIRD EGGS	$ -	$ 46,050	$ 80,890

	$0.5 M per year	$1.5 M per year	Full Program
SPORT FISH	100%	89%	83%
BIVALVES	0%	0%	1%
SMALL FISH	0%	7%	10%
BIRD EGGS	0%	4%	6%

Figure 1. Consumption advisories in California, January 2006.

Figure 2. Current status of net pollutant impact on the fishing beneficial use in California. Based on concentrations of several chemicals (mercury, PCBs, DDTs, dieldrin, and chlordanes) from analysis of edible tissue in a variety of species from 1998 – 2003. Size limits were applied for evaluation of mercury data. Dots represent sampling locations. Dot colors indicate degree of net impact.

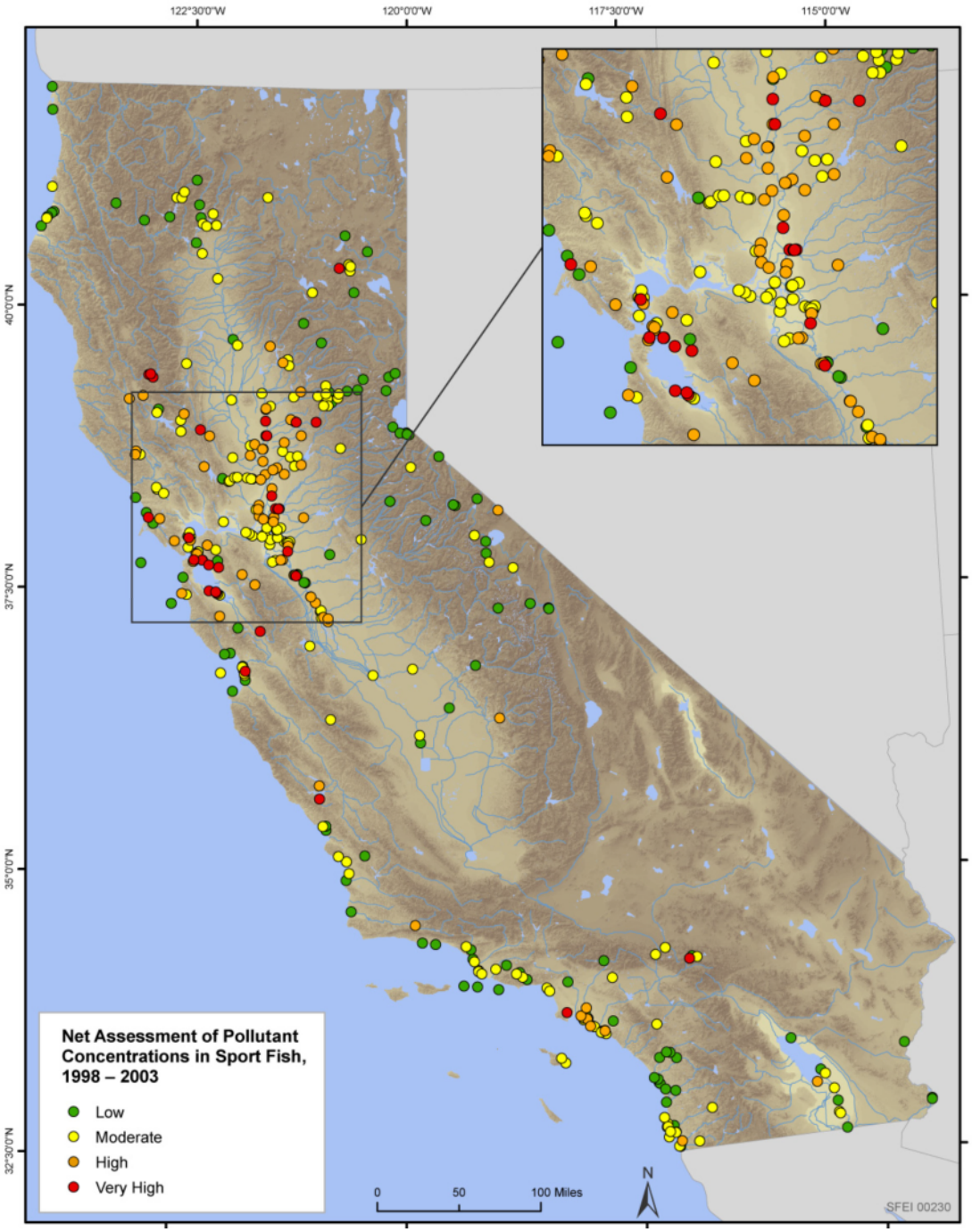

Figure 3. “Integrated” sport fish monitoring.

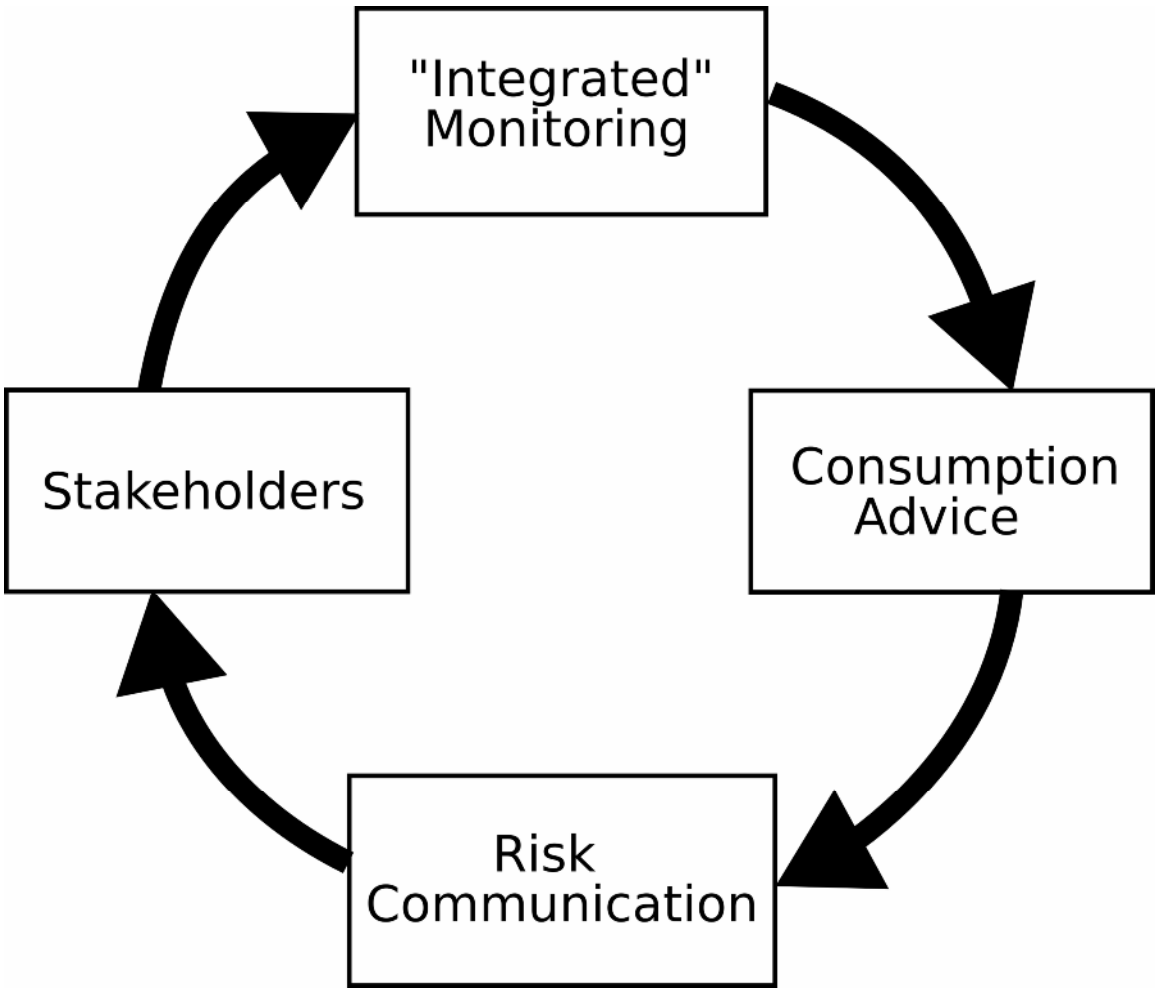

Figure 4. Organizational structure of the proposed program.

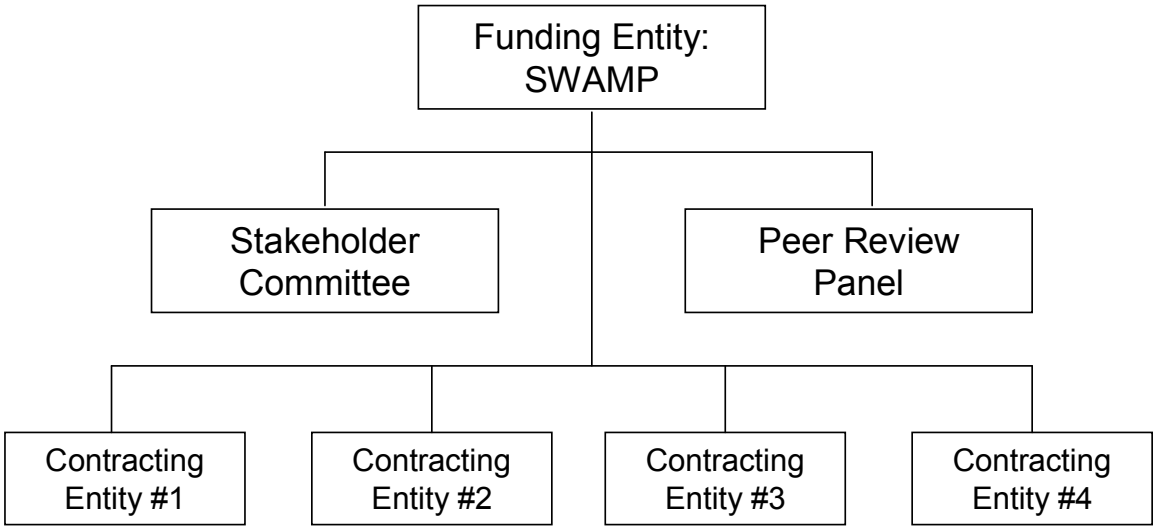

Figure 5. The FMP, SRWP, and Central Valley Regional Board together sampled these 70 sites in the Central Valley in 2005