SWAMP
Surface Water Ambient Monitoring Program

CONTAMINANTS IN FISH FROM THE CALIFORNIA COAST, 2009-2010: SUMMARY REPORT ON A TWO-YEAR SCREENING SURVEY

J.A. Davis
J.R.M. Ross
S.N. Bezalel
J.A. Hunt
A.R. Melwani
R.M. Allen
G. Ichikawa
A. Bonnema
W.A. Heim
D. Crane
S. Swenson
C. Lamerdin
M. Stephenson
K. Schiff

Prepared for the Surface Water Ambient Monitoring Program

May 24, 2012

CALIFORNIA Water Boards

www.waterboards.ca.gov/swamp

DEDICATION

This report is dedicated to the memory of Dr. Ross Norstrom, who passed away in November 2011. SWAMP was very fortunate to have Ross serve on the Bioaccumulation Peer Review Panel for five years, from the beginning of Bioaccumulation Oversight Group activities in 2006 through 2011. Ross had an exceptionally productive career as a pioneer and leader in the field of bioaccumulation monitoring and research. Ross received his Ph.D. at the University of Alberta, Canada, followed by postdoctoral research at the University of Bonn in Germany, Cambridge University in England, and the National Research Council in Canada. In 1969 he joined the Canadian National Research Council studying mercury and PCB contamination. He then took a research scientist position with Environment Canada, Canadian Wildlife Service in 1973 where he remained until his retirement in 2003. He also served as an Adjunct Research Professor of Chemistry at Carleton University in Ottawa. Most of his research was on persistent organic pollutants in wildlife. He had over 200 publications and was an ISI Most Highly Cited Researcher in the fields of ecology and environment. His research contributions were recognized by an honorary Ph.D. in Natural Sciences from the University of Stockholm, the Government of Canada Head of the Public Service Award, and the Canadian Wildlife Service Director General's Award for Excellence in Wildlife Science. His scientific contributions supported development of the United Nations Global Convention on Persistent Organic Pollutants. Ross shared the wisdom gained from this extensive experience in helping set SWAMP bioaccumulation monitoring on a path toward establishing a solid foundation for improving the health of California's coast, estuaries, lakes, rivers, and streams.

THIS REPORT SHOULD BE CITED AS:

Davis, J.A., J.R.M. Ross, S.N. Bezalel, J.A. Hunt, A.R. Melwani, R.M. Allen, G. Ichikawa, A. Bonnema, W.A. Heim, D. Crane, S. Swenson, C. Lamerdin, M. Stephenson, and K. Schiff. 2010. Contaminants in Fish from the California Coast, 2009-2010: Summary Report on a Two-Year Screening Survey. A Report of the Surface Water Ambient Monitoring Program (SWAMP). California State Water Resources Control Board, Sacramento, CA.

ACKNOWLEDGEMENTS

This report and the SWAMP bioaccumulation monitoring element are the result of a very large team effort. The contributions of all of the following colleagues are very gratefully acknowledged.

The Bioaccumulation Oversight Group (BOG)

Terry Fleming, USEPA
Rich Fadness, Region 1 Water Board
Karen Taberski, Region 2 Water Board
Karen Worcester, Region 3 Water Board
Michael Lyons, Region 4 Water Board
Chris Foe, Region 5 Water Board
Tom Suk, Region 6 Water Board
Lilian Busse, Region 9 Water Board
Lori Webber, State Water Board
Jennifer Salisbury, State Water Board
Jon Marshack, State Water Board
Bob Brodberg, OEHHA
Tom Maurer, USFWS
Jay Davis, SFEI
Aroon Melwani, SFEI
Mark Stephenson, CDFG
Autumn Bonnema, MLML
Cassandra Lamerdin, MLML
Dave Crane, CDFG
Gail Cho, CDFG
Gary Ichikawa, CDFG
Marco Sigala, MLML
Eric von der Geest, MLML
Ken Schiff, SCCWRP

SWAMP Bioaccumulation Peer Review Panel

Jim Wiener, Distinguished Professor, University of Wisconsin, La Crosse
Chris Schmitt, USGS, Columbia, Missouri
Harry Ohlendorf, CH2M Hill, Sacramento, CA

San Francisco Estuary Institute

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

Moss Landing Marine Laboratories

Contract Management: Rusty Fairey
Fish Collection: Gary Ichikawa, Billy Jakl, Dylan Service, Dustin Service, Sean Mundell, John Negrey
Dissection: Stephen Martenuk, Kelsey James, Duncan Fry, Jason Whitney, Brynn Hooton, Kim Smelker, Chandler Ichikawa, Sean Goetzl, Jenny Kemper
Mercury and Selenium Analysis: Adam Newman and Jon Goetzl
SWAMP Data Management Team: Cassandra Lamerdin, Mark Pranger, Stacey Swenson, Susan Mason, Marco Sigala, George Radojevic, Brian Thompson, Kyle Reynolds
SWAMP Quality Assurance Team: Beverly van Buuren, Eric von der Geest

California Department of Fish and Game Water Pollution Control Laboratory

Sample Preparation: Laurie Smith, David Gilman, Rafia Mohammed, Bethany Westerhoff
Sample Analysis: Kathleen Regalado, Gary Munoz
Data Entry and QA: Loc Nguyen

SWAMP Staff

Karen Larsen, Jennifer Salisbury, Lori Webber, and Jon Marshack of the State Water Resources Control Board guided the project on behalf of SWAMP.

A draft of this document was reviewed and much improved thanks to comments received from Jim Wiener, Chris Schmitt, Harry Ohlendorf, Jennifer Salisbury, Bob Brodberg, Margy Gassel, and Lori Webber.

This study was funded by a contract with the State Water Resources Control Board (Agreement No. 09-052-270).

The layout and design of the report were done by Doralynn Co of Greenhouse Marketing & Design, Inc.

TABLE OF CONTENTS TOC

TABLE OF CONTENTS TOC

Figures

TABLE OF CONTENTS TOC

TABLE OF CONTENTS TOC

Appendices

(available as separate documents at: http://www.waterboards.ca.gov/water_issues/programs/swamp/coast_study.shtml)

EXECUTIVE SUMMARY E

A two-year screening survey of contaminants in fish on the California coast was conducted in 2009 and 2010. This report presents new data from sampling that focused on the North and Central coasts in 2010. Five species were examined at each sampling location. The array of species selected for sampling included those known to accumulate high concentrations of contaminants and therefore serve as informative indicators of potential contamination problems. Contaminant concentrations in fish tissue were evaluated using thresholds developed by the California Office of Environmental Health Hazard Assessment (OEHHA) for methylmercury, PCBs, dieldrin, DDTs, chlordanes, and selenium, and a U.S. Environmental Protection Agency threshold for methylmercury that is being used by the State Water Resources Control Board to identify impaired water bodies.

In this two-year statewide screening study, 3,483 fish representing 46 species were collected from 68 locations on the California coast. The survey results indicate that methylmercury accumulation in sport fish is of high concern along much of the California coast, especially in the North and Central coast regions. PCBs also reached levels of moderate concern, and were the only other contaminant with problematic concentrations. None of the locations had low concentrations of all contaminants in all sampled fish species.

HIGH METHYLMERCURY CONCENTRATIONS

Overall, 43 of 68 (63%) locations had a most highly contaminated species below 0.44 ppm – this represents an estimate of the percentage of locations where frequent consumption of all species, at a number of servings per week to be determined in the future by OEHHA when sufficient data are available for evaluation, is likely to be safe. Many locations, 25 of the 68 sampled (37%), were in the high contamination category, with an average for the most contaminated species exceeding 0.44 ppm. More than half of the locations (37 of 68, or 54%) had a most highly contaminated species with an average above the 0.30 ppm threshold used by the State Water Board to identify impaired water bodies.

The North Coast (from the Oregon border to Point Reyes) had the highest percentage of locations with at least one species above 0.44 ppm (11 of 15, or 73%). The Central Coast (from Point Reyes south to Point Conception) had the second highest percentage of locations (10 of 26, or 38%) above 0.44 ppm. The South Coast (from Point Conception south to the Mexican border) had a markedly lower proportion of locations above 0.44 ppm (4 of 27, 15%).

Regional variation in the species sampled was an important factor driving the spatial patterns observed. For example, the cleaner status of the South Coast is primarily due to the different suite of species sampled compared to the North and Central coasts. In contrast to the various rockfish species, cabezon, and lingcod that predominated to the north, the species most commonly sampled on the South Coast were kelp bass, barred sand bass, chub mackerel, black perch, and white croaker.

Methlymercury body burdens increase as fish age. The rockfish and shark samples that had high concentrations were generally relatively old (8 – 20 years). On the other hand, species such as chub mackerel and shiner surfperch that were sampled at a young age (1 or 2 years) generally had low concentrations. Methylmercury concentrations also increase with each step up the food chain. All of the species with high concentrations were high level predators. In contrast, blue rockfish, which are a step lower in the food chain, had low concentrations in many locations. Overall, the survey results indicate that the supply of mercury to coastal waters appears sufficient to lead to significant food web contamination and risks to humans wherever long-lived predator fish are caught and consumed. Even offshore locations such as the Farallon Islands were found to have long-lived predators with moderate contamination.

OTHER CONTAMINANTS: PCBS ALSO A CONCERN

PCBs were the only other contaminant that reached concentrations in fish tissue that pose potential health concerns to consumers of fish caught from California coastal waters. PCBs may cause cancer, damage the liver, digestive tract, and nerves; and affect development, reproduction, and the immune system. Overall, 63 of 68 (93%) locations had a most highly contaminated species below 120 ppb – this represents an estimate of the percentage of locations where frequent consumption of all species, at a number of servings per week to be determined in the future by OEHHA when data are sufficient for evaluation, is likely to be safe. Five of the 68 locations (7%) were in the high contamination category, with an average for the most contaminated species exceeding 120 ppb. San Francisco Bay and San Diego Bay stood out as having elevated concentrations.

Other contaminants, including dieldrin, DDT, chlordanes, and selenium, were also analyzed, but were found at low levels.

CLEAN FISH ALSO PRESENT

Although species with high or moderate concentrations of methylmercury and PCBs, were observed at many locations, they were usually accompanied by species with low concentrations. For example, 26 of the 68 locations (38%) had at least one species with low concentrations of both methylmercury and PCBs, and eight locations (12%) had more than one species with low concentrations for both contaminants. Two locations (Dana Point Harbor and Oceanside Harbor) each had four species with low concentrations. On the North Coast, blue rockfish and olive rockfish had low concentrations at multiple locations. On the Central Coast, blue rockfish and black rockfish had low concentrations at four and three locations, respectively. On the South Coast, blue rockfish, chub mackerel, and spotfin croaker had low concentrations at more than one location. Overall, blue rockfish stood out as the most widely distributed species with low concentrations.

NEXT STEPS

Results from the Coast Survey will be used by the State and Regional Water Boards in prioritizing coastal areas in need of cleanup plans or further monitoring. OEHHA is using results from the Coast Survey to develop advisories. In 2011 OEHHA merged results from the Coast Survey and the San Francisco Bay Regional Monitoring Program to develop a comprehensive advisory for ten species in San Francisco Bay. OEHHA plans to merge data from the Coast Survey with additional data from other studies to develop an advisory for San Diego Bay.

To assess contaminants in fish in California rivers and streams the SWAMP fish monitoring team sampled 62 locations in 2011. Results from the Rivers and Streams Survey will be reported in May 2013. In 2012, SWAMP is conducting a study assessing methylmercury exposure and risk in wildlife on California lakes and reservoirs. This study will examine methylmercury concentrations in a bird species (Western Grebes), the small fish that they eat, and sport fish consumed by humans.

SECTION 1 INTRODUCTION

BACKGROUND

Contaminants that accumulate in the food web (or "bioaccumulate") exceed levels of concern in water bodies throughout California, posing threats to the health of humans and wildlife that consume contaminated aquatic biota. Bioaccumulation of methylmercury, PCBs, and other contaminants has led to fish consumption advisories, 303(d) listings, and TMDLs in many locations across the state. Existing information on spatial patterns and temporal trends suggests that other locations that have either not been monitored or monitored less thoroughly may also have similar problems.

Recreational and commercial fishing are a vibrant part of the economy for California and other Pacific coastal states. In 2009, recreational anglers in California took 4.7 million fishing trips, including 3.6 million trips by shore-based anglers, 676,000 trips in private boats, and 385,000 trips by for-hire boats. Together with sales of durable equipment, these trips generated 13,567 full and part-time jobs, and over $2 billion in sales (NMFS 2009). The commercial seafood industry in California generated 120,000 jobs and over $20 billion in sales (NMFS 2009). The species that were most often caught by recreational anglers in the Pacific region (California, Oregon, and Washington) were rockfishes and scorpionfishes (2.7 million fish), mackerel (2 million fish), barracuda, bass and bonito (1.6 million fish), and surfperches (1.5 million fish). Most of the rockfishes and scorpionfishes in the Pacific region were caught in California.

In spite of the importance of coastal fisheries to the economy and as a source of food for Californians, no systematic statewide monitoring of contaminants in coastal fish has yet been performed. This report summarizes results from a two-year statewide screening survey of contaminants in sport fish from California coastal waters. The report represents a major advance in understanding the extent of chemical contamination in sport fish on the California coast. The goals of the study were to:

1) define the spatial extent of contamination in fish relative to assessment thresholds developed by regulatory agencies;
2) evaluate spatial patterns of contamination within regions; and
3) identify areas where further sampling should be conducted to support development of safe eating guidelines.

The results from this screening survey will be valuable in prioritizing areas in need of further study, support development of consumption guidelines and cleanup plans, and provide information the public can use to be better informed about the degree of contamination of their favorite fishing spots. The focus of the survey was on a set of contaminants that are of primary concern in California sport fish: methylmercury, PCBs, organochlorine pesticides (DDTs, dieldrin, and chlordanes), and selenium.

The survey described in this report was performed as part of the State Water Resources Control Board's Surface Water Ambient Monitoring Program (SWAMP). This effort marks the beginning of a new long-term, statewide, comprehensive bioaccumulation monitoring program for California surface waters.

This report provides a concise technical summary of the findings of the survey. The target audience is agency scientists who are charged with managing water quality issues related to bioaccumulation of contaminants in California surface waters.

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

The Roundtable formed a committee, the Bioaccumulation Oversight Group (BOG), that guides SWAMP bioaccumulation monitoring. The BOG is composed of representatives from each of the Roundtable groups; in addition, it includes the Southern California Coastal Waters Research Project and the San Francisco Estuary Institute. The members of the BOG have extensive experience with bioaccumulation monitoring. The BOG also serves as a subcommittee for the California Water Quality Monitoring Council (http://www.waterboards.ca.gov/mywaterquality/monitoring_council/). The Council's objectives are to promote coordination and cost-effectiveness of water quality and ecosystem monitoring and assessment, enhance the integration of monitoring data across departments and agencies, and increase public access to monitoring data and assessment information.

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

The BOG has developed and is implementing a plan to evaluate bioaccumulation impacts on the fishing beneficial use in all California water bodies. Sampling of sport fish in lakes and reservoirs was conducted in the first two years of monitoring (2007 and 2008). In 2009 and 2010, sport fish from the California coast, including bays and estuaries were sampled. Sport fish from rivers and streams were sampled in 2011. Studies of the methylmercury exposure and risk in aquatic birds and a workshop on biotoxins are planned for 2012.

In 2012 the BOG will also develop a comprehensive strategy for enhancing coordination of bioaccumulation monitoring, assessment, and communication in aquatic ecosystems in California.

THE COAST SURVEY

Management Questions for This Survey

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

Management Question 1 (MQ1)

Status of the Fishing Beneficial Use

For popular fish species, what percentage of popular fishing areas have low enough concentrations of contaminants that fish can be safely consumed?

Answering this question is critical to determining the degree of impairment of the fishing beneficial use along the coast due to bioaccumulation. This question places emphasis on characterizing the status of the fishing beneficial use through monitoring of the predominant pathways of exposure – ingestion of popular fish species from popular fishing areas. This focus is also anticipated to enhance public and political support of the program by assessing the resources that people care most about. The determination of percentages mentioned in the question captures the need to perform an assessment of the entire California coast. Past monitoring of contamination in sport fish on the California coast has been patchy (reviewed in Davis et al. [2007]), and a systematic survey of the entire coast has never been performed. The emphasis on safe consumption calls for an accurate message on the status of the fishing beneficial use and evaluation of the data using thresholds for safe consumption.

The data needed to answer this question are average concentrations in popular fish species from popular fishing locations. Inclusion of as many popular species as possible is important to understanding the nature of impairment in any areas with concentrations above thresholds. In some areas, some fish may have low concentrations while others do not, and this is valuable information. Monitoring of species that are known to accumulate high concentrations of contaminants ("indicator species") is valuable in answering this question: if concentrations in these species are below thresholds, this is a strong indication that an area has low concentrations.

OEHHA uses these same types of data in development of safe eating guidelines. While the data generated for this study are intended to be usable for that purpose, this study did not generate sufficient information for development of safe eating guidelines and the assessments presented in this report should not be construed as consumption advice.

Management Question 2 (MQ2)

Regional Distribution

What is the spatial distribution of contaminant concentrations in fish within regions?

The data in this report are summarized for three coastal regions: the North Coast (Oregon border to Point Reyes), the Central Coast (Point Reyes to Point Conception), and the South Coast (Point Conception to Mexico). Answering this question will provide information that is valuable in formulating management strategies for observed contamination problems. This information will allow managers to prioritize their efforts and focus attention on the areas with the most severe problems. Information on spatial distribution within regions will also provide information on sources and fate of contaminants of concern that will be useful to managers.

This question can be answered with different levels of certainty. For a higher and quantified level of certainty, a statistical approach is needed that includes replicate observations in the spatial units to be compared. In some cases, managers can attain an adequate level of understanding for their needs with a non-statistical, non-replicated approach. With either approach, reliable estimates of average concentrations within each spatial unit are needed.

Management Question 3 (MQ3)

Need for Further Sampling

Should additional sampling of contaminants in sport fish (e.g., more species or larger sample size) in specific areas be conducted for the purpose of developing comprehensive consumption guidelines?

This screening survey of the entire California coast will provide a preliminary indication as to whether areas that have not been sampled thoroughly to date may require consumption guidelines. Consumption guidelines provide a mechanism for reducing human exposure in the near-term. OEHHA, the agency responsible for issuing consumption guidelines, considers a sample of 9 or more fish from a variety of species abundant in a water body to be the minimum needed in order to issue guidance. It is valuable to have information not only on the species with high concentrations, but also the species with low concentrations so anglers can be encouraged to target the less-contaminated species. The diversity of species on the coast demands a relatively large effort to characterize interspecific variation. Answering this question is essential as a first step in determining the need for more thorough sampling in support of developing consumption guidelines.

OVERALL APPROACH

The overall approach taken to answer these three questions was to perform a screening study of bioaccumulation in sport fish on the entire California coast. Answering these questions will provide a basis for decision-makers to understand the scope of the bioaccumulation problem and will provide regulators with information needed to establish priorities for both cleanup actions and development of consumption guidelines.

It is anticipated that the screening study may lead to more detailed followup investigations of areas where a need for consumption guidelines and cleanup actions is indicated.

Through coordination with other programs, SWAMP funds for this survey were highly leveraged to achieve a much more thorough assessment than could be achieved by SWAMP alone.

First, this effort was closely coordinated with bioaccumulation monitoring for the Southern California Bight (SCB) Regional Monitoring Program. Every five years, dischargers in the SCB collaborate to perform this regional monitoring. Bioaccumulation monitoring is one element of the Bight Program. Before the present survey, however, the Bight Program had not performed regional monitoring of contaminants in sport fish. Most of the work for this most recent round of Bight monitoring was performed in 2008. The bioaccumulation element, however, was delayed to 2009 in order to allow coordination with the SWAMP survey. The Bight group wanted to conduct sport fish sampling, but lacks the infrastructure to perform sample collection. The Bight group therefore contributed approximately $240,000 worth of analytical work (analysis of PCBs and organochlorine pesticides in 225 samples) to the joint effort. This allowed more intensive sampling of the Bight region than either program could achieve independently. A detailed description of results for the Bight was provided in Davis et al. (2011).

The SWAMP survey was also coordinated with intensive sampling in San Francisco Bay by the Regional Monitoring Program for Water Quality in the San Francisco Estuary (RMP). The RMP conducts thorough sampling of contaminants in sport fish in the Bay on a triennial basis. This sampling has been conducted since 1994. To coordinate with the SWAMP effort, the RMP analyzed additional species to allow for more extensive comparisons of the Bay with coastal areas and bays in other parts of the state. The RMP benefitted from this collaboration by SWAMP contributing production of: 1) a statewide dataset that will help in interpretation of RMP data and 2) a report (Davis et al. 2011) that included a detailed assessment and reporting of Bay data and made production of a separate report by the RMP unnecessary. The RMP effort represents $215,000 of sampling and analysis.

In addition, the Los Angeles Regional Water Quality Control Board supplemented the statewide survey with another $110,000 to provide for more thorough coverage of the Southern California Bight.

These collaborations substantially increased the total amount of funding available for sampling and analysis in the Coast Survey. Each of the collaborating programs has benefitted from the consistent statewide assessment, increased information due to sharing of resources, and efforts to ensure consistency in the data generated by the programs (e.g., analytical intercalibration).

SECTION 2 METHODS

SAMPLING DESIGN

The sampling plan was developed to address the three management questions for the project (Bioaccumulation Oversight Group 2009). Sampling was conducted at 68 locations (Figures 1-3). Fish were collected from June through November in 2009 and 2010. Cruise reports with detailed information on locations are available at: www.waterboards.ca.gov/water_issues/programs/swamp/coast_study.shtml

California has over approximately 840 miles of coastline that span a diversity of habitats and fish populations, and include dense human population centers with a multitude of popular fishing locations. Sampling this vast area with a limited budget was a challenge. The approach employed was to divide the coast into 68 spatial units called "zones". The concept of dividing the coast into sections is consistent with the approach that OEHHA used in development of consumption guidelines for over 100 miles of coast between Ventura Harbor and San Mateo Point in the SCB: they divided this stretch into three segments and issued advice for each (Klasing et al. 2009). Consumption guidelines have been issued on a pier-by-pier basis in the past in Southern California, and this approach has proven to be unsatisfactory. All of these zones were sampled (in other words, a complete census was performed), making a probabilistic sampling design unnecessary. The sampling focused on nearshore areas, including bays and estuaries, in waters not exceeding 200 m in depth, and mostly less than 60 m deep. These are the coastal waters where most of the sport fishing occurs. Popular fishing locations were identified from Jones (2004) and discussions with stakeholders. Zones were developed in consultation with Water Board staff from each of the nine regions, Bight Group stakeholders, and the BOG. Within each zone, sample collection was directed toward the most popular fishing locations. Locations shown in the map figures indicate the weighted polygon centroids to represent the latitudes and longitudes where the fish were actually collected (see cruise reports for details on each location).

The Sampling Plan (Bioaccumulation Oversight Group 2009) provides more details on the design: www.waterboards.ca.gov/water_issues/programs/swamp/coast_study.shtml

TARGET SPECIES

Selecting fish species to monitor on the California coast is a complicated task due to the high diversity of species, regional variation over the considerable expanse of the state from north to south, variation in habitat and contamination between coastal waters and enclosed bays and harbors, and the varying ecological

Figure 1. Locations sampled in the Coast Survey, 2009 and 2010.

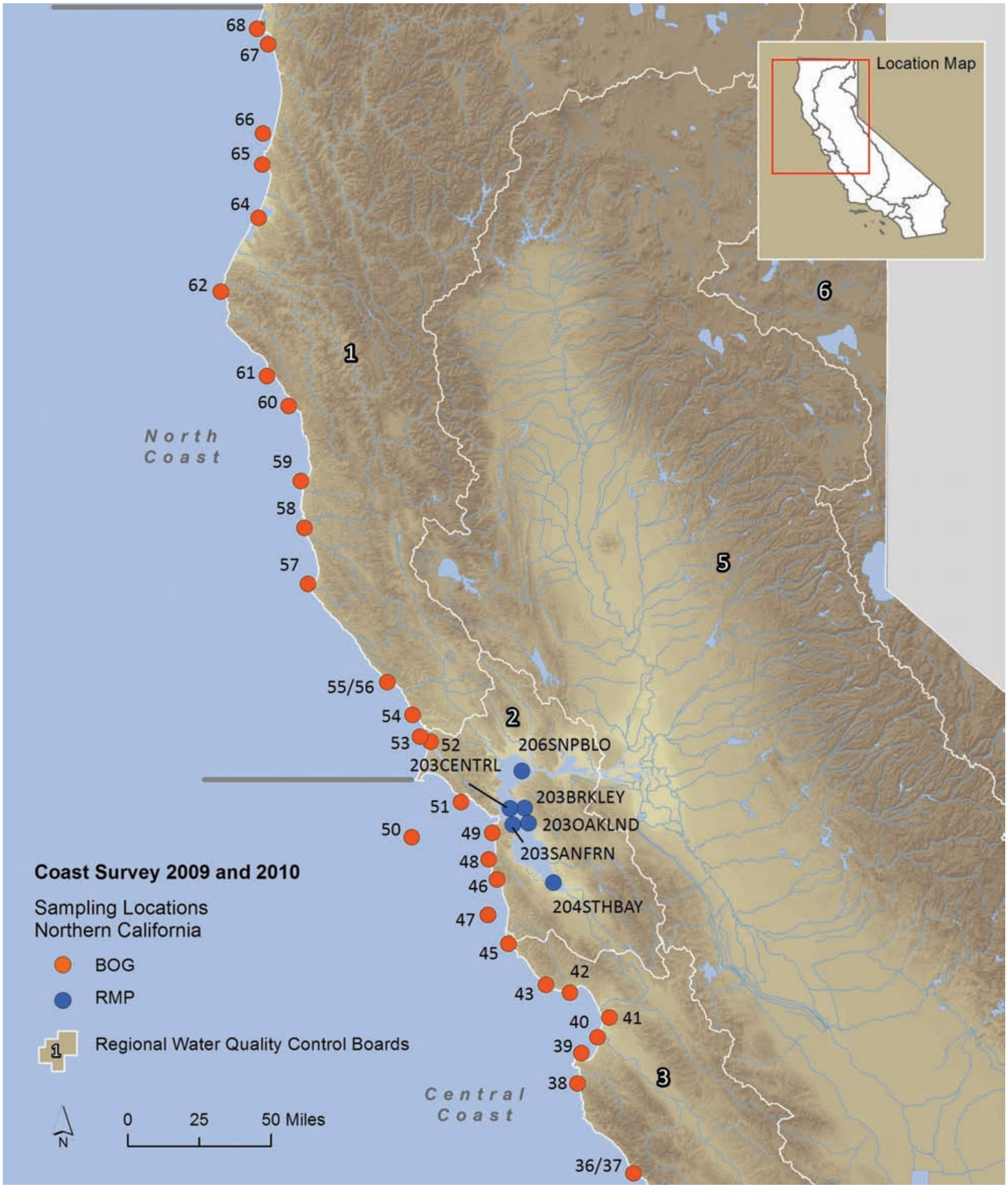

Figure 2. Locations sampled in the Coast Survey, 2009 and 2010: Northern California.

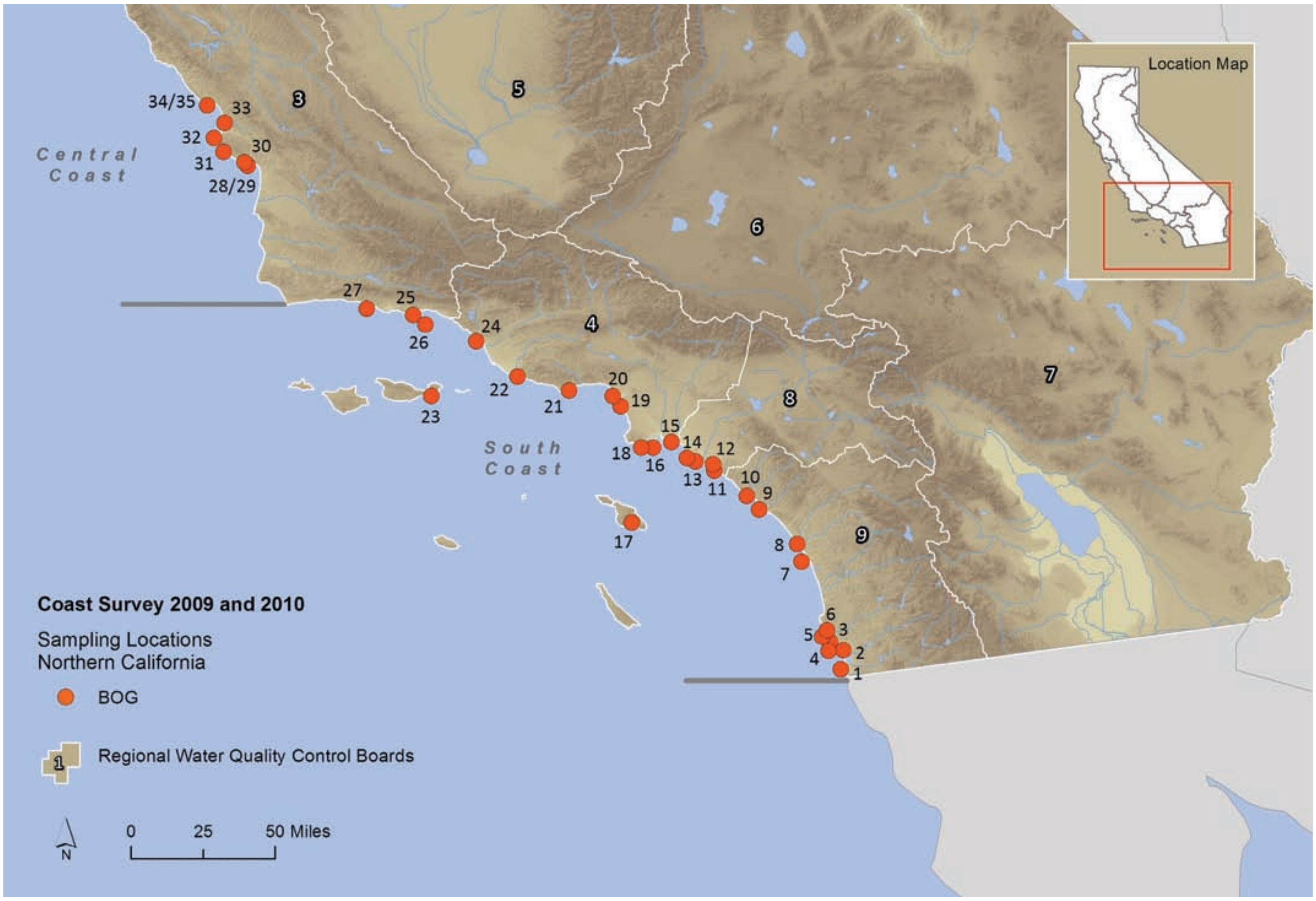

Figure 3. Locations sampled in the Coast Survey, 2009 and 2010: Southern California.

attributes of potential indicator species. The list of possibilities was narrowed down by considering the following criteria, listed in order of importance.

1. Popular for consumption
2. Sensitive indicators of contamination problems (accumulating relatively high concentrations of contaminants)
3. Widely distributed
4. Species that accumulate relatively low concentrations of contaminants
5. Represent different exposure pathways (benthic versus pelagic)
6. Continuity with past sampling

Information relating to these criteria was presented in the Sampling Plan.

The BOG elected not to include shellfish in this survey due to the limited budget available for the survey and the lower consumption rate and concern for human health. Shellfish sampling may occur in the future if the SWAMP bioaccumulation budget is sufficient.

As recommended by USEPA (2000) in the document "Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories," the primary factor considered in selecting species to monitor was a high rate of human consumption. Fortunately, good information on recreational fish catch is available from the Recreational Fisheries Information Network (RecFIN), a product of the Pacific States Marine Fisheries Commission. Many different taxonomic groups of fish are found on the coast (e.g., rockfish, surfperch, or sharks) and some of these groups consist of quite a diversity of species. The sampling design was based on inclusion of representatives of selected groups within each zone. The popular groups varied among the three regions of the state (north, central, and south) and between coastal waters and bays and harbors.

While catch data were the primary determinant of the list of target species, some adjustments were made to ensure an appropriate degree of emphasis on sensitive indicators of contamination. Including these species is useful in assessing the issue of safe consumption (contained in Management Question 1) – if the sensitive indicator species in an area are below thresholds of concern then this provides an indication that all species in that area are likely to be below thresholds. Consequently, target species in this study included both high lipid species such as croaker and surfperch that are strong accumulators of organics, and long-lived predators such as sharks that accumulate mercury. A summary of basic ecological attributes of the target species is provided in Appendix 1.

A list of the species collected in the Coast Survey is provided in Table 1. Table 1 also includes information on the number of locations sampled, fish sizes, and how the fish were processed. Statewide maps showing the locations sampled (as well as the concentrations measured) for each species can be obtained from the My Water Quality portal: www.CaWaterQuality.net

SAMPLE PROCESSING

Dissection and compositing of muscle tissue samples were performed following USEPA guidance (USEPA 2000). In general, fish were dissected skin-off, and only the fillet muscle tissue was used for analysis. Some species (e.g., shiner surfperch) were too small to be filleted and were processed whole but with head, tail, and viscera removed. Detailed information on target size ranges, compositing, and other sample processing procedures is presented in the Sampling Plan (Bioaccumulation Oversight Group 2009).

CHEMICAL ANALYSIS

All tissue concentrations in this report are expressed on a wet weight basis.

Mercury and Selenium

In most cases, nearly all (>95%) of the mercury present in fish fillets and in whole fish is methylmercury (Wiener et al. 2007, Greenfield and Jahn 2010). Consequently, monitoring programs usually analyze total mercury as a proxy for methylmercury, as was done in this study. USEPA (2000) recommends this approach,

Table 1
Scientific and common names of fish species collected, the number of locations in which they were sampled, their minimum, median, and maximum total lengths (mm), and whether they were analyzed as composites or individuals. Species marked as "analyzed for individuals" were analyzed as individuals for mercury only.

Family	Species Name	Common Name	Number of Fish	Total Number of Locations Sampled	Composites - Number of Samples	Composites - Number of Locations	Individuals - Number of Samples	Individuals - Number of Locations	Min Length (mm)	Median Length (mm)	Max Length (mm)	Analyzed as Composites	Analyzed as Individuals
Hound Sharks (Triakidae)	*Triakis semifasciata*	Leopard Shark	44	8	8	8	41	7	930	1238	1410	x	x
Hound Sharks (Triakidae)	*Mustelus californicus*	Gray Smoothhound Shark	6	2	2	2			616	630	685	x	
Hound Sharks (Triakidae)	*Mustelus henlei*	Brown Smoothhound Shark	12	4	4	4			826	978	1144	x	
Dogfish Sharks (Squalidae)	*Squalus acanthias*	Spiny Dogfish	3	1	1	1			995	1011	1140	x	
Barracudas (Sphyraenidae)	*Sphyraena argentea*	Pacific Barracuda	4	1	1	1			450	479	590	x	
Basses (Serranidae)	*Paralabrax maculatofasciatus*	Spotted Sand Bass	63	4	11	4	40	4	195	327	430	x	x
Basses (Serranidae)	*Paralabrax clathratus*	Kelp Bass	261	18	48	18	169	18	185	316	512	x	x
Basses (Serranidae)	*Paralabrax nebulifer*	Barred Sand Bass	113	14	20	14	97	14	257	346	590	x	x
Rockfish (Sebastidae)	*Sebastes serranoides*	Olive Rockfish	79	10	10	10	79	10	208	322	425	x	x
Rockfish (Sebastidae)	*Sebastes flavidus*	Yellowtail Rockfish	7	2	2	2			290	313	350	x	
Rockfish (Sebastidae)	*Sebastes caurinus*	Copper Rockfish	33	6	6	6	10	1	340	411	522	x	x
Rockfish (Sebastidae)	*Sebastes miniatus*	Vermillion Rockfish	45	10	10	10			229	437	551	x	
Rockfish (Sebastidae)	*Sebastes rosaceus*	Rosy Rockfish	15	3	3	3			175	215	257	x	
Rockfish (Sebastidae)	*Sebastes maliger*	Quillback Rockfish	3	1	1	1			423	431	439	x	
Rockfish (Sebastidae)	*Sebastes atrovirens*	Kelp Rockfish	15	3	3	3			269	294	335	x	
Rockfish (Sebastidae)	*Sebastes carnatus*	Gopher Rockfish	142	24	24	24	89	13	147	281	371	x	x
Rockfish (Sebastidae)	*Sebastes nebulosus*	China Rockfish	25	5	5	5			245	332	385	x	
Rockfish (Sebastidae)	*Sebastes auriculatus*	Brown Rockfish	52	11	11	11			205	302	392	x	
Rockfish (Sebastidae)	*Sebastes melanops*	Black Rockfish	125	14	14	14	120	13	213	380	511	x	x
Rockfish (Sebastidae)	*Sebastes chrysomelas*	Black and Yellow Rockfish	9	2	2	2			254	270	302	x	
Rockfish (Sebastidae)	*Sebastes mystinus*	Blue Rockfish	179	23	23	23	179	23	51	293	395	x	x
Rockfish (Scorpaenidae)	*Scorpaena plumieri*	Spotted Scorpionfish	10	2	2	2			200	290	322	x	
Mackerels (Scombridae)	*Scomber japonicus*	Chub Mackerel	290	20	58	20			199	240	335	x	
Croaker (Sciaenidae)	*Umbrina roncador*	Yellowfin Croaker	50	4	10	4			121	195	376	x	
Croaker (Sciaenidae)	*Genyonemus lineatus*	White Croaker	293	24	59	24			164	220	300	x	
Croaker (Sciaenidae)	*Roncador stearnsii*	Spotfin Croaker	15	3	3	3			138	221	372	x	
Croaker (Sciaenidae)	*Seriphus politus*	Queenfish	4	1	1	1			156	165	174	x	
Croaker (Sciaenidae)	*Cheilotrema saturnum*	Black Croaker	3	1	1	1			234	242	261	x	
Sand Flounder (Paralichthyidae)	*Paralichthys californicus*	California Halibut	14	5	5	5			266	670	810	x	
Eagle and Manta Rays (Myliobatidae)	*Myliobatis californica*	Bat Ray	20	3	3	3	17	2	176	405	921	x	x
Temperate Basses (Moronidae)	*Morone saxatilis*	Striped Bass	18	2	6	2	18	2	460	600	790	x	x
Tilefishes (Malacanthidae)	*Caulolatilus princeps*	Ocean Whitefish	5	1	1	1			270	279	286	x	

Family	Species Name	Common Name	Number of Fish	Total Number of Locations Sampled	Composites - Number of Samples	Composites - Number of Locations	Individuals - Number of Samples	Individuals - Number of Locations	Min Length (mm)	Median Length (mm)	Max Length (mm)	Analyzed as Composites	Analyzed as Individuals
Sea Chubs (Kyphosidae)	*Girella nigricans*	Opaleye	5	1	1	1			194	221	230	x	
Greenlings (Hexagrammidae)	*Ophiodon elongatus*	Lingcod	56	13	13	13			551	682	932	x	
Greenlings (Hexagrammidae)	*Hexagrammos decagrammus*	Kelp Greenling	23	6	6	6			220	360	422	x	
Anchovies (Engraulidae)	*Engraulis mordax*	Northern Anchovy	337	2	9	2			65	89	126	x	
Surfperch (Embiotocidae)	*Phanerodon furcatus*	White Surfperch	69	7	7	7	62	7	99	202	345	x	x
Surfperch (Embiotocidae)	*Cymatogaster aggregata*	Shiner Surfperch	585	18	27	17	114	12	50	110	199	x	x
Surfperch (Embiotocidae)	*Hypsurus caryi*	Rainbow Surfperch	33	6	6	6	28	5	185	280	342	x	x
Surfperch (Embiotocidae)	*Rhacochilus vacca*	Pile Surfperch	10	1	1	1	10	1	280	340	375	x	x
Surfperch (Embiotocidae)	*Amphistichus argenteus*	Barred Surfperch	77	9	9	9	70	9	105	186	363	x	x
Surfperch (Embiotocidae)	*Embiotoca jacksoni*	Black Perch	85	10	10	10	79	10	152	232	316	x	x
Sculpins (Cottidae)	*Scorpaenichthys marmoratus*	Cabezon	55	13	13	13			380	467	575	x	
Silversides (Atherinopsidae)	*Atherinops affinis*	Topsmelt	159	7	7	7			80	128	377	x	
Silversides (Atherinopsidae)	*Atherinopsis californiensis*	Jacksmelt	20	4	4	4			240	265	279	x	
Sturgeons (Acipenseridae)	*Acipenser transmontanus*	White Sturgeon	12	2	4	2	12	2	1170	1270	1560	x	x

Table 2
Analytes included in the study, detection limits, numbers of observations, and frequencies of detection and reporting. Frequency of detection includes all results above detection limits. Frequency of reporting includes all results that were reportable (above the detection limit and passing all QA review). Units for the MDLs are ppm for mercury and selenium, parts per trillion for dioxins and furans, and ppb for the other organics (all on a wet weight basis).

Laboratory	Class	Analyte	Method Detection Limit	Number of Observations	Frequency of Detection (%)	Frequency of Reporting (%)
MPSL-DFG	MERCURY	Mercury	0.01	1543	100	100
DFG-WPCL	CHLORDANE	Chlordane, cis-	0.4	362	26	26
DFG-WPCL	CHLORDANE	Chlordane, trans-	0.45	362	23	18
DFG-WPCL	CHLORDANE	Nonachlor, cis-	0.3	362	22	22
DFG-WPCL	CHLORDANE	Nonachlor, trans-	0.19	362	56	51
DFG-WPCL	CHLORDANE	Oxychlordane	0.47	362	4	4
DFG-WPCL	DDT	DDD(o,p')	0.1	362	17	17
DFG-WPCL	DDT	DDD(p,p')	0.12	362	53	53
DFG-WPCL	DDT	DDE(o,p')	0.18	362	19	19
DFG-WPCL	DDT	DDE(p,p')	0.56	362	92	90
DFG-WPCL	DDT	DDT(o,p')	0.21	362	3	3
DFG-WPCL	DDT	DDT(p,p')	0.15	362	32	32
DFG-WPCL	DIELDRIN	Dieldrin	0.43	362	30	21
DFG-WPCL	PCB	PCB 008	0.2	362	0	0
DFG-WPCL	PCB	PCB 018	0.2	362	2	2
DFG-WPCL	PCB	PCB 027	0.2	362	0	0
DFG-WPCL	PCB	PCB 028	0.2	362	22	22
DFG-WPCL	PCB	PCB 029	0.2	362	0	0
DFG-WPCL	PCB	PCB 031	0.2	362	8	8
DFG-WPCL	PCB	PCB 033	0.2	362	1	1
DFG-WPCL	PCB	PCB 044	0.2	362	24	24
DFG-WPCL	PCB	PCB 049	0.2	362	31	31
DFG-WPCL	PCB	PCB 052	0.2	362	46	46
DFG-WPCL	PCB	PCB 056	0.2	362	2	2
DFG-WPCL	PCB	PCB 060	0.2	362	4	4
DFG-WPCL	PCB	PCB 064	0.2	362	4	4
DFG-WPCL	PCB	PCB 066	0.2	362	37	37
DFG-WPCL	PCB	PCB 070	0.3	362	25	25
DFG-WPCL	PCB	PCB 074	0.2	362	26	26
DFG-WPCL	PCB	PCB 077	0.2	362	2	2
DFG-WPCL	PCB	PCB 087	0.3	362	25	25
DFG-WPCL	PCB	PCB 095	0.3	362	37	37

Laboratory	Class	Analyte	Method Detection Limit	Number of Observations	Frequency of Detection (%)	Frequency of Reporting (%)
DFG-WPCL	PCB	PCB 097	0.2	362	30	30
DFG-WPCL	PCB	PCB 099	0.2	362	55	54
DFG-WPCL	PCB	PCB 101	0.33	362	57	57
DFG-WPCL	PCB	PCB 105	0.2	362	45	45
DFG-WPCL	PCB	PCB 110	0.3	362	49	48
DFG-WPCL	PCB	PCB 114	0.2	362	1	1
DFG-WPCL	PCB	PCB 118	0.31	362	58	56
DFG-WPCL	PCB	PCB 126	0.2	362	0	0
DFG-WPCL	PCB	PCB 128	0.2	362	36	36
DFG-WPCL	PCB	PCB 132	0.2	56	96	96
DFG-WPCL	PCB	PCB 137	0.2	362	11	11
DFG-WPCL	PCB	PCB 138	0.22	362	70	64
DFG-WPCL	PCB	PCB 141	0.2	362	23	23
DFG-WPCL	PCB	PCB 146	0.2	362	32	32
DFG-WPCL	PCB	PCB 149	0.2	362	51	50
DFG-WPCL	PCB	PCB 151	0.2	362	31	31
DFG-WPCL	PCB	PCB 153	0.28	362	79	72
DFG-WPCL	PCB	PCB 156	0.2	362	22	22
DFG-WPCL	PCB	PCB 157	0.2	362	3	3
DFG-WPCL	PCB	PCB 158	0.2	362	23	23
DFG-WPCL	PCB	PCB 169	0.2	362	0	0
DFG-WPCL	PCB	PCB 170	0.2	362	36	36
DFG-WPCL	PCB	PCB 174	0.2	362	23	23
DFG-WPCL	PCB	PCB 177	0.2	362	29	29
DFG-WPCL	PCB	PCB 180	0.2	362	52	51
DFG-WPCL	PCB	PCB 183	0.2	362	34	34
DFG-WPCL	PCB	PCB 187	0.2	362	50	50
DFG-WPCL	PCB	PCB 189	0.2	362	1	1
DFG-WPCL	PCB	PCB 194	0.2	362	27	27
DFG-WPCL	PCB	PCB 195	0.2	362	9	9
DFG-WPCL	PCB	PCB 198	0.2	56	100	100
DFG-WPCL	PCB	PCB 198/199	0.2	306	0	0
DFG-WPCL	PCB	PCB 199	0.2	56	0	0
DFG-WPCL	PCB	PCB 200	0.2	362	9	9
DFG-WPCL	PCB	PCB 201	0.2	362	32	32
DFG-WPCL	PCB	PCB 203	0.2	362	24	24
DFG-WPCL	PCB	PCB 206	0.2	362	18	18

Laboratory	Class	Analyte	Method Detection Limit	Number of Observations	Frequency of Detection (%)	Frequency of Reporting (%)
DFG-WPCL	PCB	PCB 209	0.2	362	7	7
MPSL-DFG	SELENIUM	Selenium	0.15	483	96	96

and the conservative assumption be made that all mercury is present as methylmercury to be most protective of human health.

Total mercury and selenium in all samples were measured by Moss Landing Marine Laboratory (Moss Landing, CA). Detection limits for total mercury and all of the other analytes are presented in Table 2. Analytical methods for mercury and the other contaminants were described in the Sampling Plan (Bioaccumulation Oversight Group 2009). Mercury was analyzed according to EPA 7473, “Mercury in Solids and Solutions by Thermal Decomposition, Amalgamation, and Atomic Absorption Spectrophotometry” using a Direct Mercury Analyzer. Selenium was digested according to EPA 3052M, “Microwave Assisted Acid Digestion of Siliceous and Organically Based Matrices,” modified, and analyzed according to EPA 200.8, “Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma-Mass Spectrometry.” Mercury and selenium results were reportable for 100% and 96% of the samples analyzed, respectively (Table 2).

Mercury analyses were performed on individual fish for selected species (Table 1). Selenium analyses were performed only on composite samples.

Organics

PCBs and legacy pesticides were analyzed by the California Department of Fish and Game Water Pollution Control Laboratory (Rancho Cordova, CA). Organochlorine pesticides were analyzed according to EPA 8081AM, “Organochlorine Pesticides by Gas Chromatography.” PCBs were analyzed according to EPA 8082M, “Polychlorinated Biphenyls (PCBs) by Gas Chromatography.”

PCBs are reported as the sum of 55 congeners (Table 2). Concentrations in many locations were near or below limits of detection (Table 2). The congeners contributing most to the sum of PCBs were reportable in 48-72% of the 362 samples analyzed for PCBs. The inclusion of many samples with low concentrations caused the somewhat low percentages of reportable results. Frequencies of detection and reporting were lower for the less abundant PCB congeners that have a smaller influence on the sum of PCBs. For PCBs and all of the organics presented as “sums,” the sums were calculated with values for samples with concentrations below the limit of detection set to zero.

DDTs are reported as the sum of six isomers (Table 2). Chlordanes are reported as the sum of five compounds (Table 2).

Organics analyses were performed only on composite samples.

QUALITY ASSURANCE

The samples were analyzed in multiple batches. Quality assurance analyses for SWAMP Data Quality Objectives (DQOs) (precision, accuracy, recovery, completeness, and sensitivity) were performed for each batch as required by the SWAMP BOG QAPP (Bonnema 2009).

Data that met all measurement quality objectives (MQOs) as specified in the QAPP are classified as "compliant" and considered usable without further evaluation. Data that failed to meet all program MQOs specified in the QAPP were classified as qualified but considered usable for the intended purpose. Data that were > 2X MQO requirements or the result of blank contamination were classified as "rejected" and considered unusable. Data batches where results were not reported and therefore not validated were classified as not applicable.

The following summary of QA information describes metadata for the 2010 samples. Data for the 2009 samples were provided in Davis et al. (2011).

For 2010, there were 18,816 sample results for individual constituents including tissue composites and laboratory QA/QC samples. Of these:

- 16,772 (89%) were classified as "compliant,"
- 1971 (10%) were classified as "qualified,"
- 113 (0.6%) were classified as "rejected," and
- 1 (0.005%) was classified as "NA", since the results were not reported due to insufficient sample mass.

Classification of this dataset is summarized as follows:

- 113 results were classified as "rejected" and 12 results were classified as "qualified" due to blank contamination values.
- 1 result was classified as "qualified" due to surrogate recovery exceedances presented in Appendix 2, Table 2.
- 73 results were classified as "qualified" due to recovery exceedances presented in Appendix 2, Tables 3 and 4.
- 73 results were classified as "qualified" due to the RPD exceedances presented in Appendix 2, Table 3.
- 1,524 results were classified as "qualified" due to holding time exceedances.

Overall, all data with the exception of the 113 rejected results were considered usable for the intended purpose. A 99% completeness level was attained which met the 90% project completeness goal specified in the QAPP. Additional details are provided in Appendix 2, including data for specific analytes that did not meet MQOs.

STATISTICAL METHODS

For the organics and selenium, simple descriptive statistics are presented. For methylmercury, analysis of individual samples for selected species provided a foundation for more sophisticated procedures to adjust for the relationship with fish size. Four species were analyzed for methylmercury as individuals and met the following criteria that allowed for an analysis of covariance to be performed: 1) at least 10 sites with individuals meeting criteria; 2) 100 mm size range per site; and 3) at least 8 fish per site. These species were black rockfish, blue rockfish, olive rockfish, and kelp bass.

To perform the analysis of covariance, methylmercury concentrations in black rockfish, blue rockfish, olive rockfish, and kelp bass, results were calculated for median sizes of 380 mm, 290 mm, 320 mm, and 320 mm fish, respectively (the median lengths for each species), using the residuals of a length versus $\log_{10}$(Hg) relationship. Methylmercury concentrations were $\log_{10}$-transformed to normalize the regression residuals. The analysis was done for each species as follows. A standardized length was created by subtracting the overall mean length from the length of each individual sample. An analysis of covariance (ANCOVA) was done using $\log_{10}$(Hg) as the response variable, standardized length as the regressor (covariate), and station as a categorical factor to assess if the regression between standardized length and $\log_{10}$(Hg) were comparable between stations. A non-significant interaction between the covariate and the factor suggests the slope of the regression between standardized length and $\log_{10}$(Hg) is similar for the stations (Hebert and Keenleyside 1995). The interaction term for black rockfish ($F = 1.65$, $p = 0.091$) and blue rockfish ($F = 1.22$, $p = 0.24$) was not significant so a common regression slope was used to estimate concentrations for median-sized fish methylmercury concentrations. The interaction terms for kelp bass ($F = 2.01$, $p = 0.014$) and olive rockfish ($F = 2.54$, $p = 0.016$) were significant; therefore, individual station regressions, instead of a common regression slope, were used to estimate concentrations for median-sized fish (Hebert and Keenleyside 1995). Size-standardized concentrations were estimated using the formula:

Size-standardized concentration = intercept + (median size * slope) + residual

and then back-transformed to original units by 10^x, where x = the size-standardized concentration.

Regression models were tested using the formula:
$\log_{10}$(Hg) = intercept + (median size * slope) + residual

A simpler technique was used to evaluate size-adjusted data for gopher rockfish. For this species, concentrations could not be size-adjusted by ANCOVA due to a lack of data on individual fish at all locations. However, a correlation of location mean methylmercury with location mean size was apparent. The residuals of the length-methylmercury regression for these location means were examined as a less powerful method of obtaining a spatial assessment adjusted for size.

These size-standardized concentrations were only used for evaluation of spatial patterns for these four species. All comparisons to assessment thresholds presented in the text were made using non-standardized and untransformed data.

ASSESSMENT THRESHOLDS

This report compares fish tissue concentrations to two types of thresholds of concern for contaminants in sport fish that were developed by OEHHA (Klasing and Brodberg 2008): Fish Contaminant Goals (FCGs) and Advisory Tissue Levels (ATLs) (Table 3).

FCGs, as described by Klasing and Brodberg (2008), are:

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

Table 3
Thresholds for concern based on an assessment of human health risk by OEHHA (Klasing and Brodberg, 2008). All values given in ng/g (ppb) wet weight. The lowest available threshold for each pollutant is in bold font. One serving is defined as 8 ounces (227 g) prior to cooking. The FCG and ATLs for mercury are for the most sensitive population (i.e., women aged 18 to 45 years and children aged 1 to 17 years)

Pollutant	Fish Contaminant Goal	Advisory Tissue Level (2 servings/week)	Advisory Tissue Level (1 serving/week)	Advisory Tissue Level (No Consumption)
Chlordanes	**5.6**	190	280	560
DDTs	**21**	520	1000	2100
Dieldrin	**0.46**	15	23	46
Mercury	220	**70**	150	440
PCBs	**3.6**	21	42	120
Selenium	7400	**2500**	4900	15000

For organic contaminants (with the exception of PBDEs), FCGs are lower than ATLs.

ATLs, as described by Klasing and Brodberg (2008):

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

For methylmercury and selenium, the 2 serving and 1 serving ATLs are lower than the FCGs.

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

For methylmercury, results were also compared to a 0.3 ppm wet weight threshold that was used by the State and Regional Water Boards in the most recent round of 303(d) listing. This threshold is based on the current USEPA Clean Water Act Section 304(a) recommended criteria document that established a criterion of 0.3 ppm for methylmercury based on a protective human health default consumption rate of 17.5 grams per day (USEPA 2001).

SECTION 3
STATEWIDE ASSESSMENT

In this two-year screening study, 3483 fish representing 46 species were collected from 68 locations on the California coast (Figures 1-3, Table 1). A concise tabulated summary of the data for each location is provided in Appendix 3. Data in an untabulated format are provided in Appendices 4 and 5. Excel files containing these tables are available from SFEI (contact Jay Davis, jay@sfei.org). All data collected for this study are maintained in the SWAMP database, which is managed by the data management team at Moss Landing Marine Laboratories (swamp.mpsl.mlml.calstate.edu/). The complete dataset includes QA data (quality control samples and blind duplicates) and additional ancillary information (specific location information, fish sex, weights, etc). The complete dataset from this study will also be available on the web at www.ceden.org/. Finally, data from this study are available on the web through the California Water Quality Monitoring Council's "My Water Quality" portal (www.waterboards.ca.gov/mywaterquality/). This site is designed to present data on contaminants in fish and shellfish from SWAMP and other programs to the public in a nontechnical manner, and allows mapping and viewing of summary data from each fishing location.

METHYLMERCURY

Comparison to Thresholds

Methylmercury is the pollutant that poses the most widespread potential health concerns to consumers of fish caught in California coastal waters.

OEHHA's no consumption advisory tissue level (ATL) of 0.44 ppm provides an upper bound threshold for assessment of methylmercury in California sport fish. This value represents a relatively high concentration above which frequent consumption might not be safe for the most sensitive fish consumers (children and women of childbearing age). OEHHA's lowest advisory tissue level for methylmercury of 0.07 ppm is a lower bound threshold. Methylmercury concentrations below this level can be considered low.

Most of the locations sampled (42 of 68, or 62%) had a moderate degree of contamination, with a most highly contaminated species below 0.44 ppm and above 0.07 ppm (Figures 4-6). One of the 68 locations (1%) was in the least contaminated category (most highly contaminated species below 0.07 ppm). Overall, 43 of 68 (63%) of locations had a most highly contaminated species below 0.44 ppm – this represents an estimate of the percentage of locations where frequent consumption of all species, at a consumption frequency to be determined in the future by OEHHA when data are sufficient for evaluation, is likely to be safe.

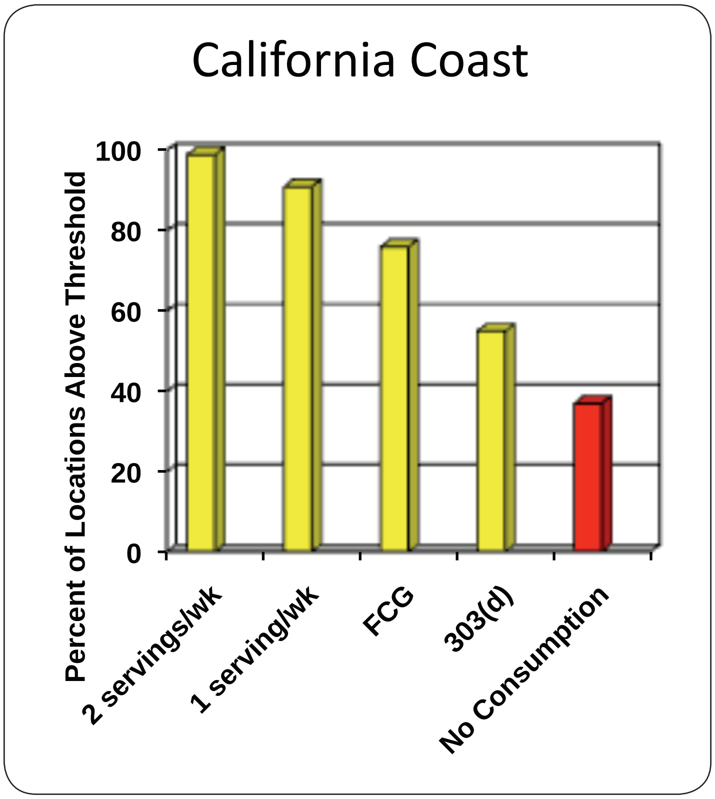

Figure 4. Percentages of coastal sampling locations above various methylmercury thresholds.

Many locations, 25 of 68 (37%), were in the high contamination category, with an average for the most contaminated species exceeding 0.44 ppm. The 95% confidence interval for this estimate was 25-48% (Figure 6). Most locations (37 of 68, or 54%) had a most highly contaminated species with an average above the State Board's 0.30 ppm 303(d) listing threshold.

Regional variation in the occurrence of locations and species with high methylmercury concentrations was observed. The North Coast (from the Oregon border to Tomales Bay) had the highest percentage of locations with at least one species above 0.44 ppm (11 of 15, or 73%). This region also had the highest frequency of occurrence of species at each location with concentrations above 0.44 ppm (red cells in Table 4 – 24 of 77, 31%). There were only nine instances where individual species had concentrations below 0.07 ppm (Table 4). Only five of 15 (33%) locations sampled had at least one species below 0.07 ppm. No location had all species below this threshold. The consistent occurrence of species that tend to accumulate high methylmercury concentrations (copper rockfish, gopher rockfish, China rockfish, cabezon, and shark species) was a primary reason for the relatively high concentrations observed in this region. All samples of copper rockfish, gopher rockfish, and China rockfish in this region were above 0.44 ppm. A relatively low proportion of bay and harbor locations, which tend to have some species that are lower in methylmercury, also contributed to the large proportion of concentrations above 0.44 ppm. None of the species sampled at multiple locations had a majority of location means below 0.07 ppm (Table 4).

The Central Coast (defined here as stretching from Point Reyes south to Point Conception) had the second highest percentage of locations (10 of 26, or 38%) with at least one species above 0.44 ppm. While the species sampled in this region were generally similar to those on the North Coast, a lower rate of occurrence of some high methylmercury species (copper and China rockfish) and a much larger proportion of bay and harbor locations (9 of 26) contributed to a lower overall degree of contamination (Table 4). Species averages for each location were predominantly (77%) in the moderate contamination category (yellow cells in Table 4), with 12% above 0.44 ppm (red) and 11% below 0.07 ppm (green). Like the North Coast, few instances of species with concentrations below 0.07 ppm were observed in this region. Only eight of 26 locations (31%) had at least one species in this low concentration category. No location had all species below the 0.07 ppm

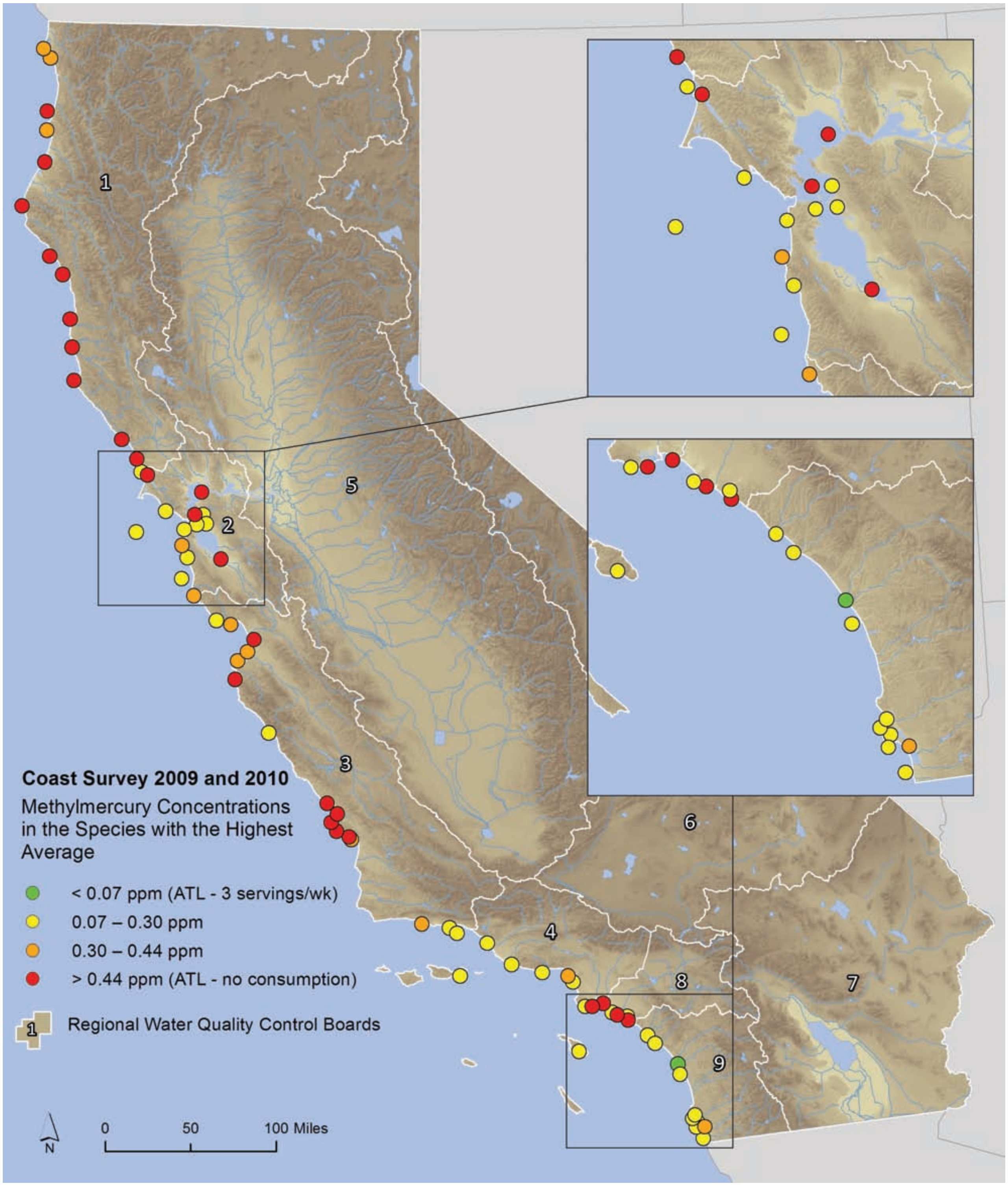

Figure 5. Spatial patterns in methylmercury concentrations among locations sampled in the Coast Survey, 2009-2010. Each point represents the highest average methylmercury concentration among the species sampled at each location.

Table 4
Classification of average methylmercury concentrations for each species at each location: North Coast. Red: >0.44 ppm . Green: <0.07 ppm . Yellow: between 0.07 and 0.44 ppm.

Coastal Species

Regional Board	Zone	Station Name	Black Rockfish	Blue Rockfish	Quillback Rockfish	Olive Rockfish	Copper Rockfish	Gopher Rockfish	China Rockfish	Vermillion Rockfish	Yellowtail Rockfish	Rosy Rockfish	Brown Rockfish	Black and Yellow Rockfish	Kelp Rockfish	Cabezon	Kelp Greenling	Lingcod	Barred Sand Bass	Kelp Bass	Spotted Sand Bass	Chub Mackerel	Spotted Scorpionfish	Pacific Barracuda	Ocean Whitefish	Rainbow Surfperch	Barred Surfperch	Black Perch	White Croaker	Black Croaker
1	68	Crescent City Coast	Yellow	Yellow	Yellow											Yellow	Yellow	Yellow												
1	67	Del Norte Coast	Yellow	Green		Green										Yellow	Yellow	Yellow												
1	66	North Humboldt County Coast Area	Yellow	Yellow	Yellow		Red	Red								Yellow		Yellow												
1	65	Trinidad Area																Yellow												
1	64	Humboldt Bay															Green													
1	62	Cape Mendocino Area	Yellow	Yellow			Red		Red							Red		Yellow												
1	61	Shelter Cove Area	Yellow	Yellow			Red	Red	Red	Yellow																				
1	60	North Mendocino County Coast Area	Yellow				Red		Red	Yellow						Red														
1	59	Fort Bragg Area	Yellow	Yellow				Red		Yellow						Red														
1	58	Mendocino Coast Area	Yellow	Yellow						Yellow	Yellow	Red				Red		Yellow												
1	57	Point Arena Area	Yellow	Yellow		Yellow		Red	Red							Yellow		Red												
1	55/56	South Sonoma Coast/North Sonoma Coast		Yellow		Yellow	Red			Yellow			Yellow																	
1	54	Bodega Harbor																								Green				
2	53	Northern Marin Coast		Green		Green							Yellow																	
2	52	Tomales Bay																												

Bay and Harbor Species

Regional Board	Zone	Station Name	Bat Ray	California Halibut	Leopard Shark	Brown Smoothhound Shark	Gray Smoothhound Shark	Spiny Dogfish	Shiner Surfperch	Pile Surfperch	White Surfperch	Yellowfin Croaker	Spotfin Croaker	Topsmelt	Jacksmelt	Striped Bass	Opaleye	Queenfish
1	68	Crescent City Coast																
1	67	Del Norte Coast																
1	66	North Humboldt County Coast Area																
1	65	Trinidad Area																
1	64	Humboldt Bay	Red	Yellow	Red				Yellow									
1	62	Cape Mendocino Area																
1	61	Shelter Cove Area																
1	60	North Mendocino County Coast Area																
1	59	Fort Bragg Area																
1	58	Mendocino Coast Area																
1	57	Point Arena Area																
1	55/56	South Sonoma Coast/North Sonoma Coast																
1	54	Bodega Harbor			Red													
2	53	Northern Marin Coast																
2	52	Tomales Bay			Red	Red			Green		Green							

Table 4 *(continued)*
Classification of average methylmercury concentrations for each species at each location: Central Coast. Red: >0.44 ppm . Green: <0.07 ppm . Yellow: between 0.07 and 0.44 ppm.

Coastal Species

Regional Board	Zone	Station Name	Black Rockfish	Blue Rockfish	Quillback Rockfish	Olive Rockfish	Copper Rockfish	Gopher Rockfish	China Rockfish	Vermillion Rockfish	Yellowtail Rockfish	Rosy Rockfish	Brown Rockfish	Black and Yellow Rockfish	Kelp Rockfish	Cabezon	Kelp Greenling	Lingcod	Barred Sand Bass	Kelp Bass	Spotted Sand Bass	Chub Mackerel	Spotted Scorpionfish	Pacific Barracuda	Ocean Whitefish	Rainbow Surfperch	Barred Surfperch	Black Perch	White Croaker	Black Croaker
2	51	Southern Marin Coast																									Yellow		Yellow	
2	206SNPBLO	San Pablo Bay (5)																												
2	203BRKLEY	Berkeley (4)																												
2	203CENTRL	Central Bay (6)																												
2	203SANFRN	San Francisco Waterfront (3)																												
2	203OAKLND	Oakland (2)																												
2	204STHBAY	South Bay (1)																												
2	50	Farallon Islands		Green		Yellow		Yellow																						
2	49	San Francisco Coast																									Yellow		Yellow	
2	48	Pacifica Coast		Yellow				Yellow										Yellow												
2	47	Half Moon Bay Coast		Yellow				Yellow					Yellow					Yellow									Yellow			
2	46	Pillar Point Harbor																										Green	Yellow	
2	45	San Mateo Coast	Green	Green		Yellow		Yellow																						
3	43	Santa Cruz Coast Area	Green	Yellow				Yellow								Yellow	Yellow	Yellow											Yellow	
3	42	Santa Cruz Area Wharfs/ Beachs						Yellow								Yellow	Yellow	Yellow											Yellow	
3	41	Elkhorn Slough																												
3	40	Moss Landing/Marina Coast	Yellow					Yellow	Yellow				Yellow	Yellow																
3	39	Monterey/Pacific Grove Coast	Yellow	Yellow				Yellow																		Yellow				
3	38	Carmel Coast		Yellow				Red		Yellow						Yellow		Red								Yellow				
3	36/37	Southern Monterey County Coast/Big Sur Coast		Green						Yellow			Yellow													Yellow				
3	34/35	Cambria/Cayucos Coast/ Northern San Luis Obispo County Coast						Red		Yellow						Yellow	Yellow										Yellow			
3	33	Morro Bay																								Yellow				
3	32	Morro Bay Coast						Yellow		Yellow		Red				Yellow														
3	31	Diablo Canyon Coast		Yellow				Red						Red	Yellow											Yellow				
3	30	Port San Luis Area						Yellow					Yellow														Yellow			
3	28/29	North Santa Barbara County Coast/Pismo Beach Area		Yellow				Yellow					Yellow					Yellow												

Bay and Harbor Species

Regional Board	Zone	Station Name	Bat Ray	California Halibut	Leopard Shark	Brown Smoothhound Shark	Gray Smoothhound Shark	Spiny Dogfish	Shiner Surfperch	Pile Surfperch	White Surfperch	Yellowfin Croaker	Spotfin Croaker	Topsmelt	Jacksmelt	Striped Bass	Opaleye	Queenfish
2	51	Southern Marin Coast																
2	206SNPBLO	San Pablo Bay (5)		Yellow	Red				Yellow						Yellow	Red		
2	203BRKLEY	Berkeley (4)							Yellow									
2	203CENTRL	Central Bay (6)		Yellow	Red											Yellow		
2	203SANFRN	San Francisco Waterfront (3)		Yellow					Yellow						Yellow			
2	203OAKLND	Oakland (2)							Yellow						Yellow			
2	204STHBAY	South Bay (1)			Red				Yellow						Yellow			
2	50	Farallon Islands																
2	49	San Francisco Coast																
2	48	Pacifica Coast																
2	47	Half Moon Bay Coast																
2	46	Pillar Point Harbor							Green		Green			Yellow				
2	45	San Mateo Coast																
3	43	Santa Cruz Coast Area																
3	42	Santa Cruz Area Wharfs/ Beachs																
3	41	Elkhorn Slough	Yellow		Red				Green					Green				
3	40	Moss Landing/Marina Coast																
3	39	Monterey/Pacific Grove Coast																
3	38	Carmel Coast																
3	36/37	Southern Monterey County Coast/Big Sur Coast																
3	34/35	Cambria/Cayucos Coast/ Northern San Luis Obispo County Coast																
3	33	Morro Bay	Yellow		Red				Green	Yellow								
3	32	Morro Bay Coast																
3	31	Diablo Canyon Coast																
3	30	Port San Luis Area																
3	28/29	North Santa Barbara County Coast/Pismo Beach Area																

Table 4 *(continued)*
Classification of average methylmercury concentrations for each species at each location: South Coast. Red: >0.44 ppm . Green: <0.07 ppm . Yellow: between 0.07 and 0.44 ppm.

Coastal Species

Regional Board	Zone	Station Name	Black Rockfish	Blue Rockfish	Quillback Rockfish	Olive Rockfish	Copper Rockfish	Gopher Rockfish	China Rockfish	Vermillion Rockfish	Yellowtail Rockfish	Rosy Rockfish	Brown Rockfish	Black and Yellow Rockfish	Kelp Rockfish	Cabezon	Kelp Greenling	Lingcod	Barred Sand Bass	Kelp Bass	Spotted Sand Bass	Chub Mackerel	Spotted Scorpionfish	Pacific Barracuda	Ocean Whitefish	Rainbow Surfperch	Barred Surfperch	Black Perch	White Croaker	Black Croaker
3	27	Goleta to Pt Conception		Green				Yellow					Yellow						Yellow	Yellow		Yellow								
3	25	Rincon to Goleta		Green		Yellow														Yellow		Green						Yellow	Yellow	
3	26	Santa Barbara Channel Oil Platform						Yellow					Yellow							Yellow		Yellow							Yellow	
3	23	Northern Channel Islands											Yellow		Yellow					Yellow								Yellow		
4	24	Ventura to Rincon																									Green		Yellow	
4	22	Pt Dume to Oxnard						Yellow												Yellow		Yellow						Green	Yellow	
4	21	North Santa Monica Bay											Yellow						Yellow	Yellow		Green						Green		
4	20	Middle Santa Monica Bay																	Yellow	Yellow		Green	Yellow				Green			Yellow
4	19	South Santa Monica Bay																	Yellow	Yellow		Green					Yellow		Yellow	
4	18	Palos Verdes						Green												Yellow		Green						Green	Yellow	
4	16	San Pedro Bay																	Yellow									Yellow	Yellow	
4	15	Long Beach																	Yellow			Yellow							Yellow	
8	14	Orange County Oil Platforms																	Yellow	Yellow		Green							Yellow	
8	13	Santa Ana River to Seal Beach																	Yellow	Yellow		Green					Green			
8	12	Newport Bay																			Yellow							Green	Yellow	
8	11	Crystal Cove to Santa Ana River																	Yellow	Yellow		Green							Yellow	
9	10	Dana Point Harbor																											Yellow	
9	9	San Onofre to Crystal Cove																	Yellow	Yellow		Yellow								
4	17	Catalina Island										Yellow								Yellow		Green						Yellow		
9	8	Oceanside Harbor																											Green	
9	7	La Jolla to San Onofre																	Yellow	Yellow		Green							Yellow	
9	6	Mission Bay																			Yellow									
9	5	Pt Loma to La Jolla						Yellow			Yellow									Yellow		Green								
9	4	Pt Loma						Yellow											Yellow	Yellow		Green						Yellow	Yellow	
9	3	SD North Bay																	Yellow		Yellow	Green								
9	2	SD South Bay																			Yellow	Green								
9	1	TJ to North Island																	Yellow	Yellow		Yellow	Yellow						Yellow	

Bay and Harbor Species

Regional Board	Zone	Station Name	Bat Ray	California Halibut	Leopard Shark	Brown Smoothhound Shark	Gray Smoothhound Shark	Spiny Dogfish	Shiner Surfperch	Pile Surfperch	White Surfperch	Yellowfin Croaker	Spotfin Croaker	Topsmelt	Jacksmelt	Striped Bass	Opaleye	Queenfish
3	27	Goleta to Pt Conception																
3	25	Rincon to Goleta																
3	26	Santa Barbara Channel Oil Platform									Green							
3	23	Northern Channel Islands																
4	24	Ventura to Rincon							Green									
4	22	Pt Dume to Oxnard																
4	21	North Santa Monica Bay																
4	20	Middle Santa Monica Bay																
4	19	South Santa Monica Bay																
4	18	Palos Verdes																
4	16	San Pedro Bay						Red	Green		Green							
4	15	Long Beach		Green		Red			Green			Green		Green				
8	14	Orange County Oil Platforms																
8	13	Santa Ana River to Seal Beach				Red							Green					
8	12	Newport Bay							Green					Green				
8	11	Crystal Cove to Santa Ana River				Red												
9	10	Dana Point Harbor							Green		Green		Green	Green			Green	
9	9	San Onofre to Crystal Cove																
4	17	Catalina Island																
9	8	Oceanside Harbor									Green	Green	Green					Green
9	7	La Jolla to San Onofre																
9	6	Mission Bay									Green	Yellow		Green				
9	5	Pt Loma to La Jolla																
9	4	Pt Loma																
9	3	SD North Bay					Yellow		Green									
9	2	SD South Bay					Yellow		Yellow			Yellow						
9	1	TJ to North Island																

Table 4 *(continued)*
Classification of average methylmercury concentrations for each species at each location: summary statistics for the entire coast. Red: >0.44 ppm . Green: <0.07 ppm . Yellow: between 0.07 and 0.44 ppm.

			Coastal Species																												Bay and Harbor Species															
Regional Board	Zone	Station Name	Black Rockfish	Blue Rockfish	Quillback Rockfish	Olive Rockfish	Copper Rockfish	Gopher Rockfish	China Rockfish	Vermillion Rockfish	Yellowtail Rockfish	Rosy Rockfish	Brown Rockfish	Black and Yellow Rockfish	Kelp Rockfish	Cabezon	Kelp Greenling	Lingcod	Barred Sand Bass	Kelp Bass	Spotted Sand Bass	Chub Mackerel	Spotted Scorpionfish	Pacific Barracuda	Ocean Whitefish	Rainbow Surfperch	Barred Surfperch	Black Perch	White Croaker	Black Croaker	Bat Ray	California Halibut	Leopard Shark	Brown Smoothhound Shark	Gray Smoothhound Shark	Spiny Dogfish	Shiner Surfperch	Pile Surfperch	White Surfperch	Yellowfin Croaker	Spotfin Croaker	Topsmelt	Jacksmelt	Striped Bass	Opaleye	Queenfish
		# above 0.44 ppm	0	0	0	0	6	7	4	0	0	2	0	1	0	4	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	8	4	0	1	0	0	0	0	0	0	0	1	0	0
		# between 0.07 and 0.44 ppm	12	16	1	8	0	16	1	10	2	1	11	1	2	9	5	11	14	18	4	6	2	1	1	5	6	5	20	1	2	4	0	0	2	0	7	1	0	2	0	1	4	1	0	0
		# below 0.07 ppm	2	7	0	2	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	14	0	0	0	1	3	5	1	0	0	1	0	0	0	0	11	0	7	2	3	6	0	0	1	1
		Total	14	23	1	10	6	24	5	10	2	3	11	2	3	13	6	13	14	18	4	20	2	1	1	6	9	10	21	1	3	5	8	4	2	1	18	1	7	4	3	7	4	2	1	1
		% above 0.44 ppm	0	0	0	0	100	29	80	0	0	67	0	50	0	31	0	15	0	0	0	0	0	0	0	0	0	0	0	0	33	0	100	100	0	100	0	0	0	0	0	0	0	50	0	0
		% between 0.07 and 0.44 ppm	86	70	100	80	0	67	20	100	100	33	100	50	67	69	83	85	100	100	100	30	100	100	100	83	67	50	95	100	67	80	0	0	100	0	39	100	0	50	0	14	100	50	0	0
		% below 0.07 ppm	14	30	0	20	0	4	0	0	0	0	0	0	33	0	17	0	0	0	0	70	0	0	0	17	33	50	5	0	0	20	0	0	0	0	61	0	100	50	100	86	0	0	100	100

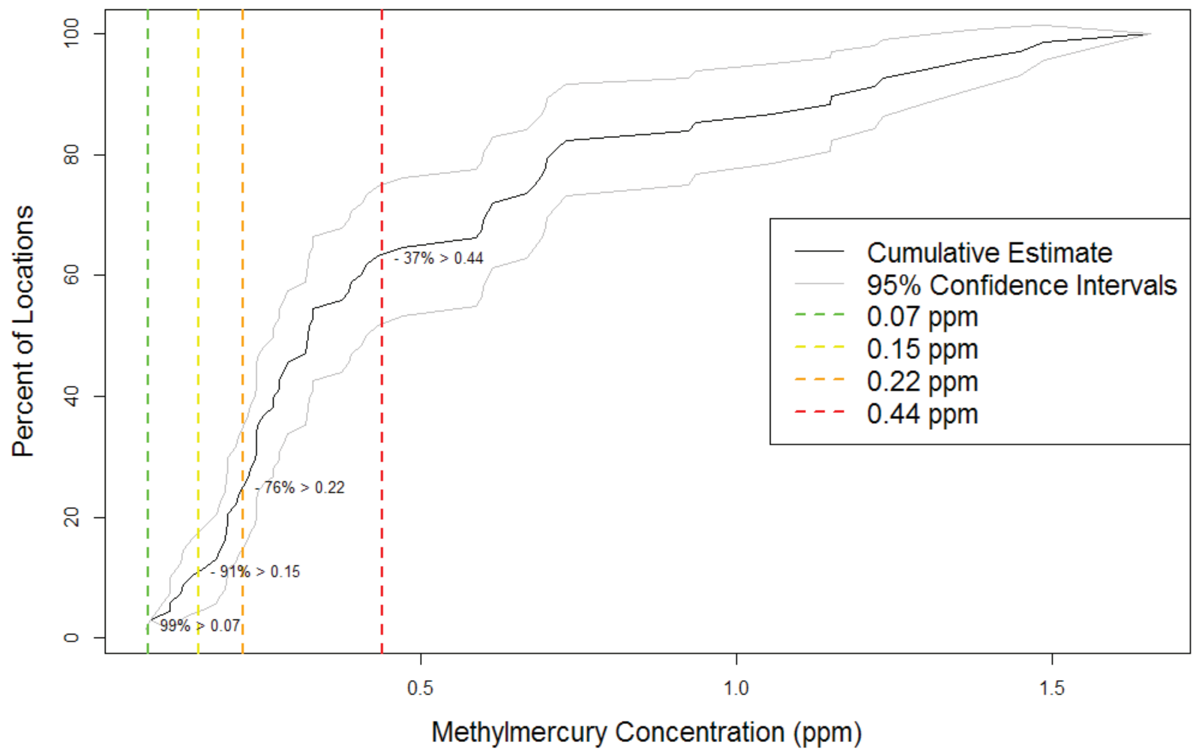

Figure 6. Cumulative distribution function (CDF) plot for methylmercury, shown as percent of locations sampled. Based on the highest species average concentration (ppm wet weight) for each location. Vertical lines are threshold values.

threshold. Gopher rockfish and cabezon were sampled at multiple locations in this region, and, in contrast to the North Coast, gopher rockfish exceeded 0.44 ppm at only three of 14 locations (compared to four of four in the North Coast) and cabezon was below 0.44 ppm at all five locations (compared to four of eight above in the North Coast). None of the species sampled at multiple locations had a majority of location means below 0.07 ppm.

The South Coast (from Point Conception south to the Mexican border) had a markedly lower proportion of locations and species above 0.44 ppm, and a much higher proportion below 0.07 ppm. In this region species-location means exceeded 0.44 ppm in only four of 139 (3%) instances. Shark samples accounted for all four location means above 0.44 ppm. On the other hand, a relatively large proportion of species-location means (48 of 139, 35%) were below 0.07 ppm. Chub mackerel, a popular species on the outer coast, accounted for many of these low location means, with 14 of 20 (70%) below 0.07 ppm. Other species sampled at multiple locations and with a majority of location means below 0.07 ppm included blue rockfish, barred surfperch, shiner surfperch, white surfperch, spotfin croaker, and topsmelt.

One important factor that likely contributes to the cleaner status of the South Coast is the difference in the suite of species sampled compared to the North and Central coasts. The species most commonly sampled at locations on the outer North and Central coasts were various rockfish species, cabezon, kelp greenling, lingcod, rainbow surfperch, and barred surfperch. In contrast, the species most commonly sampled on the outer South Coast were kelp bass, barred sand bass, and chub mackerel.

The species sampled in bays and harbors were more consistent across the state, mainly due to the presence of shiner surfperch in the North, Central, and South coast regions. Regional comparisons to methylmercury thresholds for a few species that were present in all regions appear to suggest that food web contamination is lower in the South. In particular, concentrations in gopher rockfish, barred surfperch, and shiner surfperch were more frequently in the lower threshold categories in the South. However, examination of size-adjusted data, presented in the Spatial Patterns section below, indicate a lack of distinct regional differences. In other words, the species sampled in the South tended to be smaller and younger, and therefore had lower methylmercury concentrations.

Another way to assess concentrations relative to the thresholds is to base the comparisons on the least contaminated species at each location. This provides an indication of the availability of low methylmercury species. Using this metric, five of 15 North Coast locations (33%), nine of 26 (35%) on the Central Coast, and 24 of 27 (89%) on the South Coast were below 0.07 ppm. Across the entire coast, 38 of 68 (56%) locations had at least one low methylmercury species.

Variation Among Species

A large amount of the variation observed in this dataset is due to differences among species in the degree to which they accumulate methylmercury. The strong influence of interspecific variation on methylmercury accumulation is illustrated by the frequent occurrence of shark species with concentrations above 1 ppm at the same locations as other species with concentrations below 0.07 ppm. In addition to these extreme examples, consistent patterns of interspecific variation were also observed among the other species sampled. These patterns resulted in large differences among species in the distribution of location means among the concentration categories (Table 4) and in the overall species means for the dataset as a whole (Figure 7). Factors that can vary among species and have a substantial influence on methylmercury accumulation include age (with length often used as a surrogate for age), trophic position, physiology, concentrations in prey, and habitat type (Wiener et al. 2007, Sandheinrich and Wiener 2011).

Seven species had statewide average methylmercury concentrations above 0.44 ppm: three shark species (leopard, brown smoothhound, and spiny dogfish), three rockfish species (copper, rosy, and China), and striped bass (Figure 7). These species are generally long-lived and high trophic level predators (Appendix 1). More detailed discussion of the species that accumulated high concentrations is provided later in this section.

Other species with relatively high average methylmercury concentrations included black croaker (0.41 ppm), cabezon (0.39 ppm), black and yellow rockfish (0.39 ppm), quillback rockfish (0.39 ppm), gopher

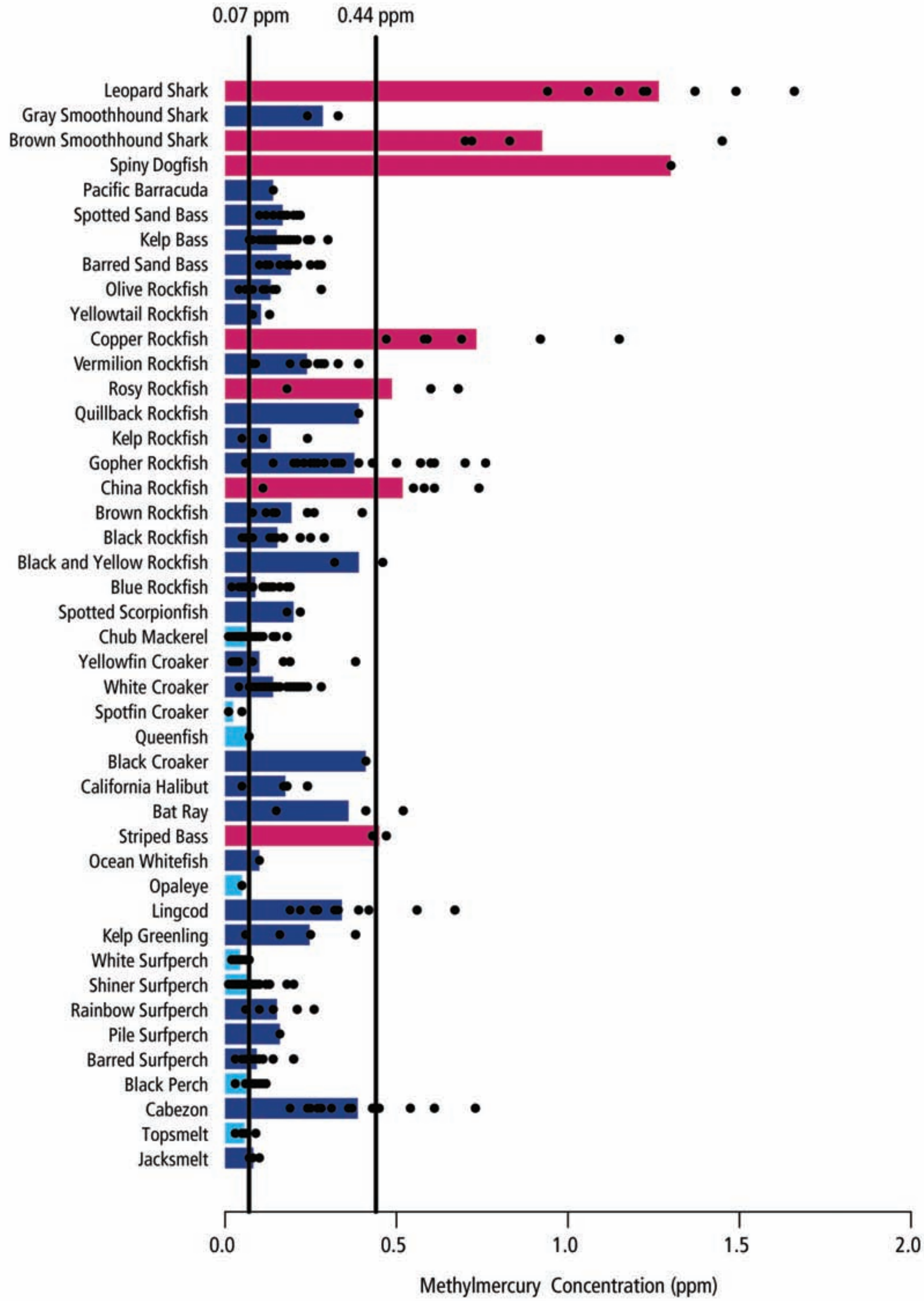

Figure 7. Methylmercury concentrations (ppm wet weight) in sport fish species on the California coast, 2009-2010. Bars indicate average concentration. Points represent individual samples (either composites or individual fish). Note that the averages for some species (e.g., spiny dogfish) are based on only one sample. Red line indicates 0.44 ppm; green line indicates 0.07 ppm.

rockfish (0.38 ppm), bat ray (0.36 ppm), and lingcod (0.34 ppm) (Figure 7). Of these species, cabezon, gopher rockfish, and lingcod were sampled at a sufficient number of locations for a reasonable estimate of the average concentration, and each of these three species had multiple locations that exceeded 0.44 ppm. Lingcod have a high estimated trophic position (4.3) and moderate age (5-6 yr) (Appendix 1). Gopher rockfish and cabezon have a similar trophic position (both at 3.6), but gopher rockfish have a much higher estimated age (7 yr) than cabezon (3-4 yr) (Appendix 1). These three species all occupy similar habitats. Given these considerations, cabezon accumulated surprisingly high concentrations.

Three species with samples from more than two locations had average concentrations below 0.07 ppm: chub mackerel, white surfperch, and topsmelt (Figure 7). Average white surfperch concentrations at all locations were below 0.07 ppm (Table 4). All but one topsmelt locations were below this threshold. Chub mackerel were below 0.07 ppm at most (14 of 20, 70%) locations. These species occupy a relatively low trophic position and are generally shorter-lived (Appendix 1). The estimate for chub mackerel is particularly robust, based on measurements in 58 composite samples. Chub mackerel are unusually fast-growing: the fish sampled had an average length of 240 mm, which in this species corresponds to an age of one year. This is a positive outcome as chub mackerel is one of the most popular sport fish species on the South Coast.

Sharks

Average concentrations in two shark species exceeded 1 ppm: leopard shark at 1.27 ppm and spiny dogfish at 1.30 ppm, though the latter was based on only one sample. Brown smoothhound had an average of 0.93 ppm based on four samples. One shark species (gray smoothhound) had a lower average (0.29 ppm), though based on only two samples. The high concentrations observed in the shark samples collected in this study are consistent with past monitoring in California (Gassel et al. 2002, Davis et al. 2006) and in other parts of the world (e.g., Pethybridge et al. 2009, Suk et al. 2009, Newman et al. 2011) indicating that sharks often accumulate exceptionally high concentrations of methylmercury. The age of the sharks sampled appears to be an important factor influencing methylmercury accumulation (Appendix 1). Age versus length curves are available for three of the shark species sampled. Two of the species with very high concentrations are long-lived, with the specimens collected having estimated average ages of 16 yr (leopard shark) and 15 yr or greater (brown smoothhound). The gray smoothhound, on the other hand, had an estimated average age of 2 yr. A growth curve for spiny dogfish was not available.

Rockfish

The thirteen rockfish species sampled exhibited wide variation in methylmercury concentrations. Four species had location means that frequently exceeded 0.44 ppm: copper, rosy, gopher, and China (Figure 7, Table 4). Plots of location mean length (not size adjusted) versus location mean methylmercury for the rockfish (Figure 8) indicate strong relationships. Wide variation among species in age versus length growth curves and the size/age of the fish sampled for these species are likely a primary driver of the spatial patterns observed. The three species with the highest average concentrations also had the highest estimated ages: copper rockfish at 0.73 ppm mercury and 9 yr; China rockfish at 0.52 ppm and 11 yr; and rosy rockfish

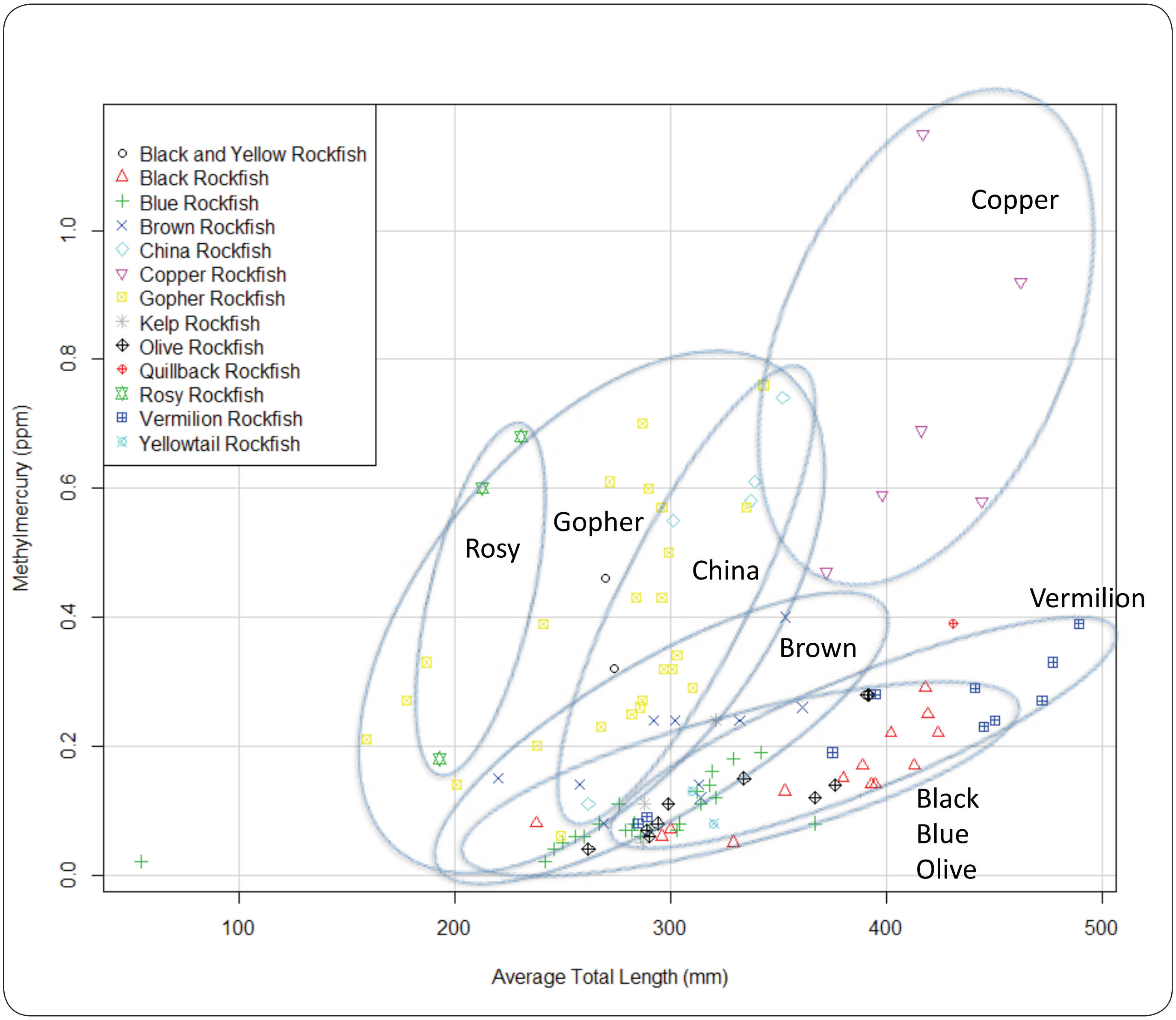

Figure 8. Methylmercury (ppm wet weight) versus length (mm) for rockfish species. Each point represents an average concentration and average length for a sampling location.

at 0.49 ppm and 8 yr (Figure 7). Olive rockfish were at the other end of the rockfish age spectrum with an estimated average age of 4 yr, and a correspondingly low average methylmercury concentration of 0.13 ppm.

Trophic position was also likely a factor influencing variation among the rockfish species. Blue rockfish were collected in many locations across all three regions, and had the lowest average concentration and the highest frequency of locations below 0.07 ppm (7 of 23 locations with blue rockfish, or 30%). Based on trophic position estimates from Fishbase (www.fishbase.org), blue rockfish is the one species sampled with a significantly different trophic position (2.8 ± 0.3, mean and s.e.) from the other species, which range from 3.4 to 4.4 with minimum standard errors of each mean of 0.5 (Appendix 1).

Black rockfish, on the other hand, had the highest estimated trophic position among the rockfish species sampled (4.4), yet had a relatively low average methylmercury concentration. Black rockfish were also in the middle of the rockfish age range, with an estimated average age of 7 yr. Habitat use may be another important factor and provide an explanation for the black rockfish results. Three of the rockfish species (black, blue, and olive) are classified as pelagic species. These three species all had relatively low methylmercury concentrations, suggesting that perhaps the coastal pelagic food webs are less contaminated than the benthic food webs.

This discussion of the influence of age, trophic position, and habitat on methylmercury in rockfish and other species, while likely accurate at a general level, is all rather speculative. None of these parameters were directly measured, and these factors can vary considerably in space and time.

Striped Bass

Striped bass, collected only in San Francisco Bay, was the one other species that had an average methylmercury concentration (0.45 ppm) above 0.44 ppm. This average was based on only two locations in the Bay, but this is a robust estimate due to the number of fish analyzed and repeated sampling of the Bay over the past 40 yr. The estimated age of striped bass at the average length collected was moderate compared to the other species (6 yr) (Appendix 1). However, striped bass tied with Pacific barracuda and California halibut for the highest trophic position (4.5) among all of the species sampled. The methylmercury concentrations observed were consistent with this age and trophic position.

Spatial Patterns

Regional variation in how methylmercury concentrations compared to OEHHA thresholds was discussed above. This section provides a more quantitative assessment of spatial patterns in order to attempt to discern whether the degree of food web contamination really varies among the regions. If significant variation exists, this could suggest a need for different control strategies in different regions or for placing a higher priority on managing the most contaminated areas.

Methylmercury concentrations in a given species vary with the age, trophic position, habitat use, and prey selection of the specimens collected, and these attributes all can vary across time and space. These variables must be controlled or adjusted to obtain an accurate evaluation of spatial variation in the degree of food web contamination. In this survey, length data were recorded that can be used as a surrogate for age to adjust for this important variable. Size-adjusted data for methylmercury in a few species are presented in this section (and only in this section) as part of a more thorough evaluation of spatial patterns. Data on trophic position, habitat use, and diet were not collected, so adjustments for these factors were not possible.

Species with the greatest spatial coverage were the focus of this evaluation. Unfortunately, the change in the fish community assemblage from north to south precluded sampling of any one species across the entire study area. The two coastal species with the greatest coverage were gopher rockfish (24 locations) and blue rockfish (23 locations) (Table 4). Both of these species were largely absent from the South Coast, however. Black rockfish and olive rockfish had moderately good coverage in the North and Central regions (13 and 10 locations, respectively). In coastal waters in the South, kelp bass were widely distributed and sampled (18 locations). Chub mackerel were sampled at more South Coast locations (20) but are less useful for evaluating patterns due to their low degree of contamination. The sampling plan identified blue rockfish, black rockfish, olive rockfish, and kelp bass as potential spatial indicators and called for analysis of individual fish for these species to support analysis of covariance (ANCOVA). Unfortunately, gopher rockfish were only analyzed as individuals at 13 locations, precluding ANCOVA for this species.

Shiner surfperch was the most consistently sampled species in bays and harbors – they were collected at 17 locations spread across the three regions. White croaker were collected at 24 locations, but this species was collected in both bays and harbors and coastal waters making it less useful for regional comparisons.

Methylmercury concentrations in blue rockfish adjusted to a standard size of 290 mm (Figure 9) for the sole purpose of evaluating spatial patterns indicate a lack of distinct spatial variation among the three regions. The adjusted concentrations were consistently low, hovering near the 0.07 ppm threshold. Even the sample from the Farallon Islands, 18 miles offshore of the mainland of California, had a concentration approaching 0.07 ppm and the statewide size-adjusted blue rockfish mean of 0.09 ppm.

Gopher rockfish concentrations could not be size-adjusted by ANCOVA due to a lack of data on individual fish at all locations. A correlation of location mean methylmercury with location mean size was apparent, however (Figure 8). The residuals of the length-methylmercury regression for these location means (Figure 10) were examined as a less powerful method of obtaining a spatial assessment adjusted for size. Although the sample size was small, the gopher rockfish at the four North Coast locations sampled all had relatively high concentrations. The distributions of concentrations in the Central and South regions were similar and lower on average than the North. The Farallon Island mean (0.20 ppm) again was comparable to the low end of the range for other coastal locations, and well above the 0.07 ppm threshold.

Size-standardized methylmercury concentrations in black rockfish and olive rockfish (Figure 9) were generally similar across the regions, with the highest values on the Central Coast.

Size-standardized kelp bass concentrations (Figure 9) were quite consistent across the South Coast, with 17 of the 18 locations ranging between 0.07 and 0.20 ppm. One location (the northernmost one in the region—Goleta to Pt. Conception) stood out with a lower value of 0.07 ppm. The kelp bass data suggest rather uniform food web contamination across this region.

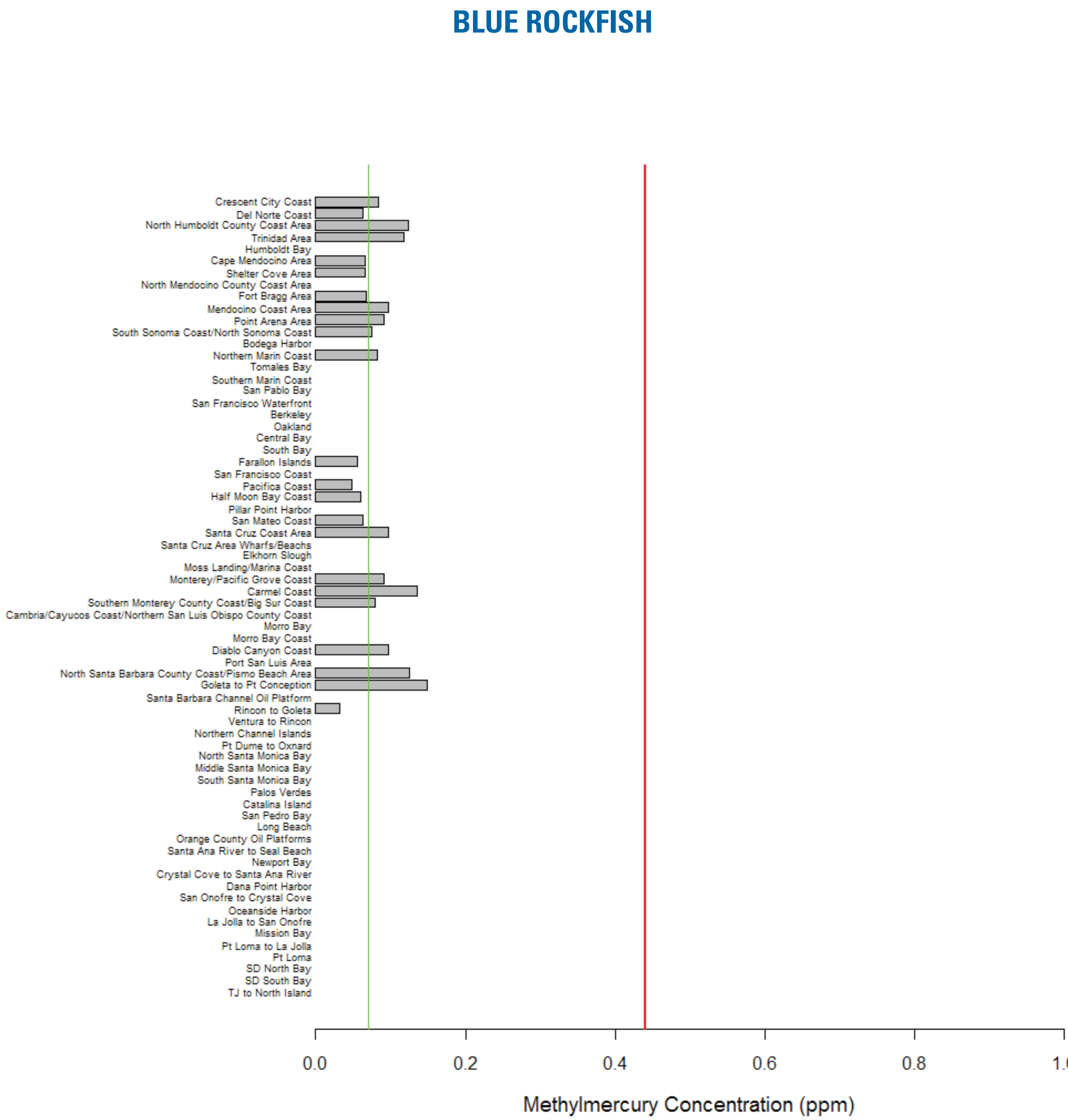

Figure 9a. Methylmercury concentrations (ppm wet weight) in species with wide distributions. See Methods for description of procedures for estimating concentrations at a standard size for blue rockfish, black rockfish, olive rockfish, and kelp bass. Red line indicates 0.44 ppm; green line indicates 0.07 ppm.

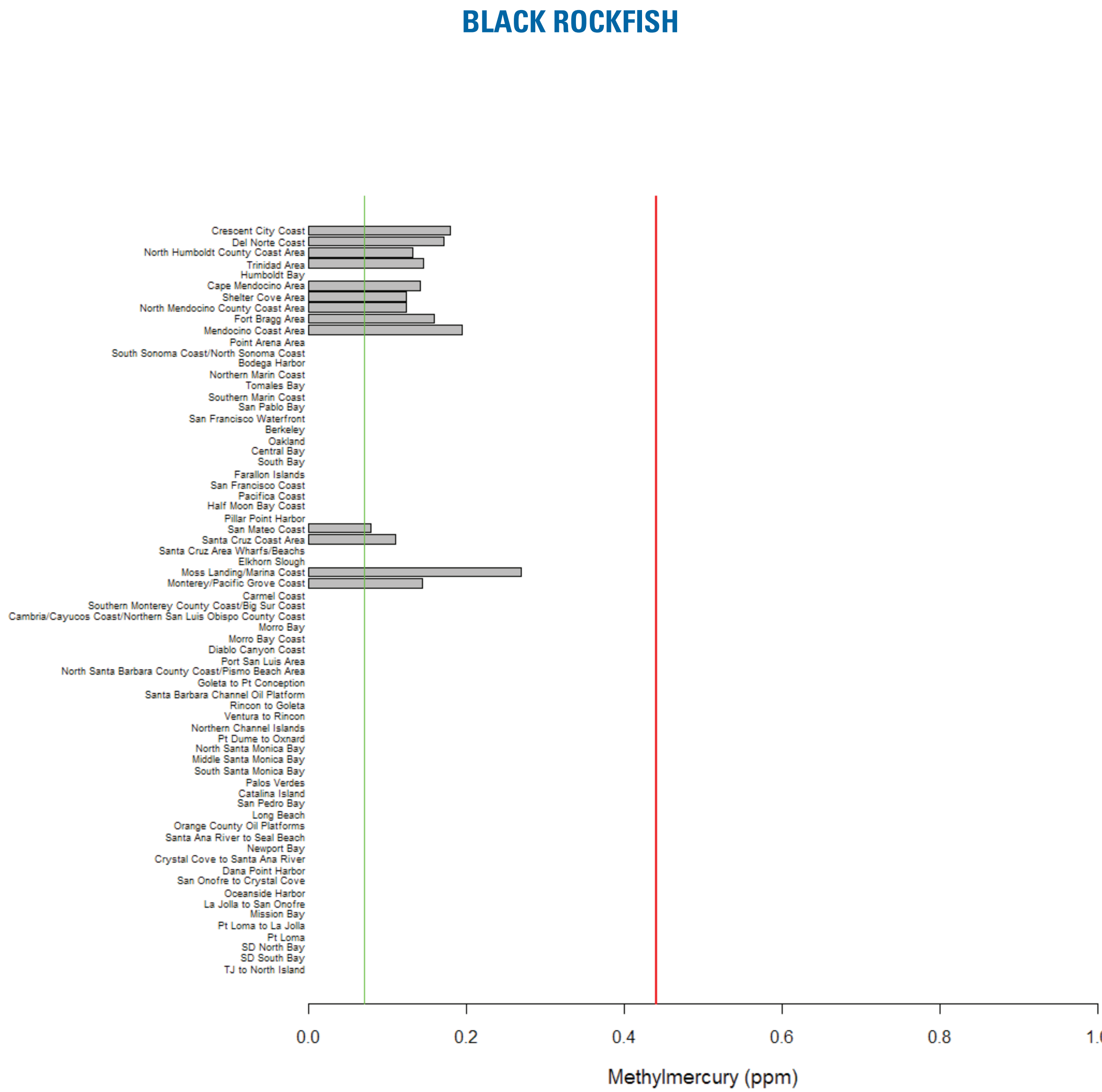
BLACK ROCKFISH
Crescent City Coast
Del Norte Coast
North Humboldt County Coast Area
Trinidad Area
Humboldt Bay
Cape Mendocino Area
Shelter Cove Area
North Mendocino County Coast Area
Fort Bragg Area
Mendocino Coast Area
Point Arena Area
South Sonoma Coast/North Sonoma Coast
Bodega Harbor
Northern Marin Coast
Tomales Bay
Southern Marin Coast
San Pablo Bay
San Francisco Waterfront
Berkeley
Oakland
Central Bay
South Bay
Farallon Islands
San Francisco Coast
Pacifica Coast
Half Moon Bay Coast
Pillar Point Harbor
San Mateo Coast
Santa Cruz Coast Area
Santa Cruz Area Wharfs/Beachs
Elkhorn Slough
Moss Landing/Marina Coast
Monterey/Pacific Grove Coast
Carmel Coast
Southern Monterey County Coast/Big Sur Coast
Cambria/Cayucos Coast/Northern San Luis Obispo County Coast
Morro Bay
Morro Bay Coast
Diablo Canyon Coast
Port San Luis Area
North Santa Barbara County Coast/Pismo Beach Area
Goleta to Pt Conception
Santa Barbara Channel Oil Platform
Rincon to Goleta
Ventura to Rincon
Northern Channel Islands
Pt Dume to Oxnard
North Santa Monica Bay
Middle Santa Monica Bay
South Santa Monica Bay
Palos Verdes
Catalina Island
San Pedro Bay
Long Beach
Orange County Oil Platforms
Santa Ana River to Seal Beach
Newport Bay
Crystal Cove to Santa Ana River
Dana Point Harbor
San Onofre to Crystal Cove
Oceanside Harbor
La Jolla to San Onofre
Mission Bay
Pt Loma to La Jolla
Pt Loma
SD North Bay
SD South Bay
TJ to North Island
0.0
0.2
0.4
0.6
0.8
1.0
Methylmercury (ppm)

Figure 9b.

OLIVE ROCKFISH

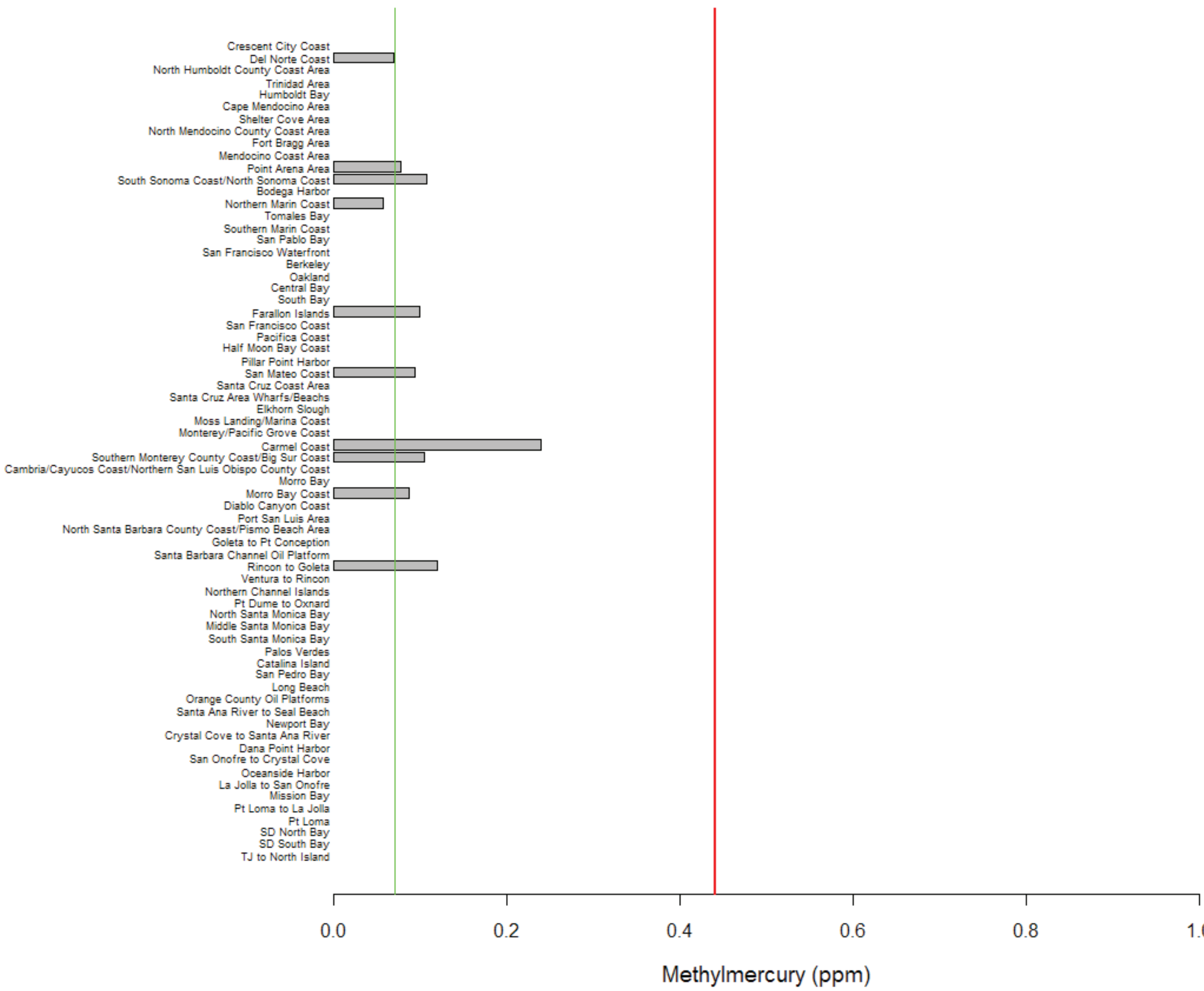

Figure 9c.

SHINER SURFPERCH

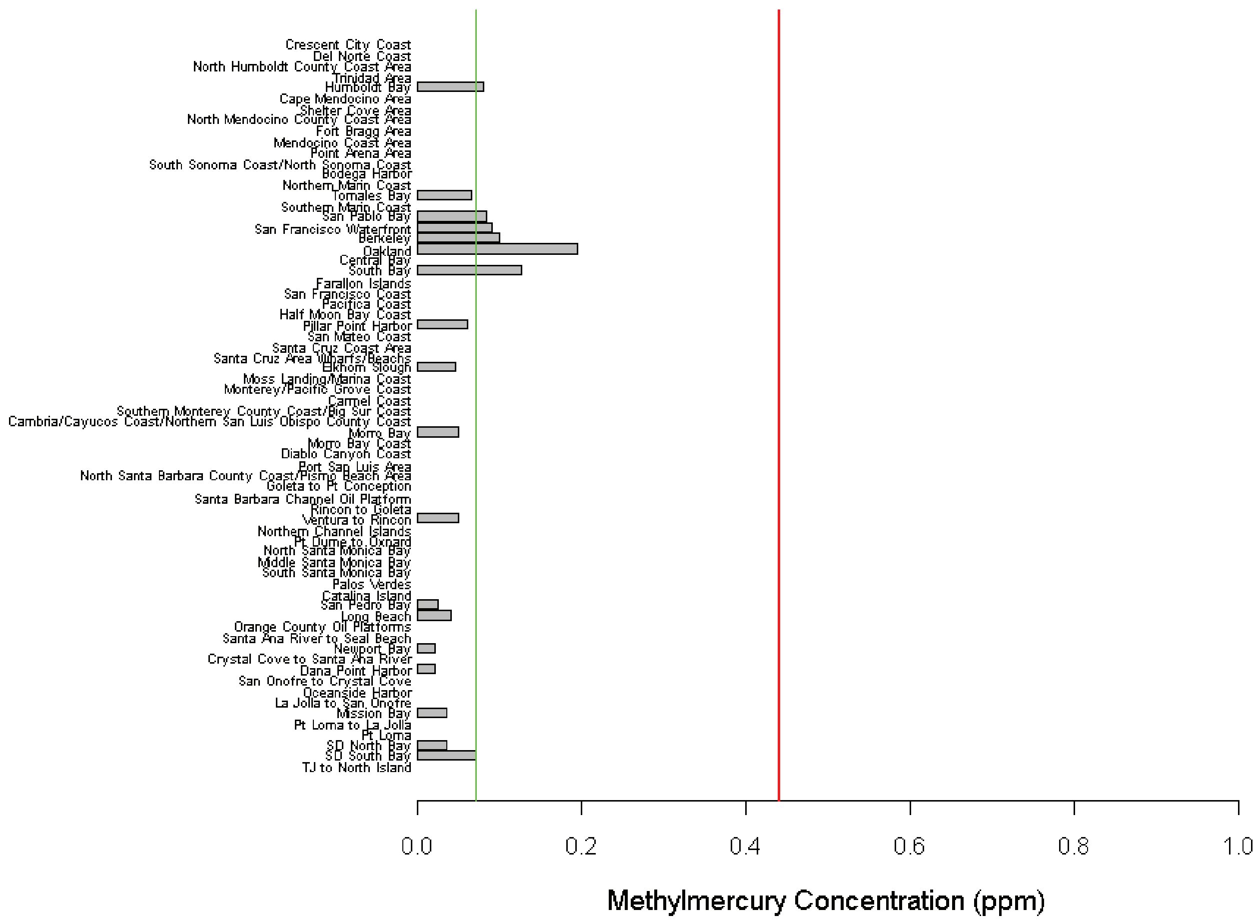

Figure 9d.

KELP BASS

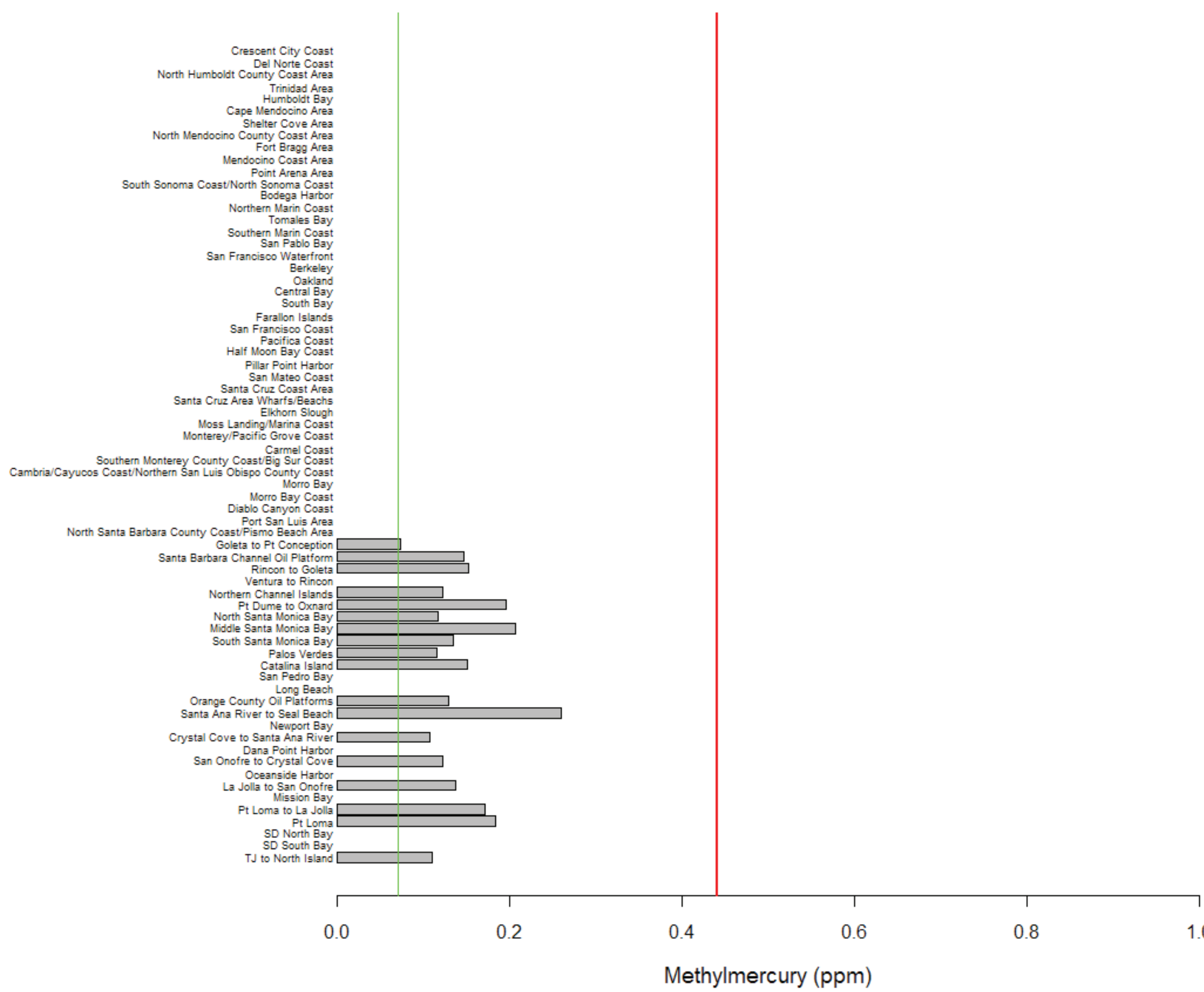

Figure 9e.

BARRED SAND BASS

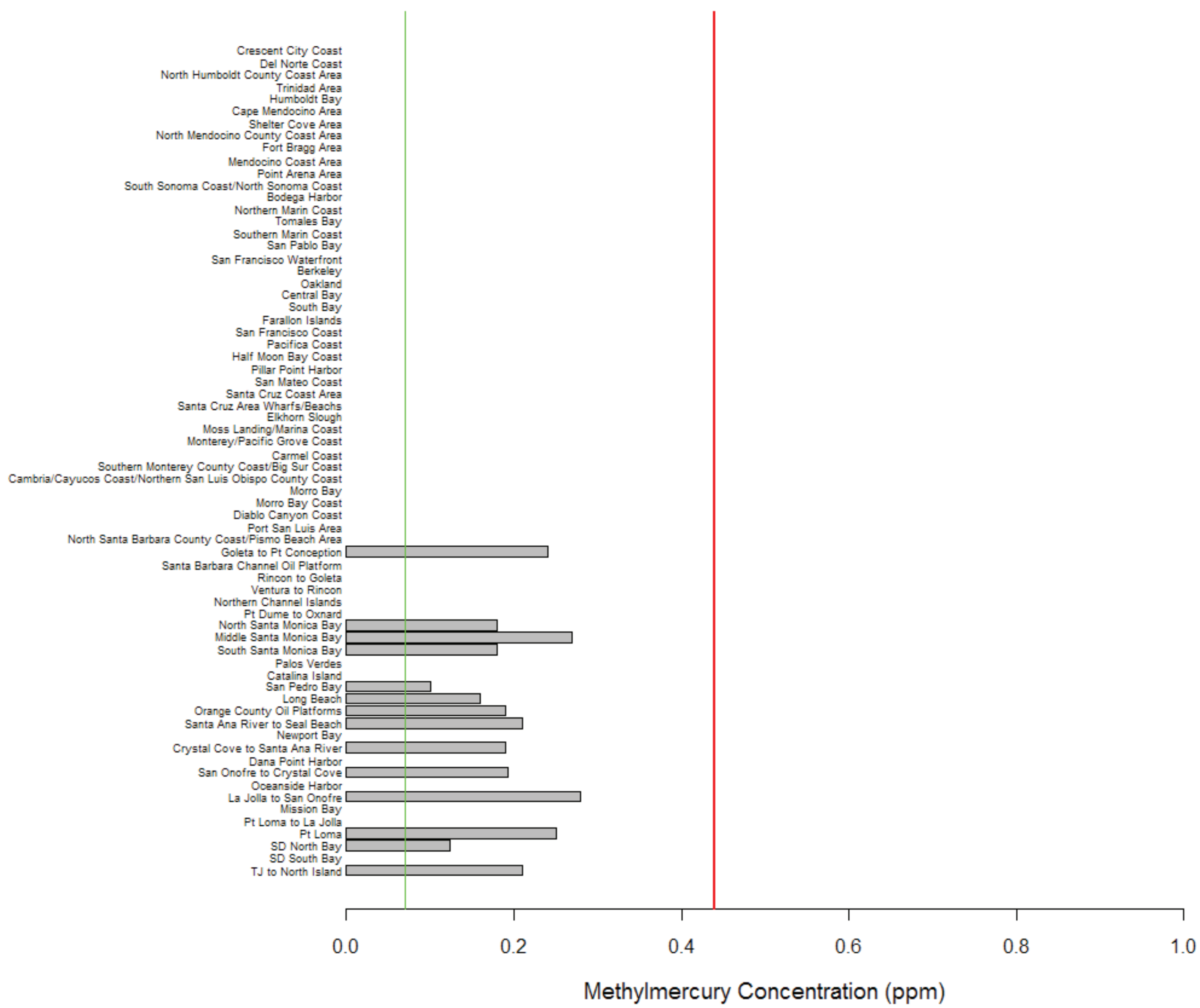

Figure 9f.

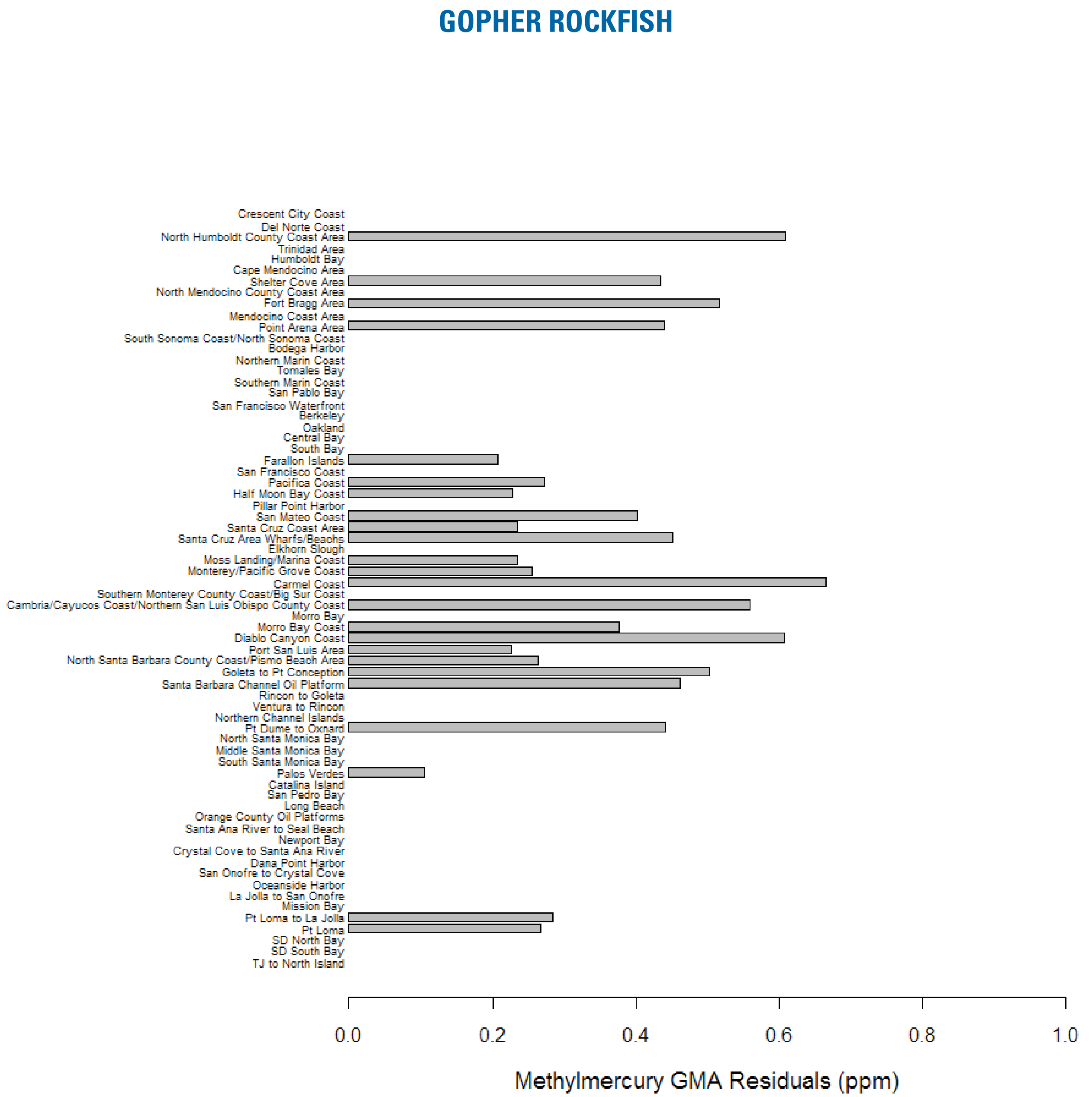

Figure 10. Length-adjusted methylmercury concentrations (ppm wet weight) in gopher rockfish. Bars represent the residuals of a regression of location average length versus location average methylmercury, added to the grand mean for the whole dataset.

The data for shiner surfperch, the best statewide spatial indicator species for bays and harbors, document elevated methylmercury concentrations in the San Francisco Bay food web (Figure 9). The large number of fish that went into these shiner surfperch averages (585 in total) makes for robust estimates. The five locations sampled in the Bay accounted for the five highest concentrations for this species statewide (Figure 9). Oakland Harbor in particular stood out with the highest concentration (0.19 ppm). Only two other locations (Humboldt Bay and San Diego South Bay) had concentrations above 0.07 ppm.

Due to the patchy distribution of species and the limited availability of data on individual fish, the results from this survey were of limited utility in performing regional comparisons. The size-adjusted data that are available, however, do not appear to indicate clear regional differences in the degree of methylmercury contamination of coastal food webs. San Francisco Bay, based on the shiner surfperch results, was the only area that stood out as having distinctly elevated concentrations.

Temporal Trends

Few data are available to assess long-term trends in methylmercury concentrations in sport fish on the California coast. Historic data are very limited for the rockfish family, which stood out as important indicators in this survey. The one major statewide coastal sport fish monitoring program that existed prior to this effort was the Coastal Fish Contamination Program (CFCP). This was a short-lived program (1999-2003) of limited scope. Few rockfish samples were analyzed by the CFCP.

A relatively extensive historical dataset exists for striped bass in San Francisco Bay, allowing evaluation of trends over 39 years from 1971-2009 (Davis et al. 2011). Overall, intra-annual variance has been high and average size-standardized concentrations in recent years are not significantly different from those measured in the early 1970s.

There have been few studies of methylmercury concentrations in sport fish from the South Coast. The most prominent study available for comparison was conducted in 2002 and used for the existing fish consumption advisory in the Los Angeles area (NOAA 2007). Davis et al. (2011) concluded that concentrations in kelp bass, chub mackerel, and white croaker between the two surveys were similar and that tissue concentrations have remained steady in the area near Los Angeles between 2002 and 2009.

Comparison to Other Parts of the World

Few studies have been published on mercury in the rockfish or shark species sampled in the present survey. For rockfish, the most comprehensive dataset for comparison was described by West et al. (2001). These authors summarized fish monitoring by the the Puget Sound Ambient Monitoring Program (PSAMP) from 1989-1999, including data for four rockfish species. Three of these species (brown, copper, and quillback) were also sampled in the present survey. The PSAMP also determined the ages of the fish sampled. Brown rockfish had a mean age of 22 yr, mean length of 258 mm, and a mean mercury concentration of 0.75 ppm in 12 composite samples (compared to a median length of 302 mm and mean mercury of 0.19 ppm in this study). Copper rockfish had a mean age of 6 yr, mean length of 322 mm, and a mean mercury concentration of 0.15 ppm in 36 composite samples (compared to a median length of 411 mm and mean mercury of 0.73 ppm in this study). Quillback rockfish, the most intensively sampled rockfish species in the PSAMP, had a mean age of 14 yr, mean length of 316 mm, and a mean mercury concentration of 0.30 ppm in 226 composite samples (compared to a median length of 431 mm and mean mercury of 0.39 ppm in this study). The PSAMP also collected two samples of another species, yelloweye rockfish, that had a mean age of 73 yr and the highest mean mercury that they observed (1.18 ppm). Mean mercury in other species sampled by PSAMP were relatively low: 0.06 ppm in English sole (492 composites); 0.09 ppm in chinook salmon (106 composites); and 0.05 ppm in coho salmon (108 composites). The PSAMP data provide further evidence of the tendency of long-lived predatory rockfish species to accumulate relatively high methylmercury concentrations.

Other published rockfish studies have also documented the potential for rockfish species to accumulate high concentrations of mercury. deBruyn et al. (2006) reported site mean concentrations ranging between 0.04 ppm to 0.43 ppm for copper and quillback rockfish. Due to a lack of significant differences between these species, the data were pooled and lengths and ages were not provided or discussed.

Published data on sharks are also very limited, particularly for the species sampled in the SWAMP survey. Childs and Gaffke (1971) reported a mean mercury concentration of 0.60 ppm in 88 samples of spiny dogfish (compared to 1.3 ppm in one sample in this study). Garcia-Hernandez et al. (2007) reported a concentration of 0.08 ppm in one 100 cm leopard shark from the Gulf of California.

Published studies of other shark species indicate a tendency to accumulate high concentrations of mercury, even far from anthropogenic sources. Newman et al. (2011) examined three deepwater species at three North Atlantic locations. Despite the long distances from anthropogenic sources, all species from all locations had mean concentrations exceeding 1.72 ppm. Pethybridge et al. (2009) examined 16 demersal shark species on the southeast coast of Australia. Twelve of the species sampled had mean concentrations above 1 ppm, and only one species had a mean concentration below 0.5 ppm. Ages were not measured but likely ranged between 15 and 48 years. Suk et al. (2009) measured mercury in common thresher and shortfin mako sharks, two species of commercial and recreational importance, off the coast of southern California. Higher concentrations in shortfin mako (1.13 ppm versus 0.13 ppm) were attributed to higher trophic position and higher daily food intake. Each of these studies concluded that trophic position was an important factor influencing accumulation. Only Pethybridge et al. (2009), however, included any discussion of the influence of age.

On the other hand, several studies have been published on mercury in striped bass in US estuaries. Striped bass are a relevant and useful indicator species for comparing methylmercury contamination across US estuaries due to several factors: their popularity for consumption (this is the most popular species for consumption in San Francisco Bay – SFEI, 2000); their dependence on estuaries (Able, 2005); their broad spatial integration across the estuaries in which they reside due to their variable use of fresh, brackish, and saline habitat (Secor and Piccoli, 2007) – though their high mobility also represents a drawback in some respects; their wide distribution on the east, west, and Gulf coasts; and a generally strong correlation between size and methylmercury concentration. Striped bass from San Francisco Bay have the highest average methylmercury concentration measured for this species in US estuaries. The average concentration measured in 2009 in San Francisco Bay (a length-adjusted mean of 0.44 ppm at 60 cm – Davis et al. 2011) was higher than average concentrations recently reported for five other USA coastal areas. The New Jersey coast (Burger and Gochfeld 2011) had the second highest average concentration (0.39 ppm – based largely on fish greater than 85 cm). Average concentrations in striped bass from other US coastal areas ranged from 0.12 to 0.23 ppm (Mason et al. 2006; Piraino et al. 2009; Glover et al. 2010; Katner et al. 2010, and Burger and Gochfeld 2011).

PCBs

Comparison to Thresholds

PCBs (measured as the sum of 55 congeners – Table 2) were the only other pollutant sampled across the state to reach concentrations in fish tissue that pose potential health concerns to consumers of fish caught from the locations sampled in the Coast Survey (dioxins also reached concentrations of concern, but were only sampled in San Francisco Bay – see Davis et al. [2011]).

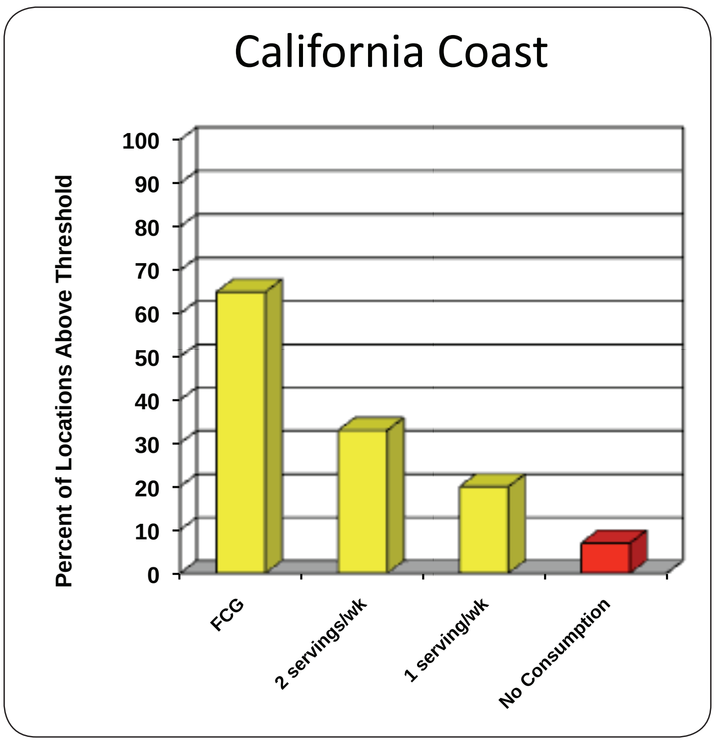

Figure 11. Percentages of coastal sampling locations above various PCB thresholds.

OEHHA's no consumption advisory tissue level (ATL) for PCBs of 120 ppb wet weight (all concentrations expressed on a wet weight basis) provides an upper bound threshold for assessment of PCBs in California sport fish. This value represents a relatively high concentration above which frequent consumption might not be safe for the most sensitive fish consumers (children and women of childbearing age). OEHHA's fish contaminant goal for PCBs of 3.6 ppb is a lower bound threshold. PCB concentrations below this level can be considered low.

Most of the locations sampled (40 of 68, or 59%) had a moderate degree of contamination, with a most highly contaminated species below 120 ppb and above 3.6 ppb (Figures 11-13, Table 5). Twenty-three of the 68 locations (34%) were in the least contaminated category, with a most highly contaminated species below 3.6 ppb. Overall, 63 of 68 (93%) locations had a most highly contaminated species below 120 ppb – this represents an estimate of the percentage of locations where frequent consumption of all species, at a consumption frequency to be determined in the future by OEHHA when data are sufficient for evaluation, is likely to be safe.

Five of the 68 locations (7%) were in the high contamination category, with an average for the most contaminated species exceeding 120 ppb. The 95% confidence interval for this estimate was 1-14% (Figure 12).

Regional variation in the occurrence of locations and species with high PCB concentrations was observed. The most severe PCB contamination (concentrations above 120 ppb) was measured near the major urban centers of the San Francisco Bay Area, Los Angeles, and San Diego (Figure 13). Broad areas of moderate contamination surrounded these relatively localized hotspots. The South Coast (Point Conception to the Mexico border) had the most extensive spatial extent of this moderate contamination, with every near-coastal location sampled having at least one species exceeding 3.6 ppb (Figure 13). The only locations in the South Coast region that had all species below 3.6 ppb were the offshore islands (Catalina Island and Northern Channel Islands). The South Coast also had the highest overall frequency of occurrence (68%) of species with average concentrations above 3.6 ppb (red and yellow cells in Table 5).

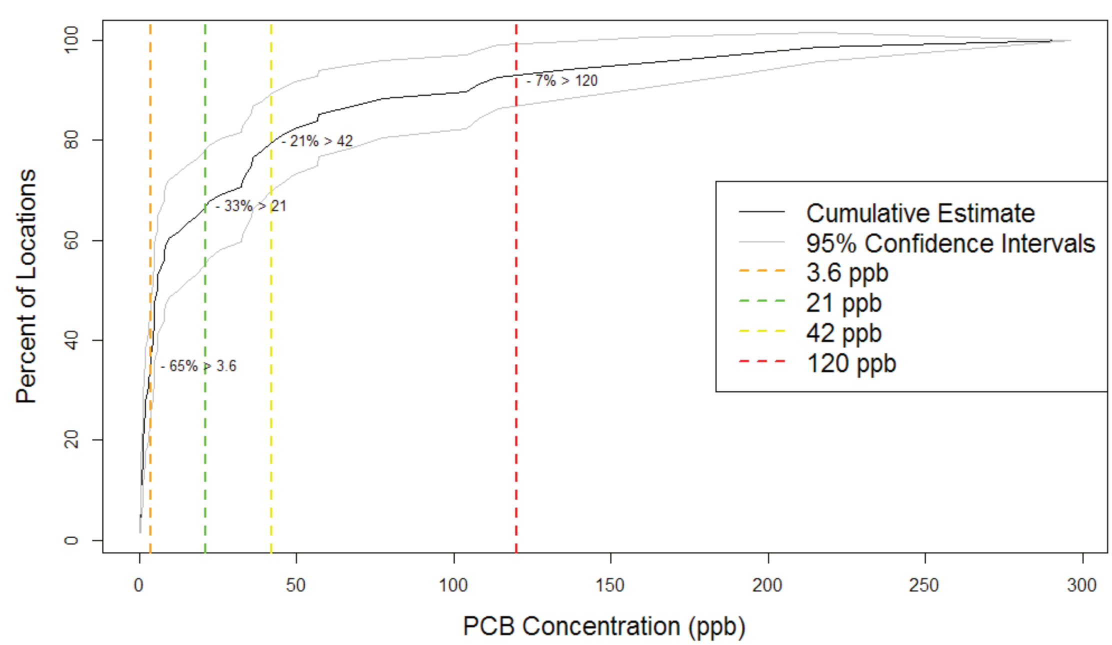

Figure 12. Cumulative distribution function (CDF) plot for PCBs, shown as percent of locations sampled. Based on the highest species average concentration (ppb wet weight) for each location. Vertical lines are threshold values.

The Central Coast (Point Reyes to Point Conception) had the second highest overall degree of PCB contamination, principally due to the widespread elevated concentrations measured in San Francisco Bay (Figure 13, Table 5). All species at all locations in the Bay were above 3.6 ppb, and two locations had a species above 120 ppb. Other Central Coast bays and harbors and outer coastal locations were all below 120 ppb, with some locations above 3.6 ppb at coastal locations in the vicinity of the Bay and other smaller urban centers (Monterey and San Luis Obispo) (Figure 13). Overall, 67% of species averages were below 3.6 ppb (green cells in Table 5), 31% were between 3.6 ppb and 120 ppb (yellow cells), and 2% were above 120 ppb (red cells).

The North Coast, which is largely nonurban, had a very low degree of PCB contamination (Figure 13, Table 5). Only two species averages were above 3.6 ppb, and these were just barely higher than that threshold: a lingcod sample at 3.6 ppb at Del Norte Coast and a topsmelt sample from Tomales Bay at 5.8 ppb. The 77 other species-location averages were all below 3.6 ppb.

Assessing concentrations for the least contaminated species at each location relative to the thresholds provides an indication of the availability of low PCB fish species for anglers. Using this metric, all 15 North Coast locations were below 3.6 ppb, 19 of 26 (73%) on the Central Coast, and 13 of 27 (48%) on the South Coast. Statewide, 47 of 68 locations (69%) had at least one low PCB species.

Variation Among Species

Concentrations of PCBs and other persistent organics vary considerably among species due to differences in proximity to contaminant sources, lipid content, and trophic position. Trophic position was less of a factor in this dataset, as illustrated by two lower trophic level species (shiner surfperch and northern anchovy) having the second and third highest average concentrations (Figure 14).

Spiny dogfish was the only species in the year one sampling that had an average PCB concentration (296 ppb) above the 120 ppb no consumption ATL (Figure 14). Only one sample was collected for this species though (from San Pedro Bay), so this value may not be representative for the species more generally.

Northern anchovy were sampled in San Francisco Bay by the Regional Monitoring Program (RMP), and, surprisingly, given their low trophic position, had the second highest average concentration (118 ppb), just below the 120 ppb threshold. Northern anchovy are not a target for human consumption, but they are collected in the sport fish trawls and analyzed as an indicator of wildlife exposure as they are an important prey item in the Bay. They accumulate high concentrations of PCBs and other organic contaminants in the Bay in spite of their small size (90 mm, or 3.5 in) and low trophic position. Their high lipid content and their analysis as whole body samples (including high lipid internal organs) are factors contributing to the high accumulation. It is also likely that they forage in relatively contaminated areas along the margin of the Bay.

Shiner surfperch, widely sampled in bays and harbors across the state, had the third highest average concentration (83 ppb), including many samples above 120 ppb (Figure 14). Shiner surfperch were also not

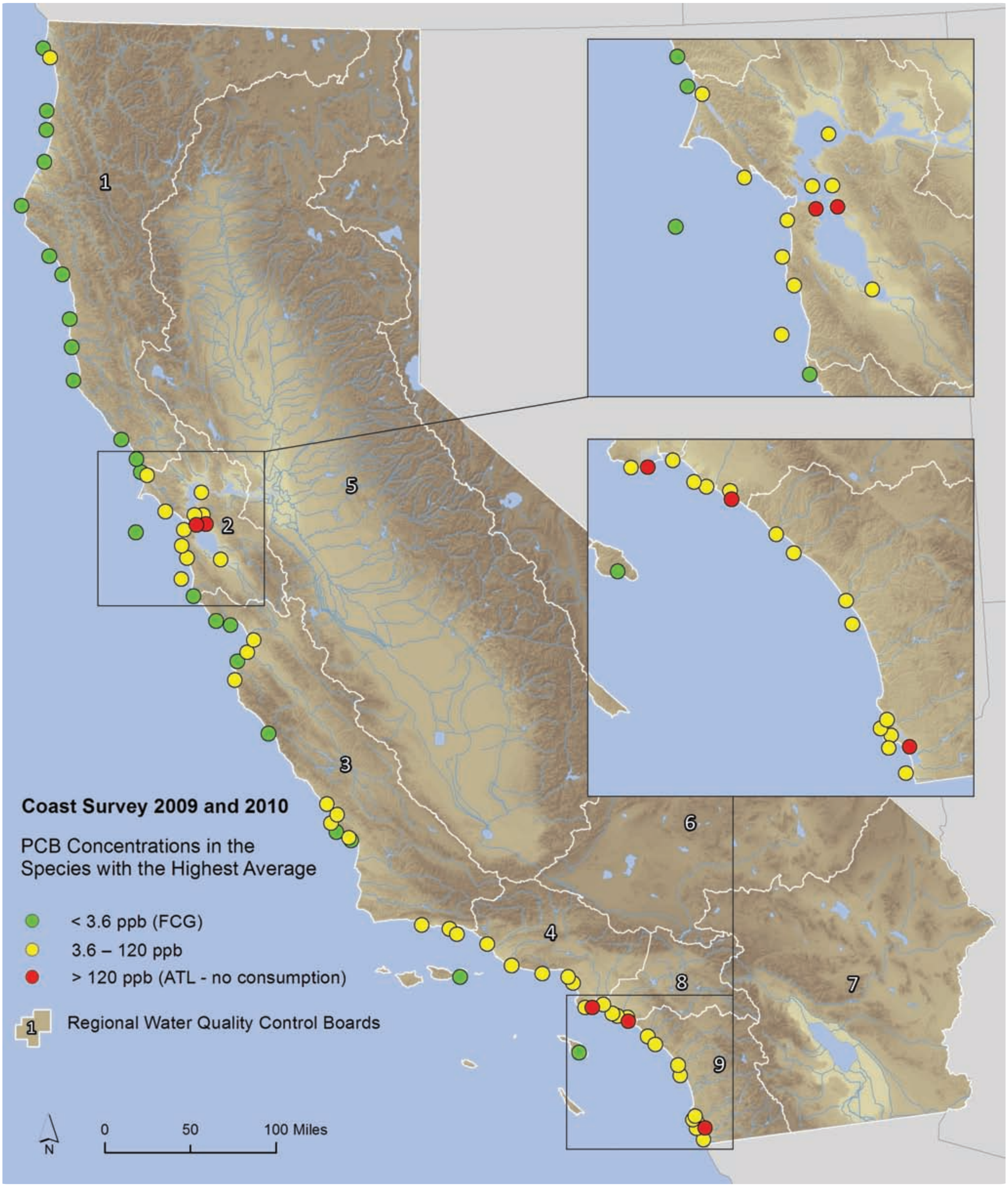

Figure 13. Spatial patterns in PCB concentrations among locations sampled in the Coast Survey, 2009-2010. Each point represents the highest average PCB concentration among the species sampled at each location.

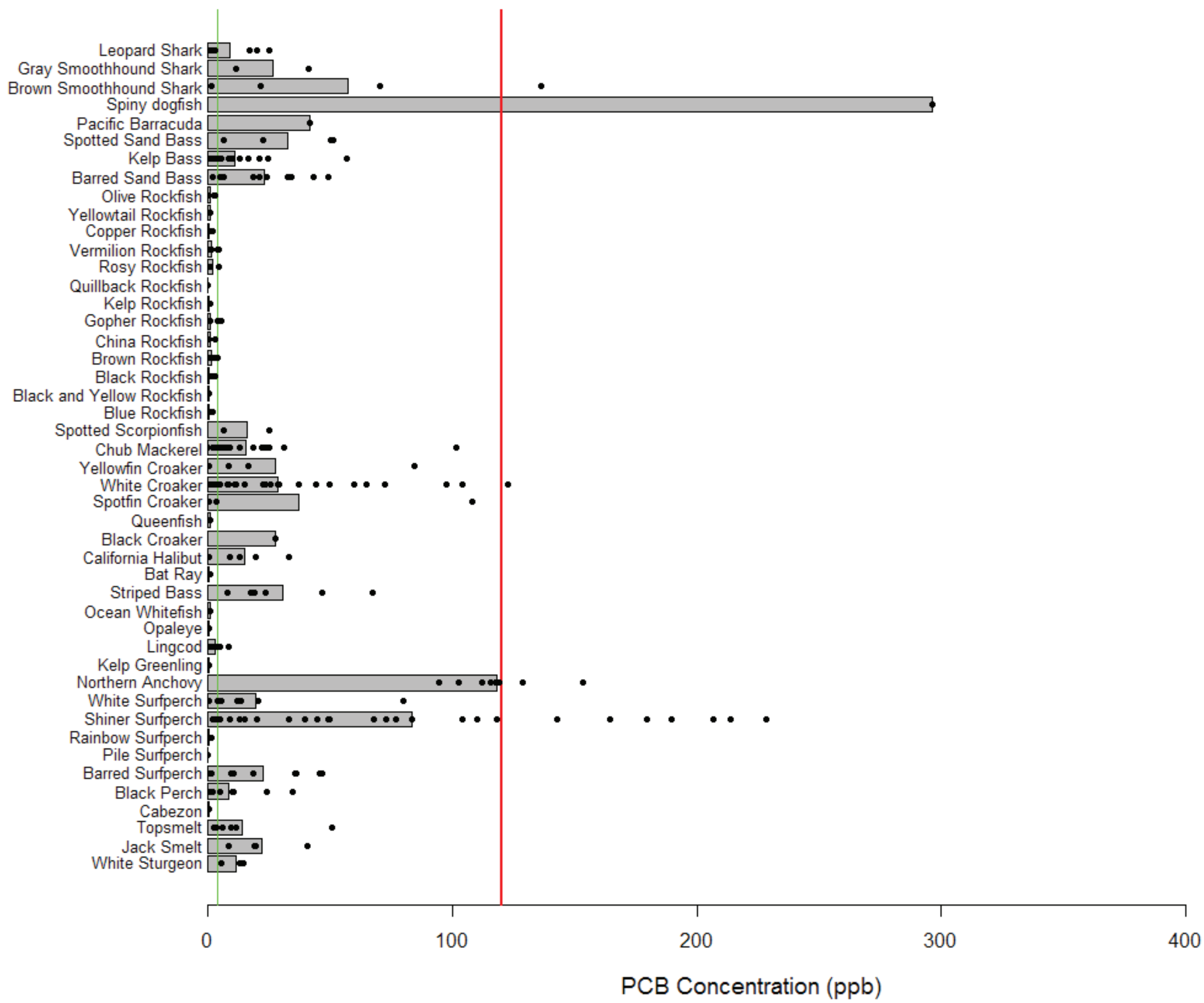

Figure 14. PCB concentrations (ppb wet weight) in sport fish species on the California coast, 2009-2010. Bars indicate average concentration. Points represent individual samples (either composites or individual fish). Note that the averages for some species (e.g., spiny dogfish) are based on only one sample. Red line indicates 120 ppb; green line indicates 0.07 ppb.

Table 5
Classification of average PCB concentrations for each species at each location: North Coast. Red: >120 ppb. Green: <3.6 ppb. Yellow: between 3.6 and 120 ppb.

Coastal Species

Regional Board	Zone	Station Name	Black Rockfish	Blue Rockfish	Quillback Rockfish	Olive Rockfish	Copper Rockfish	Gopher Rockfish	China Rockfish	Vermillion Rockfish	Yellowtail Rockfish	Rosy Rockfish	Brown Rockfish	Black and Yellow Rockfish	Kelp Rockfish	Cabezon	Kelp Greenling	Lingcod	Barred Sand Bass	Kelp Bass	Spotted Sand Bass	Chub Mackerel	Spotted Scorpionfish	Pacific Barracuda	Ocean Whitefish	Rainbow Surfperch	Barred Surfperch	Black Perch	White Croaker	Black Croaker
1	68	Crescent City Coast	Green	Green	Green											Green	Green	Green												
1	67	Del Norte Coast	Green	Green		Green										Green	Green	Yellow												
1	66	North Humboldt County Coast Area	Green	Green			Green	Green								Green		Green												
1	65	Trinidad Area	Green	Green														Green												
1	64	Humboldt Bay																												
1	62	Cape Mendocino Area	Green	Green			Green		Green							Green		Green												
1	61	Shelter Cove Area	Green	Green			Green	Green	Green	Green																				
1	60	North Mendocino County Coast Area	Green				Green		Green	Green						Green														
1	59	Fort Bragg Area	Green	Green						Green						Green														
1	58	Mendocino Coast Area	Green	Green						Green	Green	Green				Green		Green												
1	57	Point Arena Area	Green	Green		Green		Green	Green							Green		Green												
1	55/56	South Sonoma Coast/North Sonoma Coast		Green		Green	Green			Green			Green																	
1	54	Bodega Harbor																								Green				
2	53	Northern Marin Coast		Green		Green							Green																	
2	52	Tomales Bay																												

Bay and Harbor Species

Regional Board	Zone	Station Name	Bat Ray	California Halibut	Leopard Shark	Brown Smoothhound Shark	Gray Smoothhound Shark	Spiny Dogfish	Shiner Surfperch	Pile Surfperch	White Surfperch	Yellowfin Croaker	Spotfin Croaker	Topsmelt	Jacksmelt	Striped Bass	Opaleye	Queenfish
1	68	Crescent City Coast																
1	67	Del Norte Coast																
1	66	North Humboldt County Coast Area																
1	65	Trinidad Area																
1	64	Humboldt Bay	Green	Green	Green				Green									
1	62	Cape Mendocino Area																
1	61	Shelter Cove Area																
1	60	North Mendocino County Coast Area																
1	59	Fort Bragg Area																
1	58	Mendocino Coast Area																
1	57	Point Arena Area																
1	55/56	South Sonoma Coast/North Sonoma Coast																
1	54	Bodega Harbor			Green													
2	53	Northern Marin Coast																
2	52	Tomales Bay			Green	Green			Green		Green			Yellow				

Table 5 *(continued)*
Classification of average PCB concentrations for each species at each location: Central Coast. Red: >120 ppb. Green: <3.6 ppb. Yellow: between 3.6 and 120 ppb.

Coastal Species

Regional Board	Zone	Station Name	Black Rockfish	Blue Rockfish	Quillback Rockfish	Olive Rockfish	Copper Rockfish	Gopher Rockfish	China Rockfish	Vermillion Rockfish	Yellowtail Rockfish	Rosy Rockfish	Brown Rockfish	Black and Yellow Rockfish	Kelp Rockfish	Cabezon	Kelp Greenling	Lingcod	Barred Sand Bass	Kelp Bass	Spotted Sand Bass	Chub Mackerel	Spotted Scorpionfish	Pacific Barracuda	Ocean Whitefish	Rainbow Surfperch	Barred Surfperch	Black Perch	White Croaker	Black Croaker
2	51	Southern Marin Coast																											Green	
2	206SNPBLO	San Pablo Bay (5)																												
2	203BRKLEY	Berkeley (4)																												
2	203CENTRL	Central Bay (6)																											Yellow	
2	203SANFRN	San Francisco Waterfront (3)																												
2	203OAKLND	Oakland (2)																											Yellow	
2	204STHBAY	South Bay (1)																											Yellow	
2	50	Farallon Islands		Green		Green		Green																						
2	49	San Francisco Coast																									Yellow		Yellow	
2	48	Pacifica Coast		Green				Green										Yellow												
2	47	Half Moon Bay Coast		Green				Green					Green					Yellow									Green			
2	46	Pillar Point Harbor																												
2	45	San Mateo Coast	Green	Green		Green		Green																						
3	43	Santa Cruz Coast Area	Green	Green				Green																						
3	42	Santa Cruz Area Wharfs/ Beachs						Green																						
3	41	Elkhorn Slough																												
3	40	Moss Landing/Marina Coast	Green					Green	Green																					
3	39	Monterey/Pacific Grove Coast	Green	Green				Green																						
3	38	Carmel Coast		Green		Green		Green																						
3	36/37	Southern Monterey County Coast/Big Sur Coast		Green		Green																								
3	34/35	Cambria/Cayucos Coast/ Northern San Luis Obispo County Coast						Green																						
3	33	Morro Bay																												
3	32	Morro Bay Coast				Green		Green																						
3	31	Diablo Canyon Coast		Green				Green																						
3	30	Port San Luis Area					Green	Green																						
3	28/29	North Santa Barbara County Coast/Pismo Beach Area		Green				Green																						

Bay and Harbor Species

Regional Board	Zone	Station Name	Bat Ray	California Halibut	Leopard Shark	Brown Smoothhound Shark	Gray Smoothhound Shark	Spiny Dogfish	Shiner Surfperch	Pile Surfperch	White Surfperch	Yellowfin Croaker	Spotfin Croaker	Topsmelt	Jacksmelt	Striped Bass	Opaleye	Queenfish
2	51	Southern Marin Coast																
2	206SNPBLO	San Pablo Bay (5)		Yellow	Yellow				Yellow						Yellow	Yellow		
2	203BRKLEY	Berkeley (4)							Yellow									
2	203CENTRL	Central Bay (6)		Yellow	Yellow											Yellow		
2	203SANFRN	San Francisco Waterfront (3)		Yellow					Red						Yellow			
2	203OAKLND	Oakland (2)							Red						Yellow			
2	204STHBAY	South Bay (1)			Yellow				Yellow						Yellow			
2	50	Farallon Islands																
2	49	San Francisco Coast																
2	48	Pacifica Coast																
2	47	Half Moon Bay Coast																
2	46	Pillar Point Harbor																
2	45	San Mateo Coast																
3	43	Santa Cruz Coast Area																
3	42	Santa Cruz Area Wharfs/ Beachs																
3	41	Elkhorn Slough																
3	40	Moss Landing/Marina Coast																
3	39	Monterey/Pacific Grove Coast																
3	38	Carmel Coast																
3	36/37	Southern Monterey County Coast/Big Sur Coast																
3	34/35	Cambria/Cayucos Coast/ Northern San Luis Obispo County Coast																
3	33	Morro Bay																
3	32	Morro Bay Coast																
3	31	Diablo Canyon Coast																
3	30	Port San Luis Area																
3	28/29	North Santa Barbara County Coast/Pismo Beach Area																

Table 5 *(continued)*
Classification of average PCB concentrations for each species at each location: South Coast. Red: >120 ppb. Green: <3.6 ppb. Yellow: between 3.6 and 120 ppb.

Coastal Species

Regional Board	Zone	Station Name	Black Rockfish	Blue Rockfish	Quillback Rockfish	Olive Rockfish	Copper Rockfish	Gopher Rockfish	China Rockfish	Vermillion Rockfish	Yellowtail Rockfish	Rosy Rockfish	Brown Rockfish	Black and Yellow Rockfish	Kelp Rockfish	Cabezon	Kelp Greenling	Lingcod	Barred Sand Bass	Kelp Bass	Spotted Sand Bass	Chub Mackerel	Spotted Scorpionfish	Pacific Barracuda	Ocean Whitefish	Rainbow Surfperch	Barred Surfperch	Black Perch	White Croaker	Black Croaker
3	27	Goleta to Pt Conception		Green				Green					Green						Yellow	Green		Green								
3	25	Rincon to Goleta		Green		Green														Green		Yellow						Green	Yellow	
3	26	Santa Barbara Channel Oil Platform						Green					Green							Green		Green							Green	
3	23	Northern Channel Islands											Green		Green					Green								Green		
4	24	Ventura to Rincon																									Yellow		Yellow	
4	22	Pt Dume to Oxnard						Green												Yellow		Yellow						Green	Green	
4	21	North Santa Monica Bay											Green						Yellow	Yellow		Green						Yellow		
4	20	Middle Santa Monica Bay																	Yellow	Yellow		Yellow					Yellow			Yellow
4	19	South Santa Monica Bay																	Yellow	Yellow		Yellow					Yellow		Yellow	
4	18	Palos Verdes						Yellow												Yellow		Yellow						Yellow	Yellow	
4	16	San Pedro Bay																	Yellow									Yellow	Yellow	
4	15	Long Beach																	Yellow			Yellow							Yellow	
8	14	Orange County Oil Platforms																	Yellow	Yellow		Yellow							Yellow	
8	13	Santa Ana River to Seal Beach																	Yellow	Yellow		Yellow					Yellow			
8	12	Newport Bay																										Yellow	Yellow	
8	11	Crystal Cove to Santa Ana River																	Yellow	Yellow		Green							Yellow	
9	10	Dana Point Harbor																											Green	
9	9	San Onofre to Crystal Cove																	Yellow	Green		Yellow		Yellow						
4	17	Catalina Island										Green								Green		Green			Green			Green		
9	8	Oceanside Harbor																											Green	
9	7	La Jolla to San Onofre																	Green	Yellow		Green							Yellow	
9	6	Mission Bay																			Yellow									
9	5	Pt Loma to La Jolla						Green			Green									Green		Yellow								
9	4	Pt Loma						Yellow											Yellow	Yellow		Yellow						Yellow	Yellow	
9	3	SD North Bay																	Yellow		Yellow	Yellow								
9	2	SD South Bay																			Yellow	Yellow								
9	1	TJ to North Island																		Yellow		Yellow	Yellow						Yellow	

Bay and Harbor Species

Regional Board	Zone	Station Name	Bat Ray	California Halibut	Leopard Shark	Brown Smoothhound Shark	Gray Smoothhound Shark	Spiny Dogfish	Shiner Surfperch	Pile Surfperch	White Surfperch	Yellowfin Croaker	Spotfin Croaker	Topsmelt	Jacksmelt	Striped Bass	Opaleye	Queenfish
3	27	Goleta to Pt Conception																
3	25	Rincon to Goleta									Yellow							
3	26	Santa Barbara Channel Oil Platform																
3	23	Northern Channel Islands							Yellow									
4	24	Ventura to Rincon																
4	22	Pt Dume to Oxnard																
4	21	North Santa Monica Bay																
4	20	Middle Santa Monica Bay																
4	19	South Santa Monica Bay																
4	18	Palos Verdes																
4	16	San Pedro Bay						Red	Yellow		Yellow							
4	15	Long Beach				Yellow						Yellow		Yellow				
8	14	Orange County Oil Platforms																
8	13	Santa Ana River to Seal Beach				Yellow												
8	12	Newport Bay							Yellow									
8	11	Crystal Cove to Santa Ana River				Red												
9	10	Dana Point Harbor							Yellow		Yellow		Green	Green			Green	
9	9	San Onofre to Crystal Cove																
4	17	Catalina Island																
9	8	Oceanside Harbor									Yellow	Green	Green					Green
9	7	La Jolla to San Onofre																
9	6	Mission Bay							Yellow		Yellow	Yellow		Yellow				
9	5	Pt Loma to La Jolla																
9	4	Pt Loma																
9	3	SD North Bay					Yellow		Yellow									
9	2	SD South Bay					Yellow		Red			Yellow						
9	1	TJ to North Island																

Table 5 *(continued)*
Classification of average PCB concentrations for each species at each location: summary statistics for the entire coast. Red: >120 ppb. Green: <3.6 ppb. Yellow: between 3.6 and 120 ppb.

# above 120 ppb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
# between 3.6 and 120 ppb	0	0	0	0	0	2	0	2	0	1	1	0	0	0	0	4	12	11	4	14	2	1	0	0	7	5	16	1
# below 3.6 ppb	14	23	1	10	6	22	5	8	2	2	9	2	3	13	6	9	1	7	0	6	0	0	1	6	2	5	8	0
Total	14	23	1	10	6	24	5	10	2	3	10	2	3	13	6	13	13	18	4	20	2	1	1	6	9	10	24	1
% above 120 ppb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% between 3.6 and 120 ppb	0	0	0	0	0	8	0	20	0	33	10	0	0	0	0	31	92	61	100	70	100	100	0	0	78	50	67	100
% below 3.6 ppb	100	100	100	100	100	92	100	80	100	67	90	100	100	100	100	69	8	39	0	30	0	0	100	100	22	50	33	0

# above 120 ppb	0	0	0	1	0	1	3	0	0	0	0	0	0	0	0	0
# between 3.6 and 120 ppb	0	3	3	2	2	0	12	0	6	3	1	5	4	2	0	0
# below 3.6 ppb	3	1	5	1	0	0	2	1	1	1	2	2	0	0	1	1
Total	3	4	8	4	2	1	17	1	7	4	3	7	4	2	1	1
% above 120 ppb	0	0	0	25	0	100	18	0	0	0	0	0	0	0	0	0
% between 3.6 and 120 ppb	0	75	38	50	100	0	71	0	86	75	33	71	100	100	0	0
% below 3.6 ppb	100	25	63	25	0	0	12	100	14	25	67	29	0	0	100	100

processed as fillets (they were processed whole with head, viscera, and tail removed due to their small size - typically 11 cm, or 4.3 in), but these fish are caught and consumed by anglers. Shiner surfperch have high site fidelity and are an excellent indicator of spatial patterns. Their sensitivity as a spatial indicator is evident from the 100-fold range in average concentrations observed – from a high of 216 ppb in Oakland Harbor to a low of 2 ppb in Humboldt Bay. Average PCB concentrations in shiner surfperch exceeded 120 ppb at three locations (two in San Francisco Bay and one in San Diego Bay), and were below 3.6 ppb at only two of the 17 locations where they were sampled (Table 5).

The only other species with any samples exceeding 120 ppb were brown smoothhound shark and white croaker (one sample each) (Figure 14). The average concentrations for these two species and all of the others were much lower than the top three (spiny dogfish, northern anchovy, and shiner surfperch). Brown smoothhound was the only other species with an average concentration (57 ppb) above the 42 ppb 1 serving ATL.

On the other hand, 22 of 46 species had a statewide average below the 3.6 ppb Fish Contaminant Goal (Figure 14). Notably, all 13 rockfish species had average concentrations below this threshold. Furthermore, very few rockfish samples (Figure 14) or species-location averages (6 of 113 – Table 5) exceeded 3.6 ppb.

Half of the species (23 of 46) had a statewide average between 3.6 ppb and 120 ppb.

Spatial Patterns

Regional variation in how PCB concentrations compared to OEHHA thresholds was discussed above. This section provides a more focused assessment of spatial patterns to attempt to discern whether the degree of food web contamination really varies among the regions. If significant variation exists, this could suggest a need for different control strategies in different regions or for placing a higher priority on managing the most contaminated areas.

The strong spatial component of variance in PCB concentrations in selected indicator species allows for straightforward evaluation of patterns in food web contamination across the state through examination of the untransformed wet weight data. A clear picture of statewide spatial variation emerges from examination of species that accumulate high PCB concentrations and that were collected across multiple locations.

As described above, shiner surfperch can accumulate high PCB concentrations and are reliable indicators of spatial patterns. This species was collected at 17 locations, from Humboldt Bay in the north to San Diego Bay in the south (Figure 15), with location-average concentrations ranging from 216 ppb at Oakland to 2 ppb in Humboldt Bay. The shiner surfperch results highlight the high degree of PCB contamination in San Francisco Bay and San Diego Bay, as well as other locations with moderate contamination at San Pedro Bay (50 ppb) and Dana Point Harbor (49 ppb). PCBs were relatively high in multiple species in San Pedro Bay, including the spiny dogfish sample with the highest concentration observed in the Survey (296 ppb) and white surfperch at 80 ppb. On the other hand, the shiner surfperch data indicate that Tomales Bay (3 ppb) and Humboldt Bay (2 ppb) were quite low in PCBs.

White croaker is another species that has the potential to accumulate relatively high PCB concentrations and that was collected across much of the state. Concentrations in white croaker were not as high as in shiner surfperch, but spatial variation in this species was also quite distinct (Figure 15). Long Beach had the highest average concentration in white croaker (104 ppb). Other species collected at this location also had relatively high concentrations, including topsmelt (51 ppb) and barred sand bass (49 ppb). Shiner surfperch were not collected at this location. Overall, these data indicate that Long Beach is one of the most highly contaminated locations for PCBs. White croaker from Oakland (63 ppb) and South Bay (36 ppb) in San Francisco Bay had the second and third highest average concentrations. Other areas with moderately elevated concentrations included three other locations near Long Beach (South Santa Monica Bay – 29 ppb; Palos Verdes – 22 ppb; and San Pedro Bay – 29 ppb) and two locations in the San Diego region (Point Loma – 25 ppb, and near Tijuana – 23 ppb). The white croaker results indicate that many other locations (Southern Marin Coast, Pillar Point Harbor, Santa Barbara Channel Oil Platform, Point Dume to Oxnard, Dana Point Harbor, and Oceanside Harbor) were quite low in PCBs (all below the 3.6 ppb FCG).

Spatial patterns in two other South Coast species are worth noting. Chub mackerel accumulated moderately elevated concentrations of PCBs at many locations (Figure 15, Table 5). The maximum concentration of 101 ppb in San Diego South Bay approached the 120 ppb no consumption ATL, and corroborated the high degree of PCB contamination at this location indicated by the results for shiner surfperch (190 ppb). Concentrations at the other 19 locations where chub mackerel were collected were all below 31 ppb, with six locations below 3.6 ppb. Kelp bass also accumulated moderate concentrations of PCBs, with 11 of 18 locations above 3.6 ppb (Figure 15, Table 5). The southernmost sampling location (Tijuana to North Island) had the highest concentration in kelp bass (57 ppb), suggesting somewhat elevated food web contamination in this area.

Temporal Trends

As for methylmercury, few data are available to assess long-term trends in PCB concentrations in sport fish on the California coast. The best long-term datasets are for PCBs in white croaker and shiner surfperch in San Francisco Bay, as discussed in some detail in Davis et al. (2011). No trend is evident in these data for a time series that has included triennial sampling since 1994. A few data from the Coastal Fish Contamination Program (CFCP) may contribute to time series for selected locations. These time series would have to be assembled with caution for shiner surfperch, given their high sensitivity to spatial variation. Also, attention would have to be paid to how the samples were processed: most of the CFCP samples were fillets, in contrast to the processing in this survey (whole with head, viscera, and tail removed). For white croaker, sample processing was consistent between the two programs. Although this species has lower site fidelity, it would still be advisable to match sampling locations as closely as possible. Since only two time points would be available and not much time has passed relative to the likely rate of change of methylmercury and PCBs, evaluating these time series was not attempted for this report.

SHINER SURFPERCH

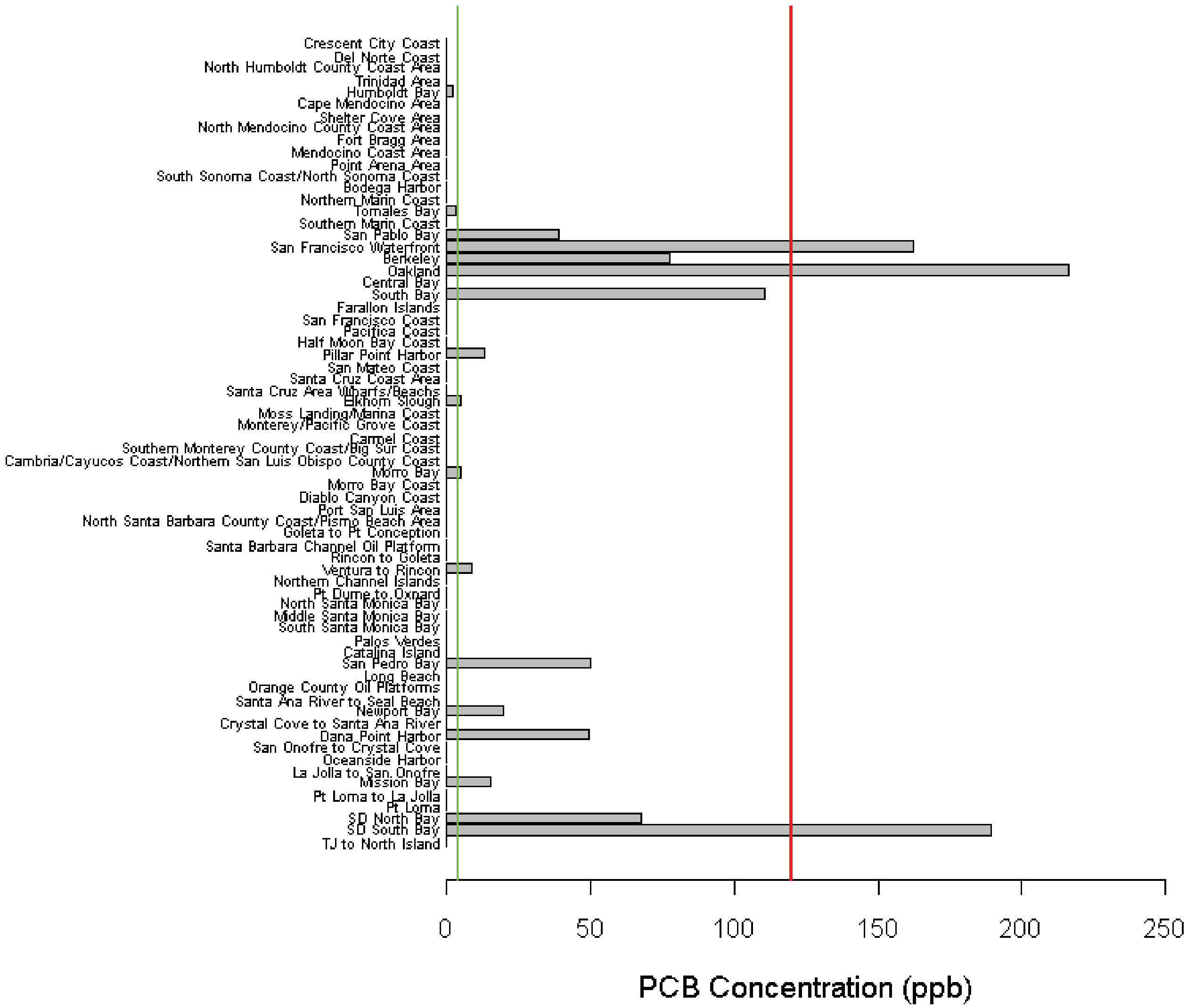

Figure 15. PCB concentrations (ppb wet weight) in species with wide spatial distributions. Red line indicates 120 ppb; green line indicates 0.07 ppb.

WHITE CROAKER

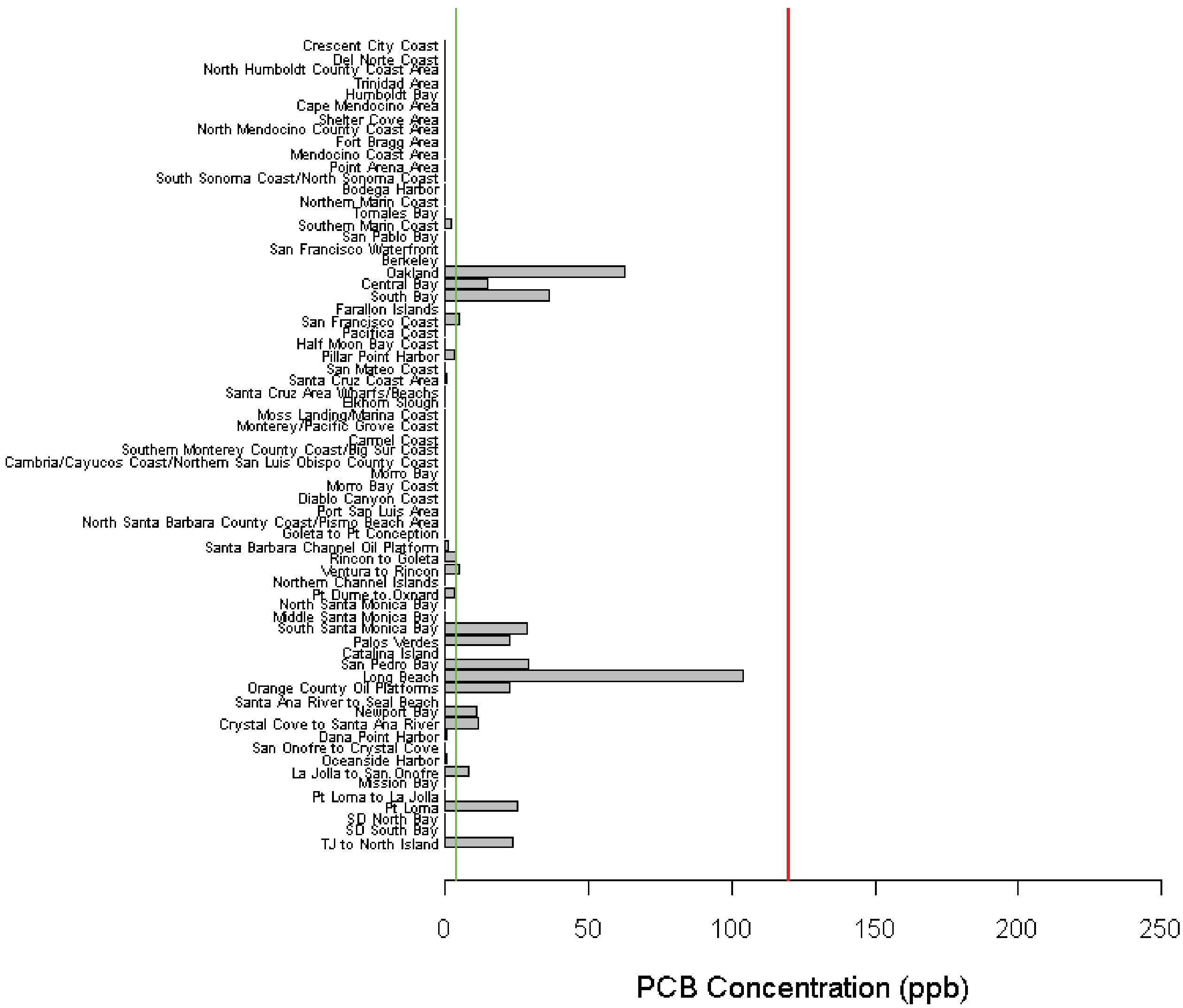

Figure 15b.

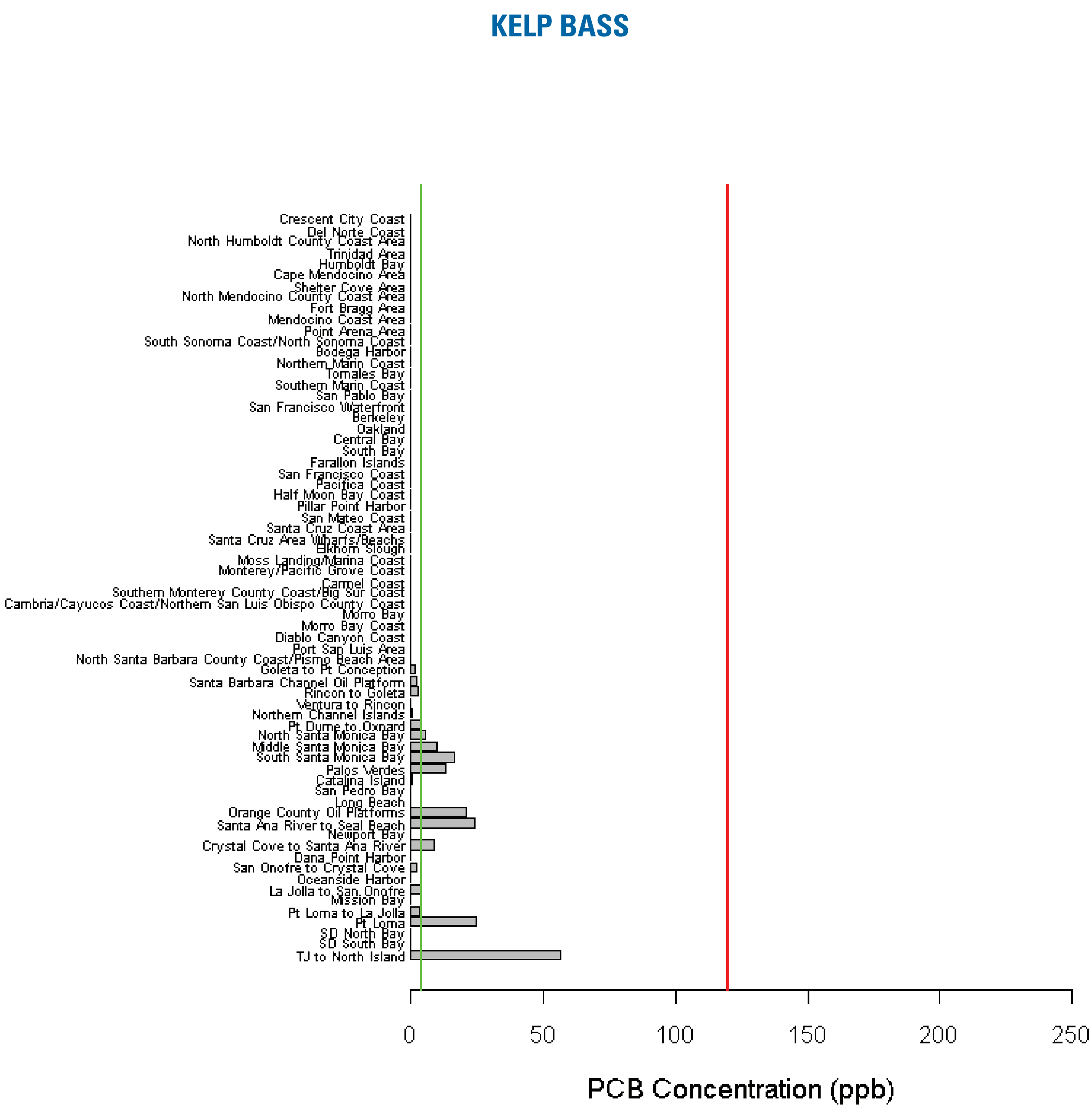
KELP BASS
Crescent City Coast
Del Norte Coast
North Humboldt County Coast Area
Trinidad Area
Humboldt Bay
Cape Mendocino Area
Shelter Cove Area
North Mendocino County Coast Area
Fort Bragg Area
Mendocino Coast Area
Point Arena Area
South Sonoma Coast/North Sonoma Coast
Bodega Harbor
Northern Marin Coast
Tomales Bay
Southern Marin Coast
San Pablo Bay
San Francisco Waterfront
Berkeley
Oakland
Central Bay
South Bay
Farallon Islands
San Francisco Coast
Pacifica Coast
Half Moon Bay Coast
Pillar Point Harbor
San Mateo Coast
Santa Cruz Coast Area
Santa Cruz Area Wharfs/Beachs
Elkhorn Slough
Moss Landing/Marina Coast
Monterey/Pacific Grove Coast
Carmel Coast
Southern Monterey County Coast/Big Sur Coast
Cambria/Cayucos Coast/Northern San Luis Obispo County Coast
Morro Bay
Morro Bay Coast
Diablo Canyon Coast
Port San Luis Area
North Santa Barbara County Coast/Pismo Beach Area
Goleta to Pt Conception
Santa Barbara Channel Oil Platform
Rincon to Goleta
Ventura to Rincon
Northern Channel Islands
Pt Dume to Oxnard
North Santa Monica Bay
Middle Santa Monica Bay
South Santa Monica Bay
Palos Verdes
Catalina Island
San Pedro Bay
Long Beach
Orange County Oil Platforms
Santa Ana River to Seal Beach
Newport Bay
Crystal Cove to Santa Ana River
Dana Point Harbor
San Onofre to Crystal Cove
Oceanside Harbor
La Jolla to San Onofre
Mission Bay
Pt Loma to La Jolla
Pt Loma
SD North Bay
SD South Bay
TJ to North Island
0
50
100
150
200
250
PCB Concentration (ppb)

Figure 15c.

CHUB MACKEREL

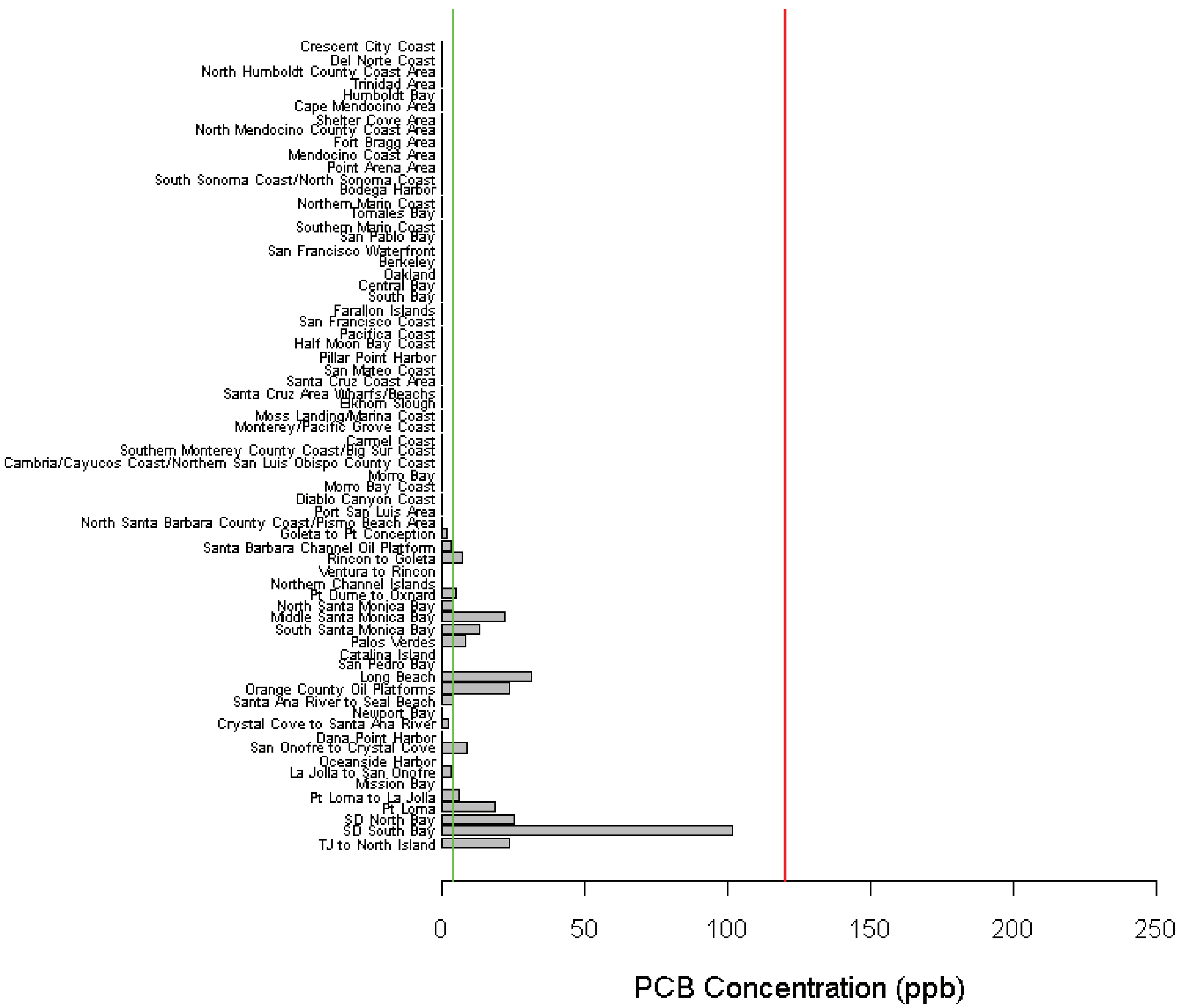

Figure 15d.

OTHER CONTAMINANTS WITH THRESHOLDS

OEHHA (Klasing and Brodberg 2008) has developed thresholds for four other contaminants that were analyzed in this survey: DDTs, dieldrin, chlordanes, and selenium. Concentrations of these contaminants did not exceed any of the no consumption ATLs, and rarely exceeded any ATL. The organic contaminants, however, did frequently exceed the FCGs.

Results for these contaminants are briefly summarized below.

DDTs

The maximum species averages for DDTs were below the lowest threshold (the 21 ppb FCG) in 42 (62%) of the 68 locations sampled (Figure 16). Twenty-five locations (37%) fell between the FCG and the next lowest threshold (the 520 ppb 2-serving ATL – note that this threshold is not shown on Figure 16). One location was above 520 ppb: the San Pedro Bay spiny dogfish sample had 1077 ppb. The highest concentrations were found primarily in three regions: San Francisco Bay, near the Palos Verdes Peninsula, and near San Diego and the Mexican border. The spatial distribution of the highest concentrations resembled the general pattern for PCBs, with elevated values near the major urban centers.

Dieldrin

The maximum species averages for dieldrin were below the lowest threshold (the 0.46 ppb FCG) in 40 (61%) of the 66 locations sampled (results were not reported for two locations due to QA issues) (Figure 17). The remaining 26 locations fell between the FCG and the next lowest threshold (the 15 ppb 2-serving ATL). The highest concentration measured was 3.0 ppb in a shiner surfperch sample from Dana Point Harbor. As for DDTs, the highest concentrations were found primarily in three regions: San Francisco Bay, near the Palos Verdes Peninsula, and near San Diego and the Mexican border. However, the spatial pattern was a little different from DDT in that the North Coast had a large proportion of locations above the FCG.

Chlordanes

The maximum species averages for chlordanes were below the lowest threshold (the 5.6 ppb FCG) in 58 (85%) of the 68 locations sampled (Figure 18). The other ten locations fell between the FCG and the next lowest threshold (the 190 ppb 3 serving ATL). The highest concentration measured was 42 ppb in a spiny dogfish sample from San Pedro Bay. The highest concentrations were found in San Francisco Bay and near the Palos Verdes Peninsula.

Selenium

The maximum species averages for selenium were below the lowest threshold (the 2.5 ppm 3 serving ATL) in 100% of the 68 locations sampled. The highest average or composite concentration measured was 2.4 ppm in a barred sand bass sample from North Santa Monica Bay.

SUMMARY ACROSS CONTAMINANTS

Figure 19 presents a summary of the degree of contamination at each location that incorporates results for both methylmercury and PCBs. To simplify the presentation the other contaminants were not included. The results for each contaminant were classified based on the most highly contaminated species at the location and in comparison to the same thresholds used in Figures 5 and 13. Table 6 summarizes the proportions of locations falling into each category. Locations that were classified as green for both contaminants had a low overall degree of contamination. No locations fell into this category. At the other end of the spectrum, locations classified as red for both contaminants have at least one species with a high overall degree of contamination. Two South Coast locations fell into this category: San Pedro Bay and Crystal Cove to Santa Ana River. These locations are within the area covered by the existing consumption advisory for the southern California coast from Ventura Harbor to San Mateo Point. The vast majority of locations fell into the intermediate contamination categories.

Table 7 presents a multiple contaminant summary that focuses on the least contaminated species. This table lists the species that were below thresholds for all contaminants at each location. A total of 26 of 68 locations (38%) had at least one species below all thresholds. Eight locations (12%) had more than one species below all thresholds. Two locations (Dana Point Harbor and Oceanside Harbor) each had four species below all thresholds. On the North Coast, blue rockfish and olive rockfish were below all thresholds at multiple locations. On the Central Coast, blue rockfish and black rockfish were below thresholds at four and three locations, respectively. On the South Coast, blue rockfish, chub mackerel, and spotfin croaker were below thresholds at more than one location. Overall, blue rockfish stood out as the most widely distributed species with concentrations below thresholds.

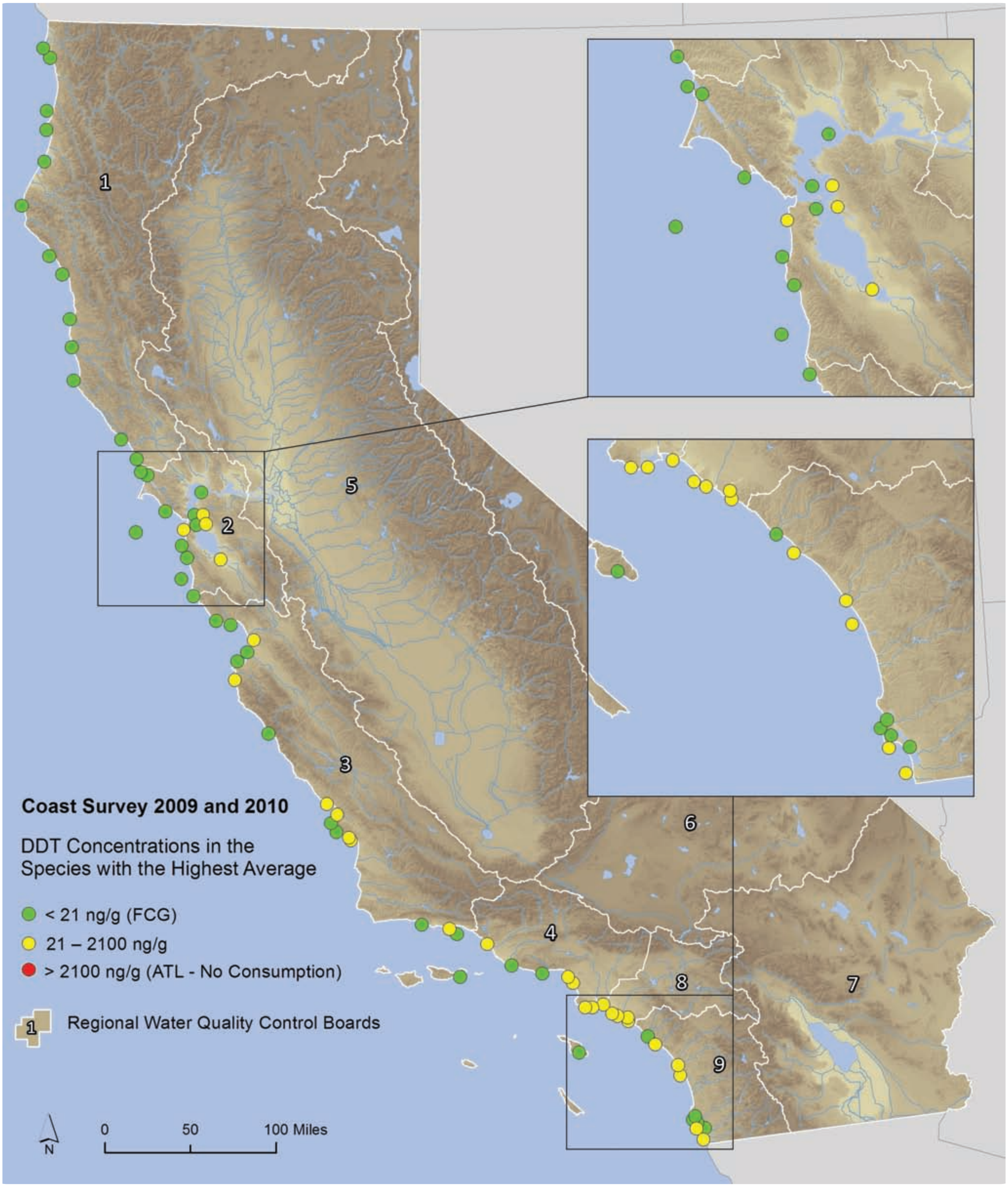

Figure 16. Spatial patterns in DDT concentrations among locations sampled in the Coast Survey, 2009-2010. Each point represents the highest average DDT concentration among the species sampled at each location.

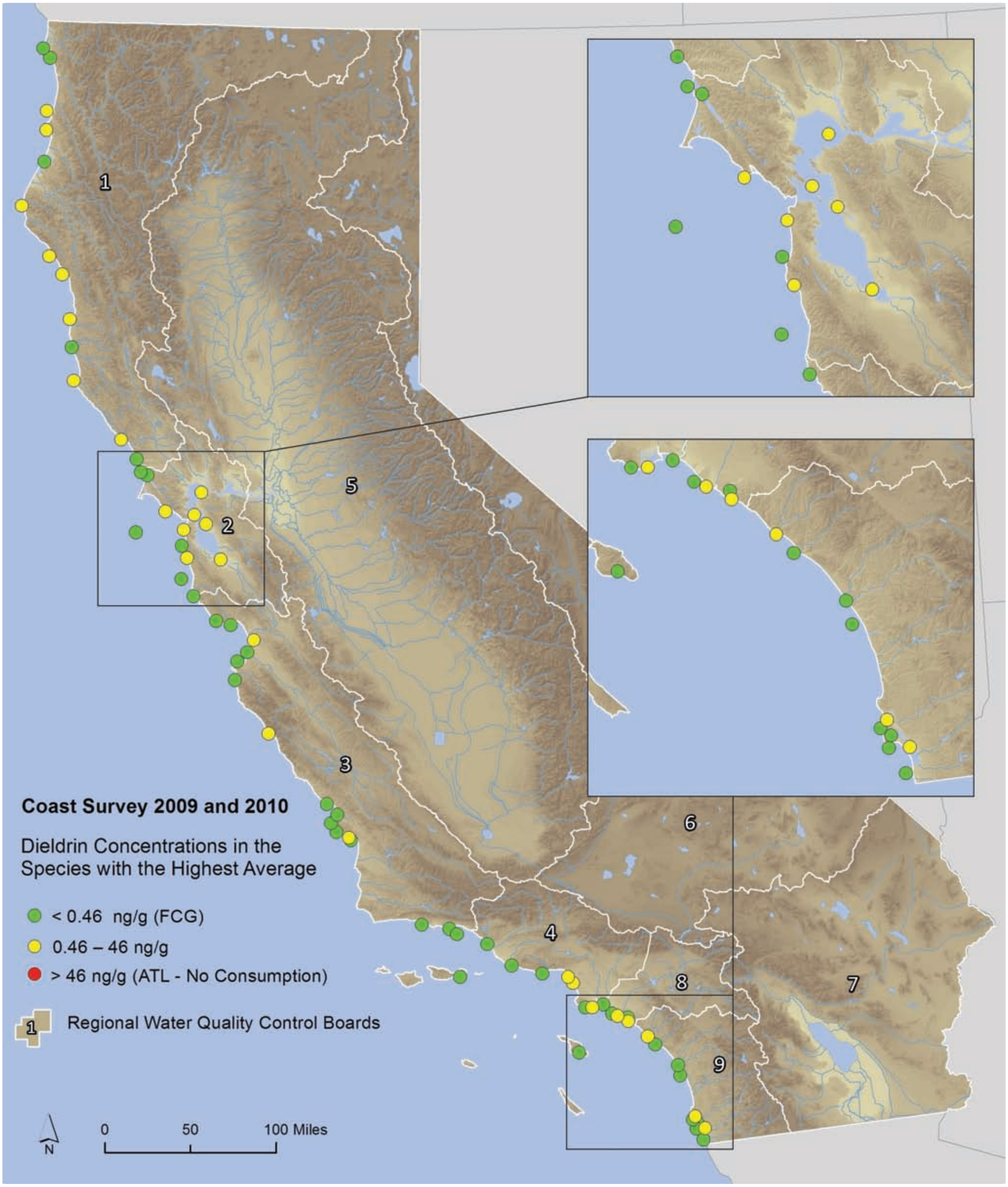

Figure 17. Spatial patterns in dieldrin concentrations among locations sampled in the Coast Survey, 2009-2010. Each point represents the highest average dieldrin concentration among the species sampled at each location.

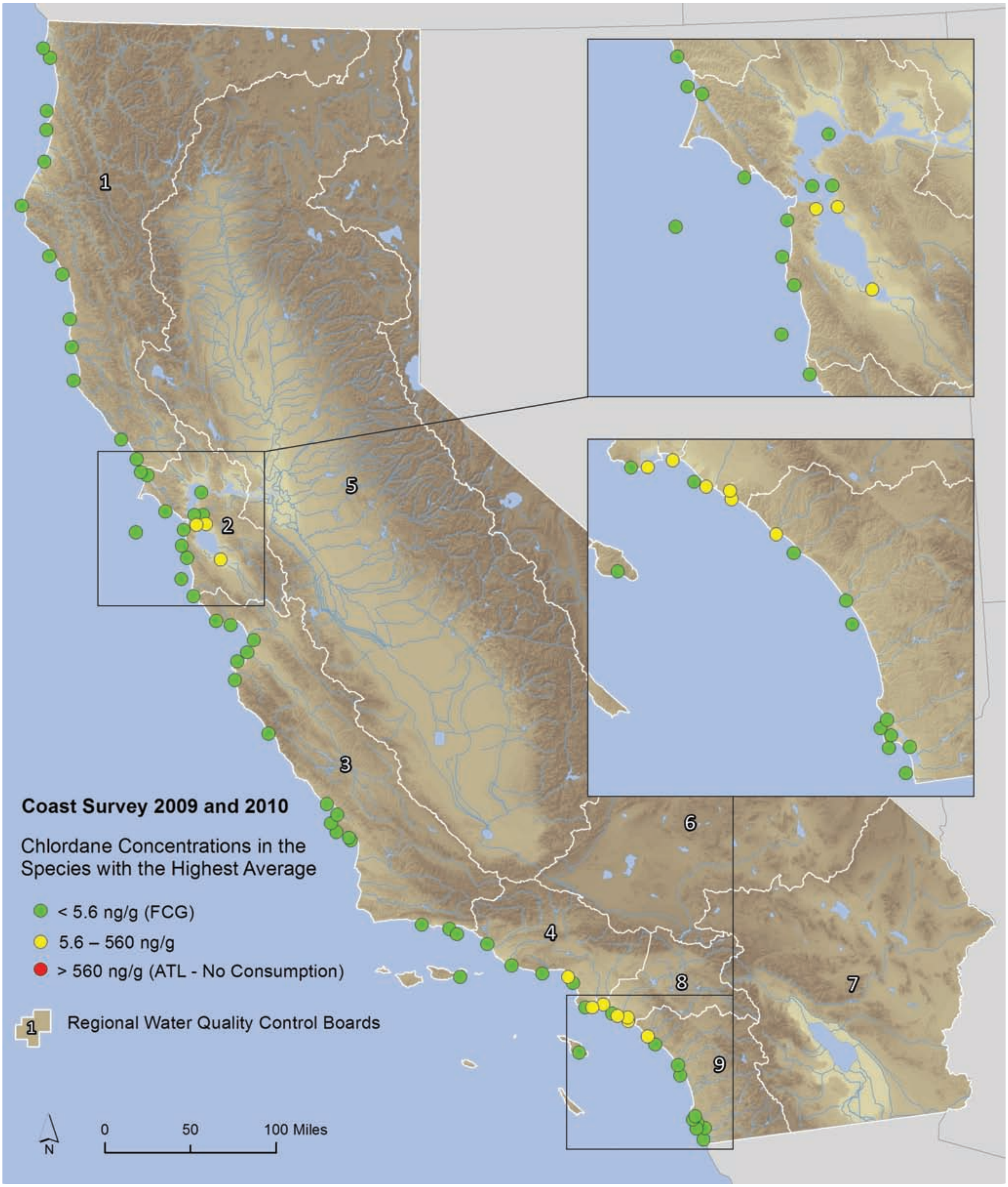

Figure 18. Spatial patterns in chlordane concentrations among locations sampled in the Coast Survey, 2009-2010. Each point represents the highest average chlordane concentration among the species sampled at each location.

COAST SURVEY 2009 and 2010

Levels of Concern for Methylmercury and PCBs for Most Contaminated Species at Each Location

Low Concern | Moderate Concern | High Concern

Methylmercury (in parts per million): 0.07 | 0.44

PCBs (in parts per billion): 3.6 | 120

Location	Methylmercury			PCBs		
	Coast	Bay	Offshore	Coast	Bay	Offshore
1 Crescent City Coast	Moderate			Low		
2 Del Norte Coast	Moderate			Moderate		
3 N Humboldt County Coast Area	High			Low		
4 Trinidad Area	Moderate			Low		
5 Humboldt Bay		High			Low	
6 Cape Mendocino Area	High			Low		
7 Shelter Cove Area	High			Low		
8 N Mendocino County Coast Area	High			Low		
9 Fort Bragg Area	High			Low		
10 Mendocino Coast Area	High			Low		
11 Point Arena Area	High			Low		
12 S Sonoma Coast/N Sonoma Coast	High			Low		
13 Bodega Harbor		High			Low	
14 N Marin Coast	Moderate			Low		
15 Tomales Bay		High			Moderate	
16 S Marin Coast	Moderate			Moderate		
17 San Pablo Bay		High			Moderate	
18 Berkeley		Moderate			Moderate	
19 Central Bay		High			Moderate	
20 Oakland		Moderate			High	
21 San Francisco Waterfront		Moderate			High	
22 South Bay		High			Moderate	
23 San Francisco Coast	Moderate			Moderate		
24 Farallon Islands			Moderate			Low
25 Pacifica Coast	Moderate			Moderate		
26 Pillar Point Harbor		Moderate			Low	
27 Half Moon Bay Coast	Moderate			Moderate		
28 San Mateo Coast	Moderate			Low		
29 Santa Cruz Coast Area	Moderate			Low		
30 Santa Cruz Area Wharfs/Beachs	Moderate			Low		
31 Elkhorn Slough		High			Moderate	
32 Moss Landing/Marina Coast	Moderate			Moderate		
33 Monterey/Pacific Grove Coast	Moderate			Low		
34 Carmel Coast	High			Moderate		
35 S Monterey Co/Big Sur Coast	Moderate			Low		
36 Cambria/Cayucos Coast/ N San Luis Obispo Co	High			Moderate		
37 Morro Bay		High			Moderate	
38 Morro Bay Coast	High			Moderate		
39 Diablo Canyon Coast	High			Low		
40 Port San Luis Area	High			Moderate		
41 N Santa Barbara Co/Pismo Beach	Moderate			Low		
42 Goleta to Pt Conception	Moderate			Moderate		
43 Rincon to Goleta	Moderate			Moderate		
44 Santa Barbara Oil Platform			Moderate			Moderate
45 Ventura to Rincon	Moderate			Moderate		
46 Pt Dume to Oxnard	Moderate			Moderate		
47 N Santa Monica Bay	Moderate			Moderate		
48 N Channel Islands			Moderate			Low
49 Middle Santa Monica Bay	Moderate			Moderate		
50 S Santa Monica Bay	Moderate			Moderate		
51 Long Beach		High			Moderate	
52 San Pedro Bay		High			High	
53 Palos Verdes	Moderate			Moderate		
54 Orange County Oil Platforms			Moderate			Moderate
55 Santa Ana River to Seal Beach	High			Moderate		
56 Newport Bay		Moderate			Moderate	
57 Crystal Cove to Santa Ana River	High			High		
58 Dana Point Harbor		Moderate			Moderate	
59 San Onofre to Crystal Cove	Moderate			Moderate		
60 Catalina Island			Moderate			Low
61 Oceanside Harbor		Low			Moderate	
62 La Jolla to San Onofre	Moderate			Moderate		
63 Mission Bay		Moderate			Moderate	
64 Pt Loma to La Jolla	Moderate			Moderate		
65 Pt Loma	Moderate			Moderate		
66 San Diego N Bay		Moderate			Moderate	
67 San Diego S Bay		Moderate			High	
68 Tijuana to N Island	Moderate			Moderate		

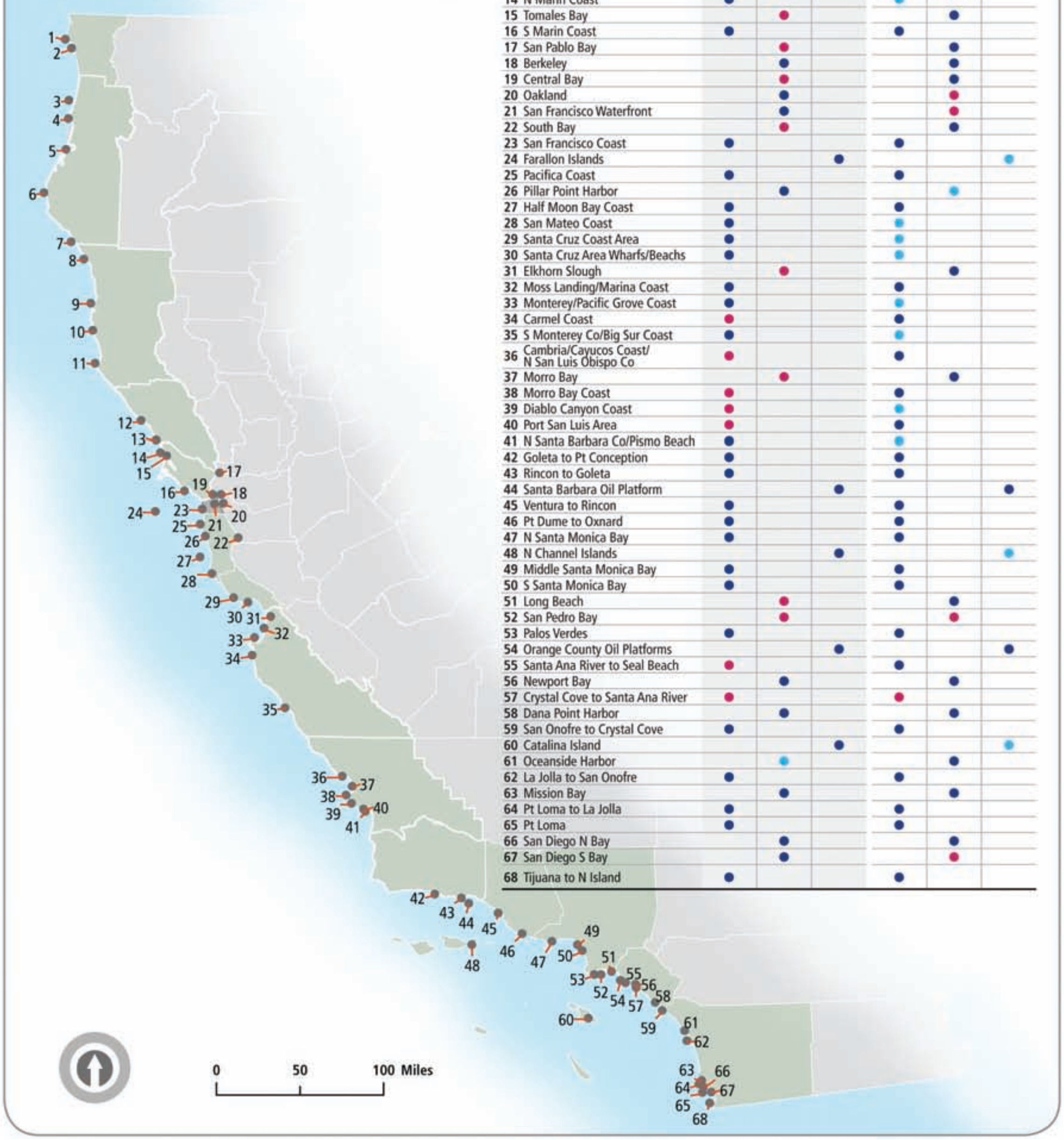

Figure 19. Classification of average methylmercury and PCB concentrations on the California coast, 2009-2010. Based on most contaminated species at each location.

Table 6
Percentages of locations falling into the contamination categories identified in Figure 19. Color categories in first column for methylmercury and PCBs (respectively).

	North		Central		South		Totals		Grand Total
	Coast	Bays	Coast	Bays	Coast	Bays	Coast	Bays	
Light blue, light blue	0	0	0	0	0	0	0	0	0
Dark blue, light blue	25	0	41	0	0	13	23	5	17
Dark blue, dark blue	8	0	29	22	87	50	43	30	39
Plum, light blue	67	67	6	0	0	0	20	10	17
Plum, dark blue	0	33	24	78	7	25	11	50	23
Plum, plum	0	0	0	0	7	13	2	5	3

Table 7
Locations with species with average concentrations of both methylmercury and PCBs below 0.07 ppm and 3.6 ppb, respectively.

Regional Board	Zone	Station Name	Rainbow Surfperch	Blue Rockfish	Olive Rockfish	Kelp Greenling	Black Rockfish	Black Perch	Shiner Surfperch	White Surfperch	Chub Mackerel	Kelp Bass	Barred Surfperch	Kelp Rockfish	Opaleye	Spotfin Croaker	Topsmelt	White Croaker	Queenfish	Yellowfin Croaker	Total Count
1	67	Del Norte Coast		X	X																2
1	64	Humboldt Bay				X															1
1	61	Shelter Cove Area		X																	1
1	57	Point Arena Area			X																1
1	55/56	South Sonoma Coast/North Sonoma Coast		X																	1
1	54	Bodega Harbor	X																		1
2	53	Northern Marin Coast		X	X																2
2	52	Tomales Bay							X	X											2
2	50	Farallon Islands		X																	1
2	47	Half Moon Bay Coast		X																	1
2	46	Pillar Point Harbor						X													1
2	45	San Mateo Coast		X			X														2
3	43	Santa Cruz Coast Area					X														1
3	39	Monterey/Pacific Grove Coast					X							X							2
3	36/37	Southern Monterey County Coast/Big Sur Coast		X																	1
3	34/35	Cambria/Cayucos Coast/Northern San Luis Obispo County Coast											X								1
3	27	Goleta to Pt Conception		X								X									2
3	26	Santa Barbara Channel Oil Platform									X										1
3	25	Rincon to Goleta		X																	1
4	22	Pt Dume to Oxnard						X													1
4	21	North Santa Monica Bay									X										1
4	17	Catalina Island									X										1
8	11	Crystal Cove to Santa Ana River									X										1
9	10	Dana Point Harbor													X	X	X	X			4
9	8	Oceanside Harbor														X		X	X	X	4
9	7	La Jolla to San Onofre									X										1
		Total Count	**1**	**10**	**3**	**1**	**3**	**2**	**1**	**1**	**5**	**1**	**1**	**1**	**1**	**2**	**1**	**2**	**1**	**1**	

SECTION 4
COMPARISON OF RESULTS FOR LAKES AND THE COAST

The overall degree of contamination of sport fish on the California coast observed in this survey was greater than that observed for California lakes (Davis et al. 2010). For methylmercury this is largely a function of longer food chains and the presence of longer-lived fish species in coastal waters. For PCBs this is more a function of the presence of sources near major urban centers.

Relative to the lakes results, the coast survey found higher proportions of locations exceeding all of the OEHHA and Water Board methylmercury thresholds (Figure 20). On the coast, 37% of locations had a species with an average above OEHHA's 0.44 ppm no consumption threshold, compared to 21% of the lakes surveyed. Higher proportions for every concentration category were observed for coastal locations. Only 1% of the coastal locations were below the 2 serving per week ATL, compared to 32% of the lakes surveyed. The lakes with low methylmercury concentrations were generally those where smaller sized (lower trophic position) trout species were sampled, and in many cases these were probably hatchery transplants. On the coast, long-lived predatory species were sampled at many locations. These factors probably account for most of the difference that is apparent in Figure 20.

The degree of PCB contamination at the locations sampled in the Coast Survey was also substantially greater than that observed in the two-year Lakes Survey (Davis et al. 2010) (Figure 21). Much higher proportions of the coastal locations fell into each concentration category. For example, 66% of coastal locations were above the lowest PCB threshold (the 3.6 ppb FCG), in contrast to only 33% of the 272 lakes found to be above this value. One primary cause of this difference appears evident from the distribution of elevated concentrations of PCBs around the major urban centers on the coast. The Lakes Survey also concluded that PCB concentrations were higher around the urbanized regions in Los Angeles and the San Francisco Bay Area (Davis et al. 2010). Another factor contributing to this difference, as for methylmercury, is the prevalence of lakes where trout species were the primary bioaccumulation indicators. The generally lower trophic position of trout, and possibly the abundance of hatchery fish (although some studies have shown relatively high PCB concentrations in hatchery-raised trout – e.g., McKee et al. [2008]), are factors that could lead to lower PCB concentrations, as seems likely for methylmercury. The wider array of species present on the coast and sampled in the Survey made it more likely to include species with a greater tendency to accumulate PCBs and other organic contaminants. Most importantly, PCB contamination is likely generally less prevalent in California lakes.

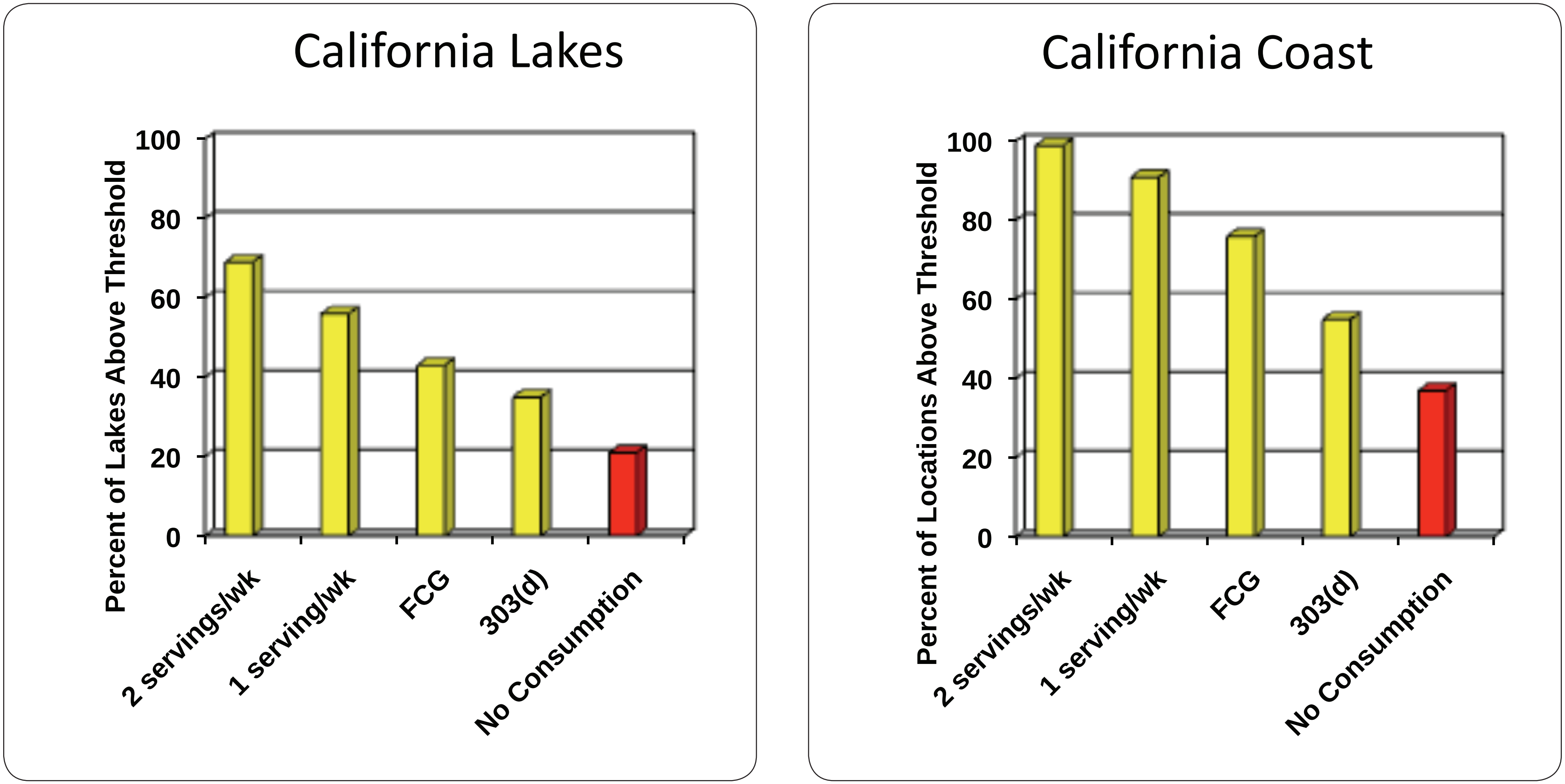

Figure 20. Percentages of lakes and coastal sampling locations above various methylmercury thresholds.

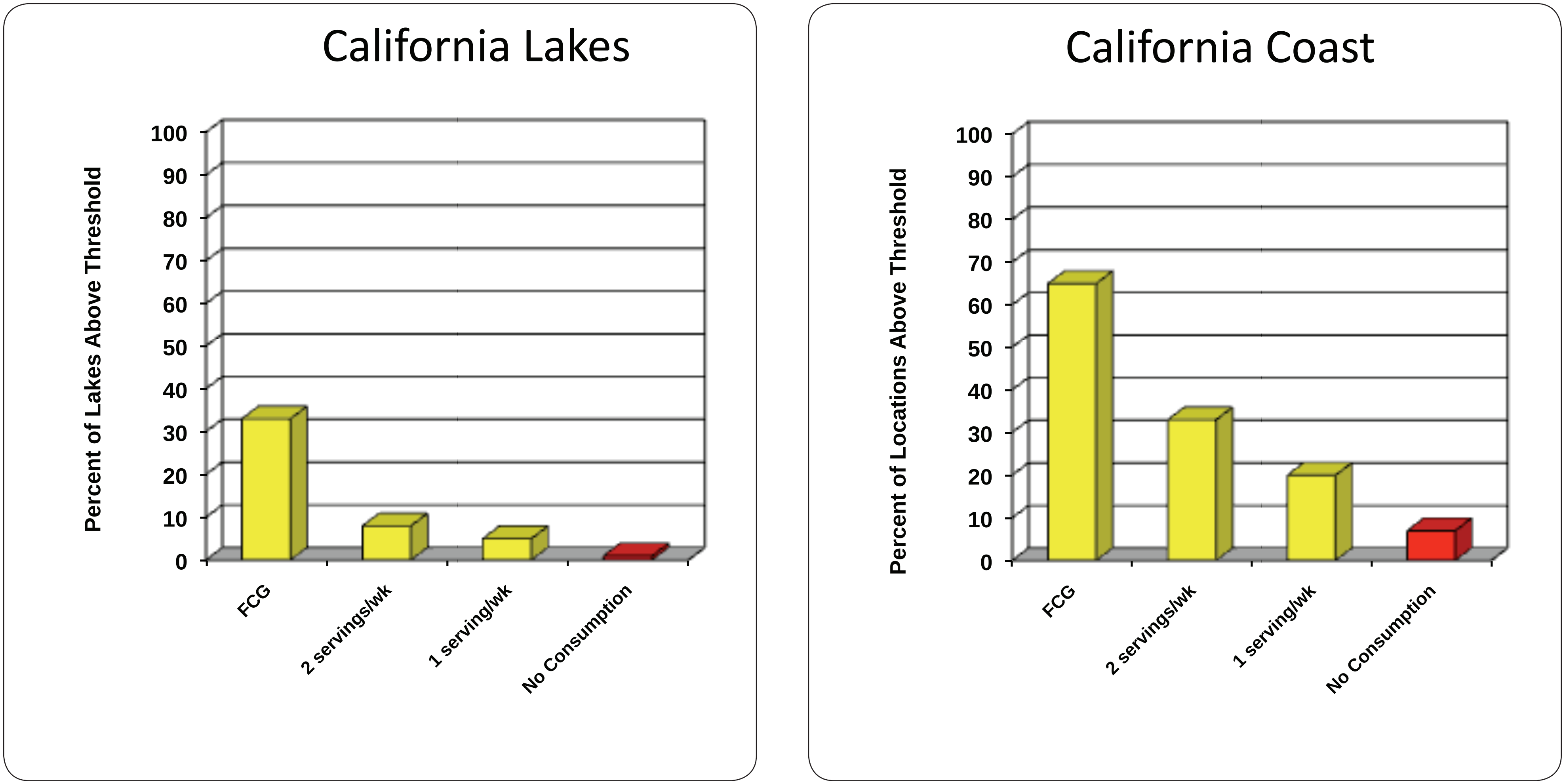

Figure 21. Percentages of lakes and coastal sampling locations above various PCB thresholds.

SECTION 5
MANAGEMENT IMPLICATIONS AND NEXT STEPS

Two contaminants, methylmercury and PCBs, were observed at concentrations that pose significant potential health risk to consumers of fish from the California coast. Contamination due to methylmercury was more severe and more widespread.

The data from this survey indicate that methymercury contamination is ubiquitous in the food webs of the California coast. The North and Central coast regions, which are relatively free of urban and industrial sources of mercury, had more locations exceeding the no consumption threshold than the areas near the urban centers of San Francisco, Los Angeles, and San Diego. Even a remote location like the Farallon Islands was found to have a moderate degree of contamination. Island locations in the South also still had moderate contamination. These data suggest that enough mercury is supplied to the entire California coast to cause problematic bioaccumulation wherever long-lived predatory fish species are caught and consumed. This mercury is derived from a variety of sources, including global emissions to the atmosphere; historic mercury, gold, and silver mining; urban and industrial wastewater and stormwater; and upwelling of organic matter from the deep ocean.

The ubiquitous contamination observed in this survey suggests that atmospheric deposition of mercury from global sources may be a significant contributor to methylmercury in California coastal food webs. Peterson et al. (2002) reached a similar conclusion based on the broad distribution of methylmercury bioaccumulation in Oregon streams. The contributions of other local sources are superimposed upon a background of global atmospheric deposition and other sources to coastal waters such as geological sources (volcanoes and vents) and the upwelling transport pathway. San Francisco Bay provides an example where local sources play a distinct and significant role.

The survey results suggest that PCB contamination is more localized and primarily attributable to discrete sources near the major urban centers of San Francisco, Los Angeles, and San Diego.

Consumption advisories currently in place on the coast cover Tomales Bay, San Francisco Bay, and the South Coast near Los Angeles (Figure 22). The methylmercury concentrations observed in this Survey indicate that development of consumption advice would be valuable for the entire coast. Development of advice for the North Coast, where locations consistently exceeded OEHHA's 0.44 ppm threshold for considering a no consumption advisory, appears to be a priority. Central Coast locations also frequently exceeded 0.44 ppm—development of advice for this region appears to be a priority as well. PCB concentrations above OEHHA's 120 ppb threshold for considering a no consumption advisory were observed in three locations that had clear signals of food web contamination: San Francisco Bay, San Pedro Bay, and San Diego Bay. Safe eating guidelines are already in place for San Francisco Bay and San Pedro Bay, but not for San Diego Bay. OEHHA plans to merge data from the Coast Survey with additional data from other studies to develop an advisory for San Diego Bay. Generating the data needed to support the development of safe eating guidelines is a high priority.

San Francisco Bay stands out as having high methylmercury and PCB concentrations. The methylmercury concentrations are high relative to other bays and estuaries in California and the rest of the U.S.. However, San Francisco Bay is being routinely and thoroughly assessed under the Regional Monitoring Program, and the consumption guidelines for the Bay were updated in 2011. TMDL control plans are also already in place for mercury and PCBs in the Bay.

Methylmercury control plans appear to also be needed for other parts of the coast. Most locations (37 of 68, or 54%) had a most highly contaminated species with an average above the State Board's 0.30 ppm 303(d) listing threshold. Tomales Bay is the only other coastal location besides San Francisco Bay with a mercury TMDL in place.

Other locations (besides San Francisco Bay) where PCB control plans appear to be needed are San Pedro Bay and San Diego Bay. TMDLs for hotspots of sediment contamination (including PCBs) in San Diego Bay are in development and a TMDL for PCBs and other contaminants in Los Angeles and Long Beach Harbor (including San Pedro Bay) has been established.

With the exception of San Francisco Bay, data that can be used to assess long-term trends in sport fish contamination are almost nonexistent. Time series are needed to track trends in fish contamination in response to local and regional management actions, as well as other factors such as changes in global atmospheric emissions of mercury and climate change. Time series should be established in priority locations for this purpose, using methods that allow for direct comparison to the data generated in this Survey.

The concentrations of methylmercury and PCBs observed in sport fish in this Survey suggest that significant risks to wildlife are also possible in coastal waters. Detailed studies in San Francisco Bay have documented substantial risks to fish-eating birds, especially due to methylmercury contamination (Ackerman et al. 2008, Eagles-Smith et al. 2009). Sampling of fail-to-hatch seabird eggs from the Farallon Islands in 2009 found mean concentrations of 0.86 ppm fresh wet weight in Pigeon Guillemot, 0.51 ppm in Rhinoceros Auklet, and 0.13 ppm in Cassin's Auklets (Aceituno et al. 2010). The concentrations in Pigeon Guillemots and Rhinoceros Auklets were elevated relative to laboratory-derived risk thresholds. Potential risks to coastal wildlife from methylmercury, PCBs, and other contaminants should be closely evaluated, and the status and trend monitoring needed to support management of any significant risks should be performed.

The Lakes Survey has led to an effort to develop a statewide TMDL for methylmercury in lakes and reservoirs. The more severe contamination observed in this Survey and high fishing pressure on the coast suggest that a control plan or control plans are also a priority for California coastal waters. Results from the Coast Survey will be used by the State and Regional Water Boards in prioritizing coastal areas in need of cleanup plans or further monitoring.

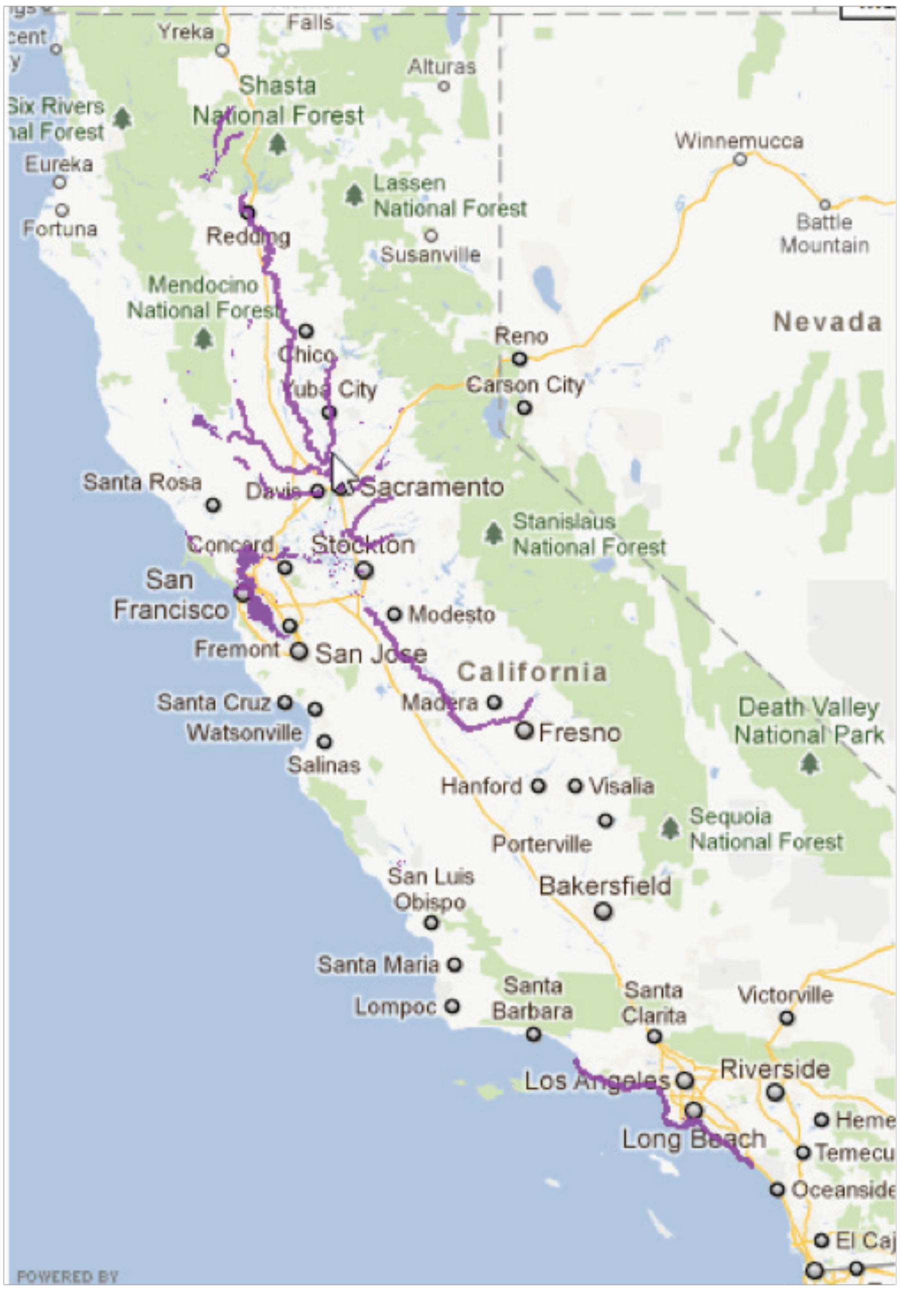

Figure 22. Consumption advisories currently in place in California. Advisories for coastal waters are in place for Tomales Bay, San Francisco Bay, and the South Coast near Los Angeles.

REFERENCES R

Able, K.W., 2005. A re-examination of fish estuarine dependence: Evidence for connectivity between estuarine and ocean habitats. Est. Coast. Shelf Sci. 64, 5-17.

Aceituno, K.M., C.S. Johnson, G. McChesney, R. Bradley, and P. Warzybok. 2010. Contaminants in Seabird Eggs from Farallon National Wildlife Refuge. Poster presented at the 20th Annual Meeting of NorCal SETAC.

Ackerman J.T., C.A. Eagles-Smith, J.Y. Takekawa, S.A. Demers, T.L. Adelsbach, J.D. Bluso, A.K. Miles, N. Warnock, T.H. Suchanek, and S.E. Schwarzbach. 2008. Mercury concentrations and space use of pre-breeding

American avocets and black-necked stilts in San Francisco Bay. Sci. Tot. Environ. 384:452-466.

Bioaccumulation Oversight Group. 2009. Sampling and Analysis Plan for a Screening Study of Bioaccumulation on the California Coast. State Water Resources Control Board, Sacramento, CA.

Bonnema, A. 2009. Quality Assurance Project Plan Screening Study of Bioaccumulation on the California Coast. Moss Landing Marine Labs. Prepared for SWAMP BOG, 46 pages plus appendices and attachments.

Burger, J., Gochfeld, M., 2011. Mercury and selenium levels in 19 species of saltwater fish from New Jersey as a function of species, size, and season. Sci. Tot. Environ. 409, 1418-1429.

Davis, J. A., J. A. Hunt, B. K. Greenfield, R. Fairey, M. Sigala, D. B. Crane, K. Regalado, and A. Bonnema. 2006. Contaminant concentrations in fish from San Francisco Bay, 2003. San Francisco Estuary Institute, Oakland CA.

Davis, J.A., J. L. Grenier, A.R. Melwani, S. Bezalel, E. Letteney, and E. Zhang. 2007. Bioaccumulation of pollutants in California waters: a review of historic data and assessment of impacts on fishing and aquatic life. Prepared for the Surface Water Ambient Monitoring Program, California Water Resources Control Board, Sacramento, CA.

Davis, J.A., A.R. Melwani, S.N. Bezalel, J.A. Hunt, G. Ichikawa, A. Bonnema, W.A. Heim, D. Crane, S. Swenson, C. Lamerdin, and M. Stephenson. 2010. Contaminants in Fish from California Lakes and Reservoirs, 2007-2008: Summary Report on a Two-Year Screening Survey. A Report of the Surface Water Ambient Monitoring Program (SWAMP). California State Water Resources Control Board, Sacramento, CA.

Davis, J.A., K. Schiff, A.R. Melwani, S.N. Bezalel, J.A. Hunt, R.M. Allen, G. Ichikawa, A. Bonnema, W.A. Heim, *D. Crane, S. Swenson, C. Lamerdin, and M. Stephenson. 2011. Contaminants in Fish from the California Coast, 2009: Summary Report on Year One of a Two-Year Screening Survey. A Report of the Surface Water Ambient Monitoring Program (SWAMP). California State Water Resources Control Board, Sacramento, CA.*

Eagles-Smith, C.A., J.T. Ackerman, S.E.W. De La Cruz, and J.Y. Takekawa. 2009. Mercury bioaccumulation and risk to three waterbird foraging guilds is influenced by foraging ecology and breeding stage. Environ. Pollut. 157: 1993-2002.

Gassel, M., R.K. Brodberg, and S. Roberts. 2002. The Coastal Fish Contamination Program: Monitoring of Coastal Water Quality and Chemical Contamination in Fish and Shellfish in California. Presented at Conference on California and the World Ocean, Santa Barbara, CA.

Glover, J.B., Domino, M.E., Altman, K.C., Dillman, J.W., Castleberry, W.S., Eidson, J.P., Mattocks, M., 2010. Mercury in South Carolina Fishes, USA. Ecotoxicology 19, 781-795.

Greenfield, B.K. and A. Jahn. 2010. Mercury in San Francisco Bay forage fish. Environmental Pollution 158: 2716-2724.

Hebert, C.E., Keenleyside, K.A., 1995. To normalize or not to normalize? Fat is the question. Environmental Toxicology and Chemistry 14 (5), 801–807.

Jones, K. 2004. Pier Fishing in California. Publishers Design Group, Roseville, CA.

Katner, A., Sun, M-H., Suffet, M., 2010. An evaluation of mercury levels in Louisiana fish: Trends and public health issues. Sci. Tot. Environ. 408, 5707-5714.

Klasing, S. and R. Brodberg. 2008. Development of Fish Contaminant Goals and Advisory Tissue Levels for Common Contaminants in California Sport Fish: Chlordane, DDTs, Dieldrin, Methylmercury, PCBs, Selenium, and Toxaphene. California Office of Environmental Health Hazard Assessment, Sacramento, CA.

Mason, R.P., Heyes, D., Sveinsdottir, A., 2006. Methylmercury concentrations in fish from tidal waters of the Chesapeake Bay. Arch. Environ. Contam. Toxicol. 51, 425–437.

McKee MJ, Kromrey GB, May TW, Orazio CE, 2008. Contaminant levels in rainbow trout, Oncorhynchus mykiss, and their diets from Missouri coldwater hatcheries. Bull Environ Contam Toxicol 80, 450-454.

Newman, M.C., X. Xu, C.F. Cotton, and K.R. Tom. 2011. High mercury concentrations reflect trophic ecology of three deep-water Chondrichthyans. Arch Environ Contam Toxicol 60:618–625.

NMFS. 2009. Fisheries economics of the U.S. http://www.st.nmfs.noaa.gov/st5/publication/econ/2009/Pacific_CATables_Econ.pdf

NOAA. 2007. 2002-2004 Southern California Coastal Marine Fish Survey. National Oceanic Atmospheric and Administration. Long Beach CA 91 pp.

Peterson SA, Herlihy AT, Hughes RM, Motter KL, Robbins JM, 2002. Level and extent of mercury contamination in Oregon, USA, lotic fish. Environ Toxicol Chem 21, 2157-2164.McKee. 2008.

Pethybridge, H., D. Cossa, and E.C.V. Butler. 2009. Mercury in 16 demersal sharks from southeast Australia: Biotic and abiotic sources of variation and consumer health implications. Mar. Environ. Res. 69: 18–26

Piraino, M.N., Taylor, D.L., 2009. Bioaccumulation and trophic transfer of mercury in striped bass (Morone saxatilis) and tautog (Tautoga onitis) from the Narragansett Bay (Rhode Island, USA). Mar. Environ. Res. 67, 117–128.

Sandheinrich, M.B., Wiener, J.G., 2011. Methylmercury in freshwater fish: recent advances in assessing toxicity of environmentally relevant exposures. Pp 169-190 in Beyer, W.N. Meador, J.P. (eds.) 2011. Environmental Contaminants in Biota: Interpreting Tissue Concentrations. CRC Press, Boca Raton, FL, USA.

Secor, D.H., Piccoli, P.M., 2007. Oceanic migration rates of Upper Chesapeake Bay striped bass (Morone saxatilis), determined by otolith microchemical analysis. Fishery Bulletin 105, 62–73.

SFEI. 2000. San Francisco Bay Seafood Consumption Study. Technical Report, San Francisco Estuary Institute, Oakland, CA.

Suk, S.H., S.E. Smith, and D.A. Ramon. 2009. Bioaccumulation of mercury in pelagic sharks from the northeast Pacific Ocean. CalCOFI Report 50: 172-177.

USEPA. 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories: Volume 1, Fish Sampling and Analysis, Third Edition. EPA 823-R-93-002B-00-007. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

USEPA. 2001. Water Quality Criterion for the Protection of Human Health: Methylmercury. EPA-823-R-01-001. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Wiener, J.G., R.A. Bodaly, S.S. Brown, M. Lucotte, M.C. Newman, D.B. Porcella, R.J. Reash, and E.B. Swain. 2007. Monitoring and evaluating trends in methylmercury accumulation in aquatic biota. Chapter 4 in R. C. Harris, D. P. Krabbenhoft, R. P. Mason, M. W. Murray, R. J. Reash, and T. Saltman (editors) Ecosystem responses to mercury contamination: indicators of change. SETAC Press, Pensacola, Florida.

SWAMP
Surface Water
Ambient Monitoring
Program

For more information, please contact:

Jay A. Davis
San Francisco Estuary Institute
4911 Central Avenue
Richmond, CA 94804
jay@sfei.org

CALIFORNIA
Water Boards

www.waterboards.ca.gov/swamp