The Coastal Fish Contamination Program: Monitoring of Coastal Water Quality and Chemical Contamination in Fish and Shellfish in California

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Abstract

The Coastal Fish Contamination Program (CFCP) is a relatively new state program initiated in 1998 to develop comprehensive monitoring and assessment of chemical contamination in sport fish and shellfish from California coastal waters. This is the first systematic program in California specifically designed to assess the health risks of consumption of sport fish and shellfish from nearshore waters along the entire California coast. Several state agencies work cooperatively to implement the program. The results of laboratory analysis from the first and second full sampling years have been finalized and are summarized here. These data provide a baseline for certain fish along much of the coast including areas that had never been sampled. Chemical concentrations were compared to screening values (SVs), concentrations of chemicals in fish or shellfish tissue that are of potential public health concern and that, when exceeded, indicate that more intensive monitoring and/or evaluation of human health risk should be conducted. Eleven chemicals that bioaccumulate in fish were evaluated to present an overall summary of the results. Comparisons of chemical concentrations to SVs showed the primary chemicals of concern to be polychlorinated biphenyl congeners (PCBs) and mercury. Preliminary trends in the geographic distributions of chemicals were found and variation among species was also documented. Based on data collected under the CFCP, the Office of Environmental Health Hazard Assessment will be able to provide consumption recommendations to protect public health. The CFCP is a critical component of a comprehensive coastal water quality protection program, and provides an important new opportunity to build a long-term coastal monitoring database for water quality and contaminants in fish.

Introduction

The Coastal Fish Contamination Program (CFCP or "Program") is a relatively new state program initiated as a result of legislation (Assembly Bill 2872) passed in 1998. The intent for the program was to develop a comprehensive monitoring program of chemical contamination in sport fish and shellfish in nearshore waters (marine and estuarine) in California. The program was specifically designed to

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provide data for the assessment of human health risks from consumption of these fish. Although several regional efforts to monitor contaminants in coastal sport fish and shellfish are in operation in coastal water bodies, the CFCP is the first systematic and comprehensive monitoring program of its kind for sport fish and shellfish from marine and estuarine waters along the entire coast of California.

The Program involves a cooperative effort among various state agencies. The State Water Resources Control Board oversees the Program, and each of the Regional Water Quality Control Boards (RWQCB) with jurisdiction over coastal waters participates. The California Department of Fish and Game collects and analyzes the tissue samples; Moss Landing Marine Laboratory analyzes for trace metals and the Water Pollution Control Laboratory analyzes for organic constituents. The Office of Environmental Health Hazard Assessment (OEHHA) plans the study design with input from the RWQCBs; maintains the dataset; evaluates the data in order to perform human health risk assessments; and issues consumption advisories when appropriate.

The Program identifies and samples sport fish and shellfish species that are frequently caught and consumed from fishing locations along the coast of California. Sampling and analysis protocol is standardized throughout the Program and incorporates recommendations by U.S. EPA (2000). Composite samples formed from muscle or edible tissue extracted from several fish or shellfish of a similar size in a given species are used for laboratory analysis; in some cases (with large fish such as sharks), tissue samples from single fish are analyzed to provide additional information on individual variation and correlations between size and chemical concentration. Quality assurance and quality control measures follow prescribed procedures as described in the Quality Assurance Project Plan (QAPP) (Ichikawa, 2000). The Program will identify fish and shellfish species that are more and less contaminated and the geographic locations where these differences occur. The information collected under the CFCP will provide the data that OEHHA needs to assess the human health risks from consumption of coastal sport fish and shellfish containing chemical contaminants at concentrations of concern for public health.

In the early years of the Program, screening studies were conducted in most regions to identify areas of potential contamination. The screening studies were planned to identify locations and species for which further sampling would be done in subsequent years. The data, once collected and evaluated, will also be used to identify specific ongoing monitoring sites or "sentinel sites" in each region that will be sampled on a regular basis in future monitoring years. In one case, a RWQCB opted to conduct more comprehensive sampling in one water body in their region. The San Francisco Bay RWQCB chose to focus sampling on fish and shellfish from Tomales Bay, a large estuary in Marin County. Tomales Bay was targeted because the San Francisco Bay RWQCB had documented significant discharge from an abandoned mercury mine in the watershed and was therefore concerned about the bioaccumulation of mercury in the fish in the bay. In addition, the San Francisco Bay RWQCB already had data for much of its estuarine waters due to ongoing sampling of San Francisco Bay, which comprises a large proportion of the coastal water bodies in the region.

San Francisco Bay has not been sampled in the CFCP. The San Francisco Estuary Regional Monitoring Program (RMP) has monitored fish in San Francisco

Bay every 3 years since 1994. Several additional special studies have also been conducted in the alternate years. Data from both programs were used to expand the scope of this evaluation and to better show the overall geographic distribution of chemical contaminants in California.

Summary of Results

In the first two years of the Program, 72 sample locations and 51 species of fish and shellfish were tested. The distribution of the samples is shown in Figure 1. The data points shown in black indicate the samples from San Francisco Bay collected under the RMP in 1994, 1997, 1998, 1999, and 2000. Sampling in San Francisco Bay differs from the CFCP in some respects. Primarily, the RMP conducts more focused sampling on a single (although complex) water body, whereas the CFCP budget has to be allocated over the entire coast of California. As a result, there were relatively more samples collected from San Francisco Bay for specific locations and species. The results from San Francisco Bay were represented in the figures as a single summary data point for each species tested.

CFCP and RMP samples of fish and shellfish were analyzed in most cases for a comprehensive suite of trace metal and organic chemicals. For this evaluation, eleven of the chemicals that bioaccumulate in fish were selected to show an overview of the results of the first two years of the Program. These eleven chemicals included polychlorinated biphenyl congeners (PCBs); four metals: arsenic, cadmium, mercury, and selenium; and six pesticides: chlordane, DDTs, dieldrin, heptachlor epoxide, hexachlorobenzene, and toxaphene. Heptachlor epoxide is not a pesticide itself, but is a metabolite of two pesticides: heptachlor and chlordane. PCB congeners were expressed as total Aroclor equivalent concentrations. The measured chemical concentrations were compared to screening values (SVs). Screening values are defined as concentrations of chemicals in fish or shellfish tissue that are of potential public health concern and that, when exceeded, indicate the need for more intensive monitoring and/or evaluation of human health risk.

The percent of samples exceeding SVs for metals and PCBs in the first two years of the CFCP are summarized in Table 1. Of the metals analyzed, only the SV for mercury (0.3 ppm) was exceeded, in 13 percent of the samples. The SV for PCBs (20 ppb) was exceeded in 29 percent of the samples. In the samples, arsenic was measured as total arsenic but evaluated here for the more toxic form, inorganic arsenic, by assuming that inorganic arsenic was four percent of total arsenic. Some samples exceeded the SV for total arsenic but none exceeded the "adjusted SV" for inorganic arsenic. The assumption that only four percent of the total measured arsenic is inorganic appears to be conservative based on preliminary measures of inorganic arsenic in fish.

Table 2 shows the percent of samples exceeding the SV for metals and PCBs in San Francisco Bay fish. Again, the two chemicals or chemical groups frequently exceeding SVs in the samples analyzed were mercury and PCBs. In San Francisco Bay, however, a higher percentage of the samples exceeded the SV for these chemicals (36 percent for mercury and 90 percent for PCBs). Three samples also exceeded the SV (2 ppm) for selenium.

Measurements of total arsenic were high in certain species including sharks (Pacific angel sharks and leopard sharks), Dungeness and red rock crabs, opaleye, and several flatfish species such as spotted turbot and diamond turbot. Relatively high concentrations of total arsenic have been measured in various shark and shellfish species in other studies (Hall et al., 1978; Cullen and Reimer, 1989; Donohue and Abernathy, 1999). The data from the first two years of the CFCP identified species in California that had relatively high concentrations of total arsenic, and showed that further study of these species is warranted. Total arsenic includes organic and inorganic forms of arsenic. The inorganic forms are more toxic and most relevant to assess human health risks. Furthermore, the ratio of inorganic to total arsenic is relatively low, and is typically less than four percent (Donohue and Abernathy, 1999). Therefore, in current and future years of the Program, inorganic arsenic will be measured in fish and shellfish species with high total arsenic. Analysis of inorganic arsenic in future samples will allow for better evaluation of the health risks from exposure to fish and shellfish containing arsenic. Preliminary results from subsequent sampling under the CFCP suggest that the proportion of inorganic arsenic to total arsenic is variable among species, but the amount of inorganic arsenic in the samples appears to be below levels of health concern.

The percentage of samples exceeding the SV for pesticides in the CFCP and the RMP are shown in Tables 3 and 4, respectively. The SV for DDTs (100 ppb) was exceeded in ten percent of the CFCP samples, and although samples exceeded the SV for dieldrin in both programs, there was a higher percentage of samples exceeding the SV for dieldrin in San Francisco Bay (eleven versus three percent). The distribution of the samples that exceeded the SV for these two pesticides is shown in Figure 2.

In summary, then, the two major chemicals of concern along the California coast are PCBs and mercury. Fish tissue samples were analyzed for total mercury; however, in this case, it is the organic form methylmercury that poses the greatest health concern. The assumption that 100 percent of the total mercury measured in the samples is methylmercury is a conservative assumption based on studies that have shown that most of the mercury in fish is methylmercury (Bloom, 1992). Therefore, "mercury" is generally used in this paper to signify methylmercury, since total mercury was actually measured in the samples. In contrast, the ratio of methylmercury to total mercury is generally lower in shellfish species and variability within and among species is high (Lasorsa and Allen-Gil, 1995). Therefore, shellfish species are being analyzed in the Program for both methylmercury and total mercury.

Geographic Distributions and Species Differences

The results from sampling and analysis in the first two years of the CFCP showed differences in the geographic distribution of the two main chemicals of concern (Figures 3 and 4). Higher concentrations of mercury occurred more frequently in fish in northern California, especially in fish from San Francisco Bay and Tomales Bay. Concentrations of PCBs were more frequently high in fish from bays in both northern and southern California, especially near large urban industrial areas. In addition to the sampling of San Francisco Bay through the RMP, more monitoring is planned in Santa Monica Bay, San Pedro Bay, and the Orange County

coast by other agencies including those participating in cleanup, restoration, and communication projects through the Montrose Settlements. The CFCP did not focus on this area during screening sampling because there is an existing advisory and known contamination. The Program plans to coordinate sampling in this area with that of other programs. Although CFCP samples were limited in this region, the trend toward bioaccumulation of PCBs in fish in southern California is apparent.

Because the CFCP is not a random study design, the influence of species must be considered as well as the geographic location of the samples. Measurements of higher concentrations of chemicals in certain locations may also depend on the species sampled. To illustrate this point, Figure 5 shows the mean concentrations of mercury and PCBs in four species of fish sampled in San Francisco Bay. Leopard sharks were extremely high in mercury relative to the other species, but were the lowest in PCBs. In contrast, the species that were higher in PCBs were lower in mercury. These species included fish that tend to be high in lipid content, such as croakers and surfperch. Figure 5 also shows that the accumulation of chemicals can vary even among species within the same family. In this case, walleye surfperch had considerably lower concentrations of PCBs than did shiner surfperch.

In the CFCP, numerous sharks were sampled from Tomales Bay. Since shark species are at the top of food webs and known to be high in mercury, the distribution of samples showing high mercury concentrations could be biased toward northern California because sharks were not sampled in southern regions. Therefore, to examine the potential geographic distributions of chemical contaminants, chemical concentrations were compared using species for which samples were collected in multiple regions. Figure 6 shows the distribution of mercury in samples of white croaker. Although white croaker is not usually a species with high concentrations of mercury (especially compared to species such as leopard shark), these samples reflect a geographic gradient with low concentrations in southern California, and concentrations in northern California that approach a level of health concern. A similar pattern was seen in samples of shiner surfperch, shown in Figure 7. To examine the distribution of PCBs in fish, white croaker and shiner surfperch samples were again compared from various locations along the coast. In the case of PCBs, there appears to be higher accumulation in fish from bays and estuaries near industrial areas such as San Francisco Bay, Santa Monica Bay, and San Diego Bay. These results are shown in Figures 8 and 9.

Focused Study in Tomales Bay

More comprehensive studies were conducted in eight fish species and red rock crabs from Tomales Bay. All samples were analyzed for mercury and complete scans for metals and organic chemicals were run in two of the fish species (shiner surfperch and California halibut). Mercury was found at levels of potential health concern in seven of the fish species. Analyses of other chemicals and species showed they were not a health concern. OEHHA performed a preliminary health risk assessment using the analytical results, and worked with the Marin County Department of Health and Human Services to develop and issue an interim advisory for Tomales Bay in December of 2000. OEHHA is following up by conducting a full health evaluation,

incorporating more recent data collected from Tomales Bay under the CFCP, in order to develop a state health advisory.

Similar efforts to carry out more comprehensive sampling and analysis are currently underway for San Diego Bay. Focused sampling in San Diego Bay is being conducted, and attempts were made to identify and collect all fish species that are commonly consumed by sport fishers and their families in that region. The results will be used to determine whether a health advisory is needed.

Synopsis

The CFCP is an important long-term monitoring and assessment tool for California. The Program is in the early stages of development, but as long as funding sources and support for the Program continue, it promises to provide a needed comprehensive database on the accumulation of chemical contaminants in fish tissue. The value of the Program is multi-faceted. The results can be used to assess water quality and to develop guidelines and specific measures to protect coastal resources and public health. It will identify fish species and areas where chemical bioaccumulation is high, and will also identify less contaminated species and areas. In areas where chemical bioaccumulation is high enough that frequent consumption of sport-caught fish or shellfish may be a health hazard, OEHHA will develop health advisories containing consumption recommendations to protect public health. The identification of less contaminated species and areas is equally important for public health. Based on these data, OEHHA will also be able to develop advice to help sport fishers learn about safer places to fish and fish species to eat. To date, an advisory has been developed for Tomales Bay as a result of the data collected under the CFCP, and comprehensive monitoring is underway to determine the need for a health advisory for San Diego Bay. Similar investigations will occur for other locations identified through the CFCP.

The Program also offers some unique benefits in addition to providing a comprehensive and long-term database. Populations (human and fish) are characteristically different in California and the west coast compared to other regions of the United States. Ethnic diversity is high, and many ethnic populations reside in this area in far greater numbers than in most of the rest of the United States. In addition, the types of fish and shellfish species in the Pacific Ocean differ from those that are common elsewhere in U.S. coastal waters, and fewer samples of Pacific coast species have been collected and analyzed. Furthermore, some of the ethnic populations consume preferred species that differ from the norms of other populations in the United States. Therefore, one further benefit of the CFCP is that the data collected under this program can provide needed information on chemical contaminants in species especially relevant to California and west coast populations. These data are important for protecting public health in varying demographic populations and can be used to address environmental justice issues; the data will also support and supplement national contaminant data.

Conclusions

The CFCP is a critical component of an integrated and comprehensive coastal water quality and fish contamination program. The CFCP itself is a comprehensive program that relies on cooperative efforts by many state agencies involved in the protection of California's coastal resources and public health. Coordination in the future with monitoring of water chemistry, sediment quality, and assessment of coastal streams could enhance the value of the Program. This could include, for example, bringing together these respective datasets. Linking coastal resources and inland watersheds, using geographical information systems (GIS) mapping, would promote the development of a fully comprehensive and effective program for California.

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Table 1: Percent of Samples Exceeding the Screening Value (SV) for Metals and PCBs in the CFCP

Chemical	Percent	N[1]
Arsenic	0	271
Cadmium	0	234
Mercury	13	271
Selenium	0	234
PCBs	29	223

Table 2: Percent of Samples Exceeding the Screening Value (SV) for Metals and PCBs in San Francisco Bay (RMP)

Chemical	Percent	N
Arsenic	0	11
Cadmium	0	8
Mercury	36	293
Selenium	3	102
PCBs	90	143

[1] N = the total number of samples analyzed for the chemical.

Table 3: Percent of Samples Exceeding the Screening Value (SV) for Pesticides in the CFCP

Chemical	Percent	N
Chlordane	<1	223
DDTs	10	223
Dieldrin	3	223
Heptachlor epoxide	0	223
Hexachlorobenzene	0	223
Toxaphene	<1	223

Table 4: Percent of Samples Exceeding the Screening Value (SV) for Pesticides in San Francisco Bay (RMP)

Chemical	Percent	N
Chlordane	2	167
DDTs	0	158
Dieldrin	11	167
Heptachlor epoxide	0	67
Hexachlorobenzene	0	67
Toxaphene	0	80

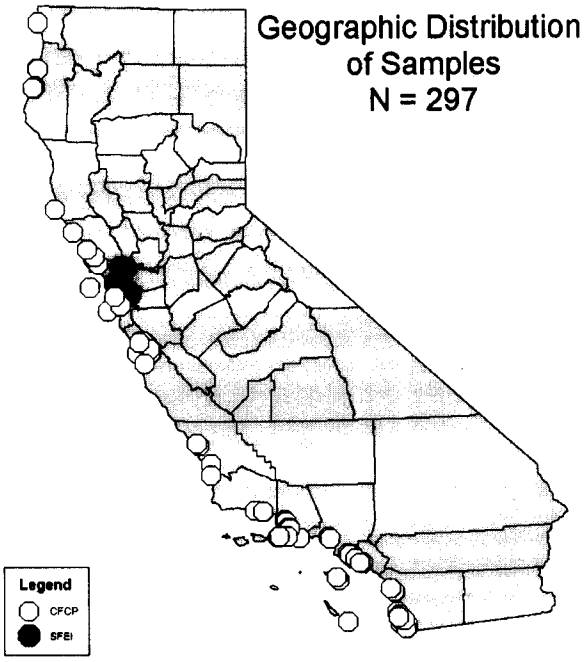

Figure 1: The geographic distribution of samples collected in the CFCP and RMP

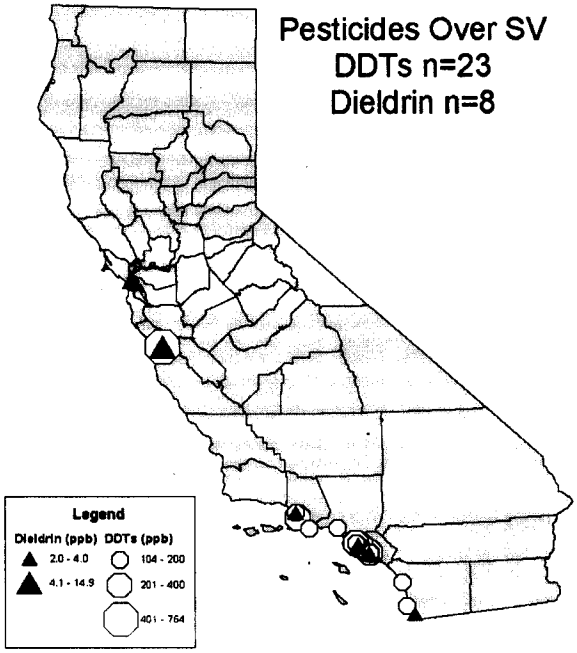

Figure 2: The distribution of the samples that exceeded the SV for the pesticides DDTs and Dieldrin

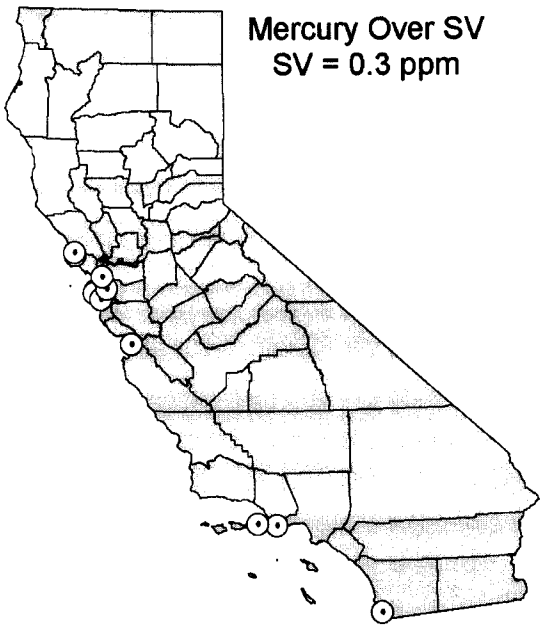

Figure 3: Samples that exceeded the screening value (SV) for mercury

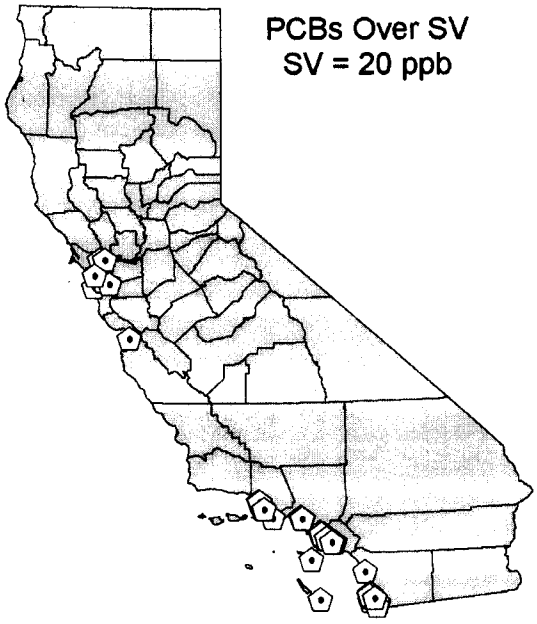

Figure 4: Samples that exceeded the screening value (SV) for PCBs

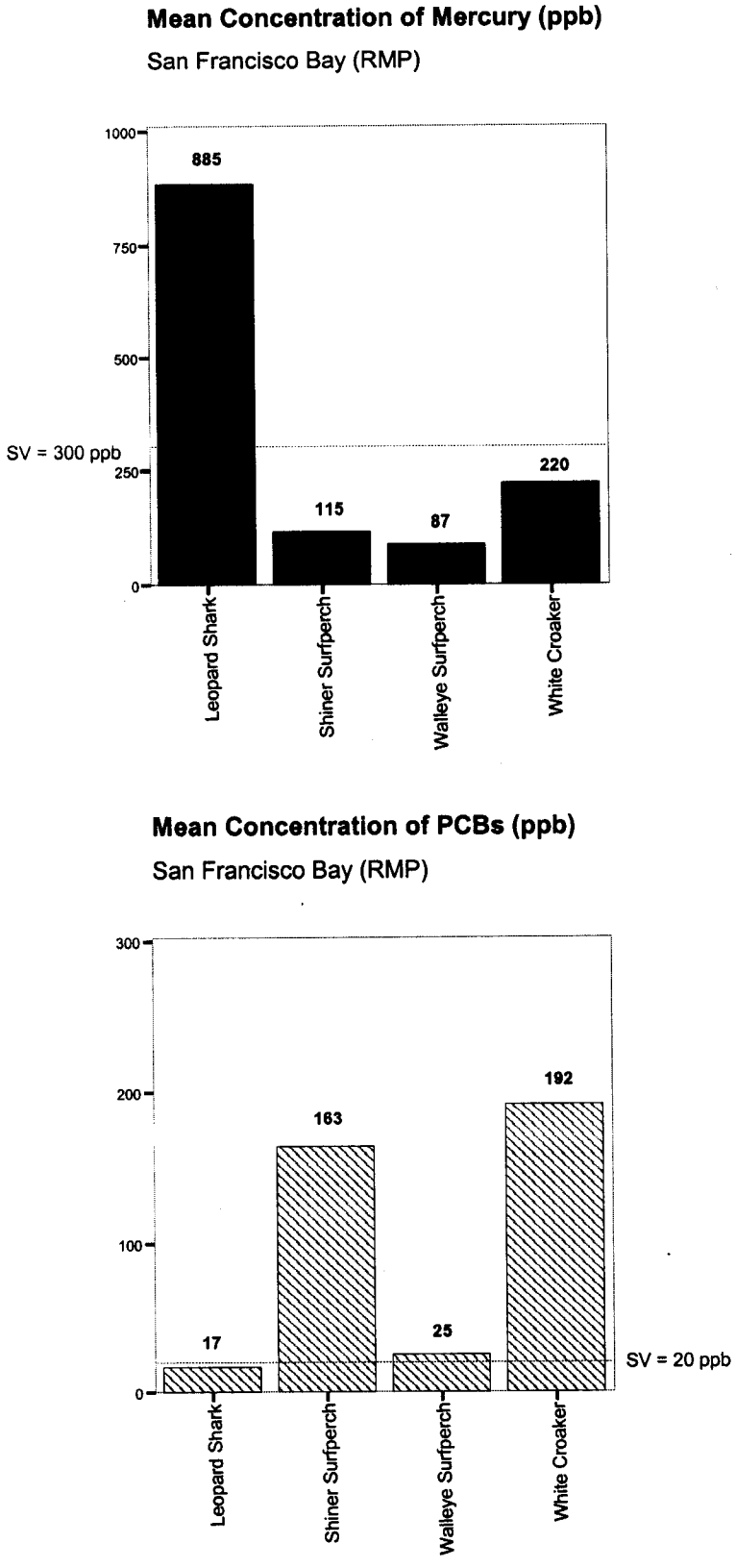

Figure 5: The mean concentrations of mercury and PCBs in fish from San Francisco Bay

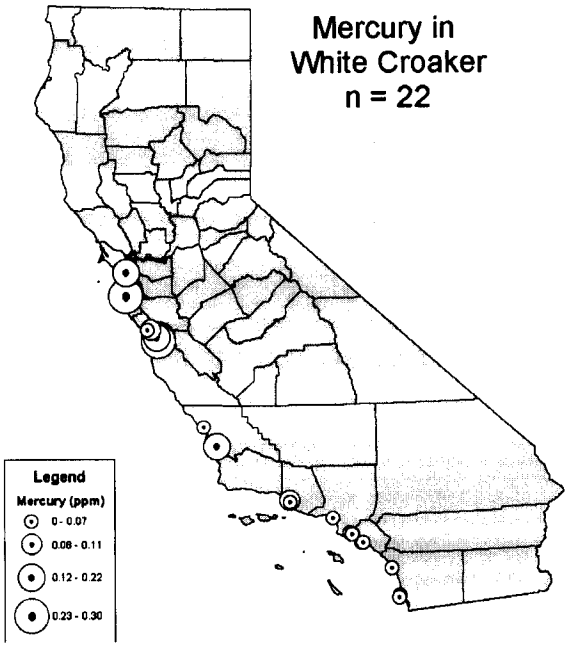

Figure 6: Mercury Concentrations in Samples of White Croaker

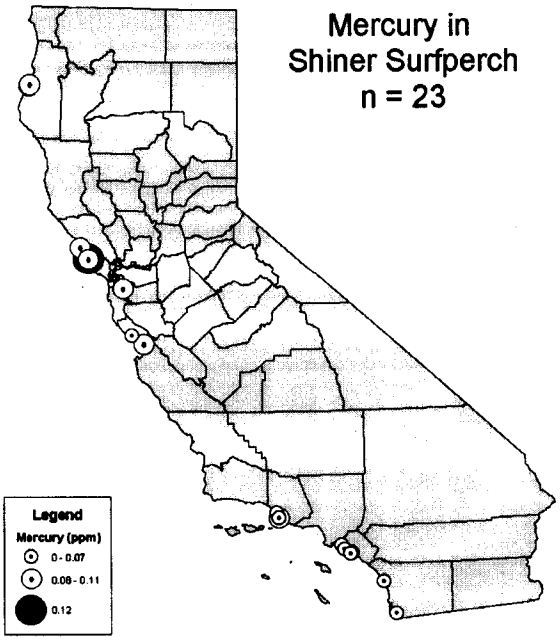

Figure 7: Concentrations of Mercury in Samples of Shiner Surfperch

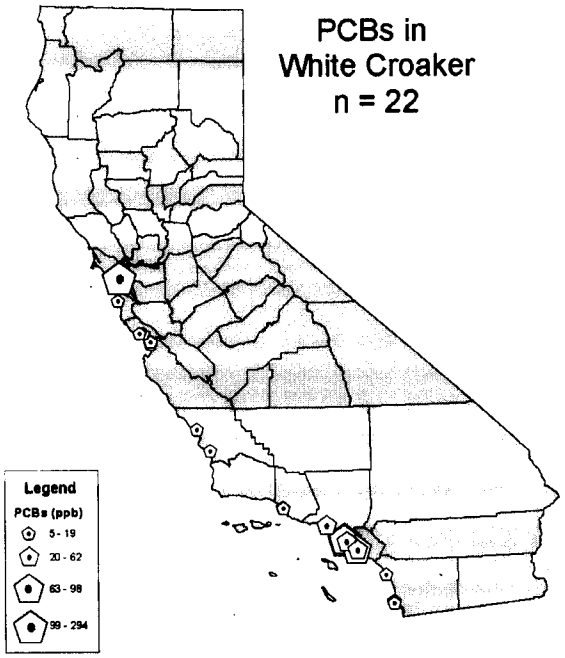

Figure 8: Concentrations of PCBs in Samples of White Croaker

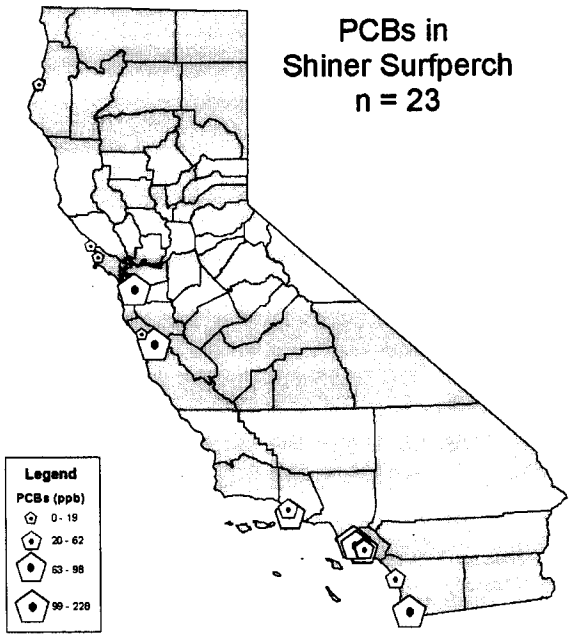

Figure 9: Concentrations of PCBs in Samples of Shiner Surfperch