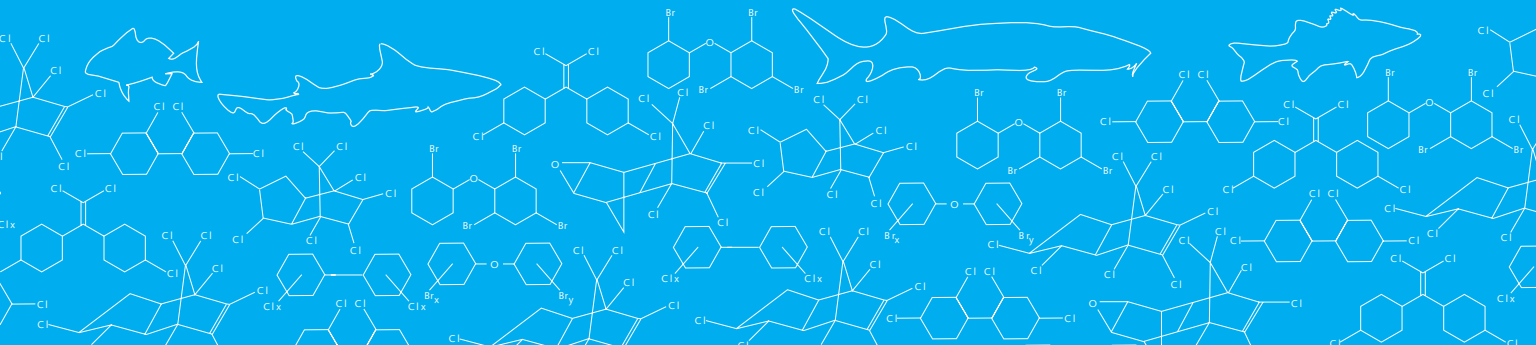
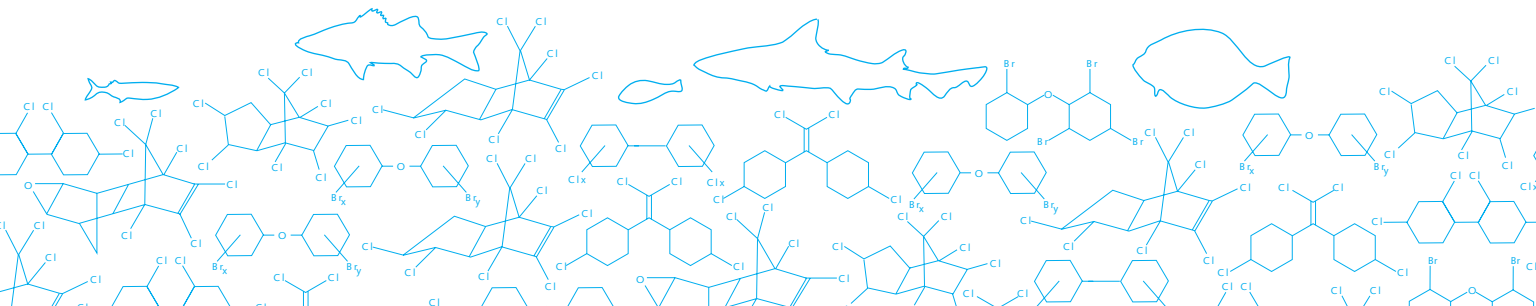


**CONTAMINANT CONCENTRATIONS
IN FISH FROM SAN FRANCISCO BAY, 2003**



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SAN FRANCISCO ESTUARY INSTITUTE

**CONTAMINANT CONCENTRATIONS
IN FISH FROM SAN FRANCISCO BAY, 2003**

REGIONAL MONITORING PROGRAM FOR WATER QUALITY IN THE SAN FRANCISCO ESTUARY

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INTRODUCTION

Fish from San Francisco Bay contain concentrations of mercury, PCBs, and other chemical contaminants that are above thresholds of concern for human health. This problem was first documented in 1994 when the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) performed a pilot study to measure concentrations of contaminants in Bay sport fish (Fairey et al. 1997). As a result of this pilot study the California Office of Environmental Health Hazard Assessment (OEHHA) issued an interim health advisory for consumption of fish from San Francisco Bay. This interim advisory is still in effect. The advisory states that:

1. Women beyond childbearing years and men should limit consumption of Bay sport fish to, at most, two meals per month, including striped bass and sturgeon caught in the Delta
2. Women beyond childbearing years and men should not eat any striped bass over 35 inches (89 cm)
3. Pregnant women or women that may become pregnant or are breast feeding, and children should not eat more than one meal of sport fish per month, and should not eat any meals of striped bass over 27 inches (69 cm) or any shark

The advisory does not apply to salmon, anchovies, herring, and smelt caught in the Bay, other ocean-caught sport fish, or commercial fish. The advice was issued due to concern over human exposure to residues of methylmercury and PCBs. Although there has also been concern regarding other contaminants in sport fish, such as dioxins and organochlorine pesticides, the advice is driven by methylmercury and PCBs.

The Clean Water Act requires California and the federal government to adopt and enforce water quality standards to protect the Bay. The Basin Plan and the California Toxics Rule contain these standards. The standards include delineation of beneficial uses of the Bay, numeric and narrative water quality criteria to protect those uses, and provisions to enhance and protect existing water quality. Section 303(d) of the Clean Water Act requires states to compile a list of “impaired” water bodies that do not meet water quality standards (the “303(d) List”). All segments of San Francisco Bay appear on the 303(d) List because the fish consumption advisory represents an impairment of the beneficial use of the Bay for sport fishing. The Clean Water Act also requires that Total Maximum Daily Loads (TMDLs), which are cleanup plans based on evaluation and reduction of loads, be developed in response to inclusion of a water body on the 303(d) List. TMDLs for mercury and PCBs are in development. In these TMDLs the emphasis is shifting away from enforcement of water quality objectives and toward enforcement of targets that are more directly linked with impairment, particularly PCB concentrations in sport fish and wildlife prey. Concentrations of mercury, PCBs, and other contaminants in sport fish are, therefore, fundamentally important indices of Bay water quality.

In 1997, as a followup to the 1994 pilot study, the RMP began monitoring contaminants in Bay sport fish. Monitoring has continued on a three year cycle and this report presents findings from the fourth round of sport fish sampling. The core of this monitoring (referred to as “Status and Trends monitoring”) targets seven species that are frequently caught and eaten by Bay anglers at five popular fishing areas in the Bay. This sampling provides information on long-term trends in mercury, PCBs, legacy pesticides (DDT, dieldrin, and chlordane), and selenium. An addition in 2003 was the analysis of polybrominated diphenyl ether (PBDE) flame retardants in the core program. These chemicals were recently discovered to be increasing rapidly in the Bay food web and raising concern for possible effects on the health of humans and wildlife. Another addition in 2003 was a preliminary screening of contaminant concentrations in several additional species of fish.

The objectives for the RMP fish contamination monitoring element are:

- ① to produce the information needed for updating human health advisories and conducting human health risk assessments;
- ② to measure contaminant levels in fish species over time to track temporal trends and to evaluate the effectiveness of management efforts;
- ③ to evaluate spatial patterns in contamination of sport fish and the Bay food web; and
- ④ to understand factors that influence contaminant accumulation in sport fish in order to better resolve signals of temporal and spatial trends.



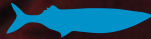
SAMPLING AND ANALYSIS

< **Figure 1.** RMP fish sampling locations in San Francisco Bay in 2003.

Fish were collected in the summer of 2003 from the Berkeley and San Francisco waterfronts, Oakland Inner Harbor, San Pablo Bay, and the South Bay (*Figure 1*). These locations were identified as popular fishing areas in 1997 and have been revisited every three years since then for the Status and Trends monitoring. The Status and Trends species collected included California halibut, jacksmelt, leopard shark, shiner surfperch, striped bass, white croaker, and white sturgeon. Status and Trends species were analyzed for mercury, PCBs, legacy pesticides, and PBDEs. In addition, leopard shark was analyzed for methylmercury and arsenic and white sturgeon was analyzed for selenium.



California Halibut



Jacksmelt



Leopard Shark



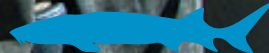
Shiner Surfperch



Striped Bass



White Croaker



White Sturgeon

A special study was initiated in 2003 to evaluate contaminants in other fish species. Brown smoothhound shark, brown rockfish, black surfperch, Chinook salmon, walleye surfperch, and northern anchovy were analyzed for PCBs and mercury. Brown smoothhound shark was also analyzed for methylmercury and arsenic. Other species, in addition to the target species, were caught and analyzed for contaminants. These species were Pacific herring, sardine, barred surfperch, diamond turbot, and starry flounder.

Fish were caught using gill nets, hook and line, or otter trawls. Each fish was carefully processed using techniques that prevent the sample from coming into contact with any potentially contaminated surface. Fish samples were dissected, composited, and analyzed in a manner similar to previous RMP fish sampling. Fillets



of muscle tissue were analyzed. For composite samples, equal weight fillets were taken from each fish. Fillets were prepared consistent with typical culinary preparation for each species. All Status and Trends species were prepared without skin except white croaker (with skin) and shiner surfperch and jacksmelt (muscle with skin and skeleton). All special study fish were prepared without skin except for walleye surfperch (with skin) and anchovy (whole body). Samples were analyzed using methods established by USEPA and in adherence with the RMP Quality Assurance Project Plan (Lowe et al. 1999). Results for one PCB congener (PCB 31) did not meet acceptance criteria, and were not included in any of the graphs or tables in this report. All other analytes were within QA limits.

In this report, contaminant concentrations in fish are compared to “screening values.” Screening values are defined as concentrations of chemicals in fish or shellfish tissue that are of potential public health concern. Exceedance of screening values should be taken as an indication that more intensive site specific monitoring and evaluation of human health risk should be conducted. With the exception of mercury and PCBs, screening values in this report were provided by OEHHA, the organization that uses these data to produce and update fish consumption advisories. The screening values for mercury and PCBs were provided by the SFBRWQCB, which has established its own screening values for these contaminants as part of the TMDL development process. Unless otherwise noted, all data presented are expressed on a wet weight basis to allow comparison to screening values.

Tables and figures summarizing all 2003 data can be found at <http://www.sfei.org/rmp/data/rmpfishtissue.htm>.

A quality assurance summary of the 2003 data is also available and can be found at the web address above.

Mercury

Mercury is a toxic heavy metal that accumulates to concentrations of concern in the Bay food web. Mercury contamination of the Bay and its watershed primarily occurred due to mining activity during the 1800s. Mercury was extensively mined in the Coast Range and transported to the Sierra Nevada for use in extracting gold from ore and placer deposits. Historical releases of mercury from these mercury and gold mining districts were substantial, and in many cases mercury continues to wash downstream from these areas today. Mercury also enters the Bay from urban runoff, atmospheric deposition, and wastewater discharges. A large amount of mercury is also stored in the deeper sediments of the Bay, and some of this is being remobilized as the Bay floor erodes.

The median mercury concentration in striped bass, the most popular Bay species that is high in mercury, was 0.35 ppm in the most recent sampling, indicating that approximately a 50% reduction is needed to bring the median concentration down below the mercury screening value used in this report (0.20 µg/g ww). Mercury concentrations in striped bass from the Bay do not appear to have declined at all over the past 35 years. In response to this persistent problem, the SFBRWQCB is developing a mercury TMDL and implementation plan to facilitate the recovery of the Bay from mercury contamination. Since so much mercury has already been distributed across the landscape and entered the Bay it will likely take many decades to achieve the recovery target. Monitoring long-term trends in mercury in Bay sport fish will be essential to tracking the effectiveness of the mercury TMDL in reducing, and eventually eliminating, the impairment of the Bay by mercury.

Mercury exposure is one of the primary concerns behind the consumption advisory for the Bay. Mercury reaches higher concentrations in higher levels of aquatic food chains. Predatory fish, birds, and mammals (including humans that consume fish) at the top of the food web are therefore particularly vulnerable to the effects of mercury contamination. Mercury is a neurotoxicant, and is particularly hazardous for fetuses and children as their nervous systems develop. When children are exposed at high doses, mercury can cause serious problems, including mental impairment, impaired coordination, and other developmental abnormalities. The advisory for the Bay has more restrictive guidelines for young children and women that are about to become pregnant, are pregnant, or breast feeding because of the greater sensitivity of fetuses and children to mercury. Similarly, in wildlife species high mercury exposure can cause damage to nervous, excretory, and reproductive systems, and early life stages are most sensitive.

Human exposure to mercury through consumption of fish can be reduced by choosing low mercury species or younger, smaller fish. Mercury accumulates in organisms by binding to proteins. Muscle tissue, with its high protein content, is a primary site for mercury accumulation. Since mercury is bound to the protein in fillets, preparation and cooking techniques are not effective at reducing mercury exposure from fish consumption. Mercury gradually accumulates in muscle tissue and other organs over the lifespan of a fish, so larger, older fish have the highest concentrations. This aspect of mercury accumulation is the reason that the advisory for the Bay specifically limits consumption of large striped bass and shark. Mercury concentrations also vary from species to species. Sharks, for example, are long lived predators that have a general tendency to accumulate high concentrations and have the highest concentrations of any Bay species. Shorter lived species lower in the food chain, such as jacksmelt or shiner surfperch, tend to have lower concentrations of mercury.

Table 1

	Number in Composite ¹	Number of Composites Analyzed (Hg-Org)	% Lipid	Length (cm)	Sum of Aroclor (ng/g ww)	Sum of PCBs (ng/g ww)	Hg (µg/g ww)	Sum of PBDE (ng/g ww)	Sum of Chlordanes (ng/g ww)	Sum of DDTs (ng/g ww)	Dieldrin (ng/g ww)
SCREENING VALUE					10		0.2		30	100	2
California Halibut	3	6-2	0.2	72	8	10	0.33	ND	ND	ND	ND
Jacksmelt	5	4-4	2.0	26	22	20	0.06	2	0.6	30	0.5
Leopard Shark	3	15-9	0.4	101	ND	4	0.79	ND	ND	ND	ND
Shiner Surfperch	20	14-14	1.4	11	218	134	0.08	15	6.0	22	1.1
Striped Bass	3	24-7	0.9	52	68	50	0.37	15	1.1	18	0.7
White Croaker	5	11-11	6.0	25	342	225	0.22	28	7.4	45	1.9
White Sturgeon	3	7-4	1.1	130	288	197	0.49	40	10.4	53	1.3

1. Composite number is target - actual number in composite may vary by 1 to 2 fish.

* California Halibut, Striped Bass, Leopard Shark, White Sturgeon analyzed as individuals for Hg

Table 2

COMMON NAME	Mercury*	Total Aroclors*	Total DDT	Total Chlordanes	Dieldrin
SCREENING VALUE	0.20 µg/g ww	10 ng/g ww	100 ng/g ww	30 ng/g ww	2 ng/g ww
California Halibut	6/6	1/2	0/2	0/2	0/2
Jacksmelt	0/4	4/4	0/4	0/4	0/4
Leopard Shark	15/15	3/9	0/9	0/9	0/9
Shiner Surfperch	0/14	14/14	0/14	0/14	0/14
Striped Bass	24/25	7/7	0/7	0/7	0/7
White Croaker	6/11	11/11	0/11	0/11	5/11
White Sturgeon	6/7	4/4	1/4	0/4	2/4
All S&T Species	57/82	44/51	1/51	0/51	7/51
All Species (Including Special Study Species)	68/109	54/72	1/55	0/55	8/55

* Total Maximum Daily Load (TMDL) Screening Value

Table 1. Summary statistics by species for mercury and synthetic organic compounds. Data are medians.

Table 2. Number of samples above human health screening values for Status and Trends species. NA = not sampled

Mercury exists in the environment in a variety of chemical forms. In terms of potential risks to humans and wildlife, the most important form of mercury in the aquatic environment is methylmercury, which is readily accumulated by biota and transferred through the food web. Most of the mercury (about 95%) that accumulates in fish tissue is methylmercury. Methylmercury is also the form of mercury of greatest toxicological concern in the environment

Additional background information on mercury is available at: <http://www.oehha.ca.gov/fish/pdf/HGfacts.pdf>.

The Latest Data

The mercury screening value used by the SFBRWQCB in the mercury TMDL is 0.2 µg/g. In the 2003 samples, as in past sampling, mercury concentrations varied considerably among the different species analyzed (*Tables 1 and 2, Figure 2*).

Leopard shark and striped bass are two key indicators of mercury impairment. Leopard shark are important because they have consistently exhibited much higher concentrations than other Bay species. However, leopard shark are not among the most popular species for consumption by Bay anglers. Striped bass are important because they are the most popular species for consumption by Bay anglers (SFEI 2000) and they also accumulate moderately high concentrations of mercury. In 2003, 100% of the leopard shark samples exceeded the screening value and the median concentration for this species was 0.79 µg/g. Striped bass had a median of 0.37 µg/g and 93% of the samples exceeded the screening value. California halibut and white sturgeon are two other relatively popular species that frequently exceeded the screening value (100% and 86% of samples, respectively). Slightly more than half (58%) of the white croaker samples exceeded the screening value. None of the jacksmelt or shiner surfperch samples were above the screening value. Two samples, one California halibut and one leopard shark, had particularly high mercury concentrations, exceeding 2 µg/g. Overall, 57 of 82 samples (69%) of the Status and Trends species had concentrations exceeding the screening value (*Table 2*).

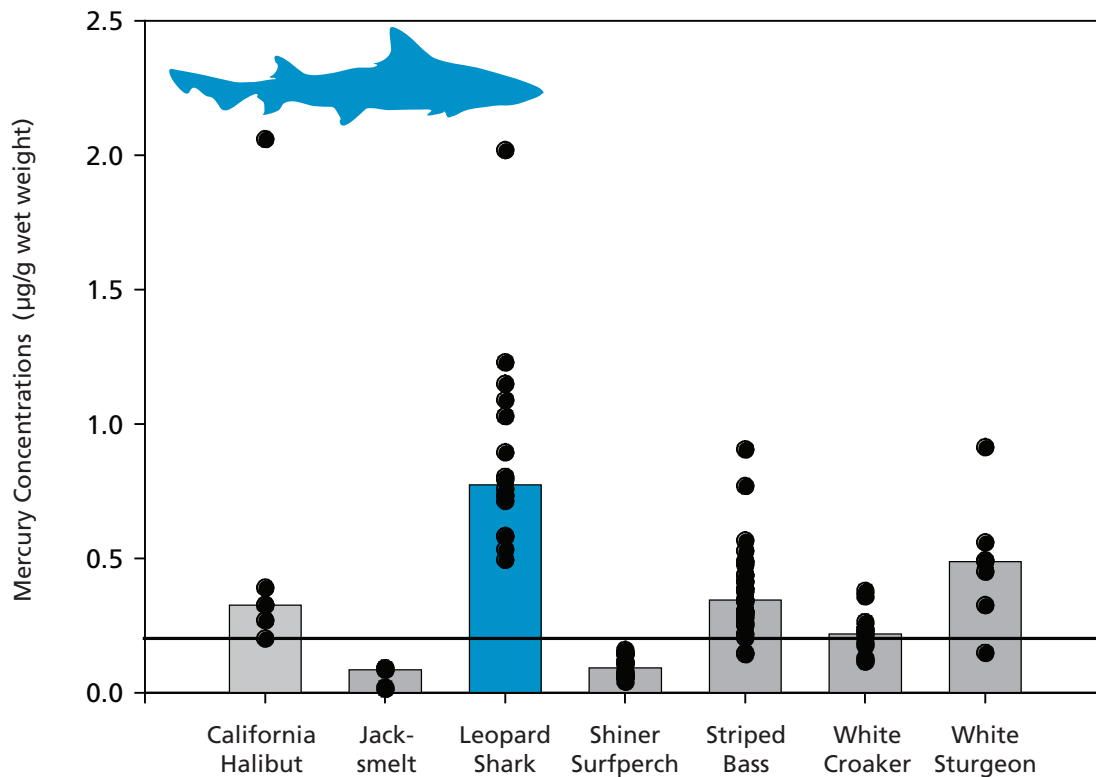


Figure 2. Mercury concentrations ($\mu\text{g/g}$) in Bay fish, 2003. Points are concentrations in each composite sample analyzed. Bars indicate median concentrations. Horizontal line indicates screening value ($0.2 \mu\text{g/g}$). Fish figure and blue bar indicate the species with the highest median contaminant concentration.

A Closer Look at Leopard Shark

Leopard sharks have consistently shown high mercury concentrations over the four rounds of sampling. All leopard sharks in the previous rounds of sampling (1994, 1997, and 2000) also exceeded the mercury screening value with very similar median values (approximately 0.8 µg/g) in all three sampling years. Long lived, larger predatory fish such as sharks are at higher risk for accumulating mercury since they are at the top of the food web and they accumulate mercury over their relatively long lifespans. The leopard sharks sampled by the RMP are approximately 10-12 years old (Davis et al. 1999). Two other species sampled by the RMP, California halibut and white sturgeon are also long lived (approximately 7-9 and 12-14 years old) and are at approximately the same level in the food chain as leopard shark ([Figure 3](#)). However, these species have much lower median concentrations than leopard shark. Leopard sharks in the Bay appear to accumulate anomalously high concentrations of mercury.

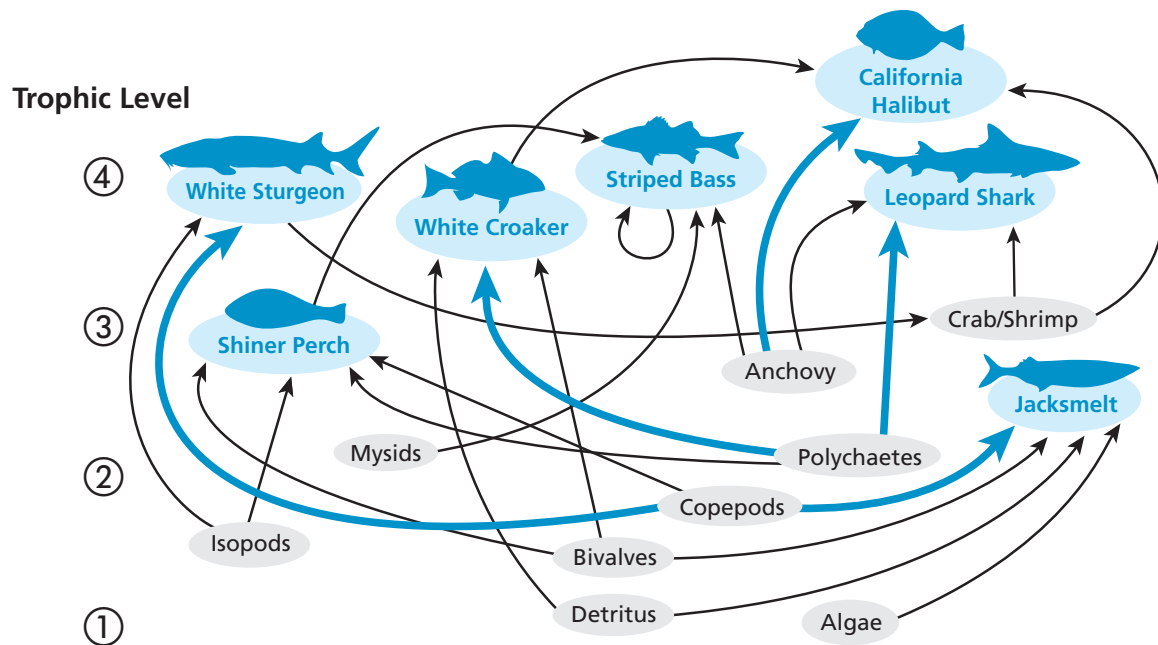


Figure 3. Schematic showing positions of Status and Trends monitoring species in the San Francisco Bay food web. Food web graphic is conceptual, not quantitative.

Some shark species appear to have a tendency to accumulate unusually high concentrations of mercury. Another shark species sampled in the Bay in 1994 and 2003, brown smoothhound, has also exhibited concentrations similar to leopard shark. Both leopard and brown smoothhound sharks also had high concentrations (both averaging over 1.0 µg/g) in recent sampling in Tomales Bay. Interestingly, however, another shark species (Pacific angel shark) in Tomales Bay, similar in size to leopard shark, had significantly lower concentrations (averaging just under 0.5 µg/g). Studies of sharks in other parts of the world have also found that some species accumulate relatively high concentrations of mercury (*Table 4*).

The mechanism behind the unusually high concentrations observed in some shark species is not known. Diet is an important factor explaining variation among some shark species. For example, fish-eating sharks from coastal Brazil showed significantly higher mercury concentrations than invertebrate consuming sharks sampled from the same area (de Pinho et al., 2002). However, available information on the diet of leopard shark in the Bay suggests that they are a bit lower in the food chain than California halibut, but they accumulate much higher mercury concentrations. Some other unknown factor seems to be at work. The tendency of leopard shark to accumulate unusually high concentrations and the relatively low rate of consumption of this species in the Bay led the SFBRWQCB to focus on striped bass as the key indicator of mercury impairment in the Bay.

Table 4. Worldwide shark Hg concentrations.

Year	Region	Common Name	Average Hg Concentration in ppm wet weight	Source
1972	Australia - Southeast Coast	Shortfin Mako Shark	3.2	Walker, 1976
1972	Australia - Southeast Coast	Southern Dogfish Shark	2.5	Walker, 1976
1972	Australia - Southeast Coast	Longnose Spurdog Shark	2.44	Walker, 1976
1972	Australia - Southeast Coast	Sharpnose Seven Gill Shark	1.33	Walker, 1976
1972	Australia - Southeast Coast	Shortspine Spurdog Shark	1.7	Walker, 1976
1972	Australia - Southeast Coast	Spinner Shark	1.48	Walker, 1976
1972	Australia - Southeast Coast	Broadnose Seven Gill Shark	1.39	Walker, 1976
1972	Australia - Southeast Coast	Great White Shark	1.29	Walker, 1976
1972	Australia - Southeast Coast	Draughtboard Swell Shark	1.28	Walker, 1976
1972	Australia - Southeast Coast	Smooth Hammerhead Shark	0.89	Walker, 1976
1972	Australia - Southeast Coast	Spiny Dogfish Shark	0.86	Walker, 1976
1972	Australia - Southeast Coast	Whiskery Shark	0.7	Walker, 1976
1972	Australia - Southeast Coast	Tope Shark	0.64	Walker, 1976
1972	Australia - Southeast Coast	Gulf Catshark	0.64	Walker, 1976
1972	Australia - Southeast Coast	Copper Shark	0.6	Walker, 1976
1972	Australia - Southeast Coast	Rusty Carpet Shark	0.54	Walker, 1976
1972	Australia - Southeast Coast	Longnose Sawshark	0.52	Walker, 1976
1972	Australia - Southeast Coast	Shortnose Sawshark	0.47	Walker, 1976
1972	Australia - Southeast Coast	Gummy Shark	0.41	Walker, 1976
1972	Australia - Southeast Coast	Port Jackson Shark	0.41	Walker, 1976
1972	Australia - Southeast Coast	Blue Shark	0.41	Walker, 1976
1972	Australia - Southeast Coast	Varied Carpetshark	0.25	Walker, 1976
1972	Australia - Southeast Coast	Thresher Shark	0.14	Walker, 1976
1972	Australia - Southeast Coast	Angel Shark	0.13	Walker, 1976
1980	Australia - Northern Coast	Grey Whaler Shark	2.07	Lyle, 1986
1980	Australia - Northern Coast	Great Hammerhead Shark	1.59	Lyle, 1986
1980	Australia - Northern Coast	Winghead Shark	1.36	Lyle, 1986
1980	Australia - Northern Coast	Scalloped Hammerhead Shark	1.15	Lyle, 1986
1980	Australia - Northern Coast	Blacktip Shark	1.05	Lyle, 1986
1980	Australia - Northern Coast	Creek Whaler Shark	0.9	Lyle, 1986
1980	Australia - Northern Coast	Spottail Shark	0.44	Lyle, 1986
1992-1995	Central Florida - East Coast	Atlantic Sharpnose Shark	1.06	Adams and McMichael, 1999
1992-1995	Central Florida - East Coast	Blacktip Shark	0.77	Adams and McMichael, 1999
1992-1995	Central Florida - East Coast	Bull Shark	0.77	Adams and McMichael, 1999
1992-1995	Central Florida - East Coast	Bonnethead Shark	0.5	Adams and McMichael, 1999
1997	South Brazil Coast	Shortspine Spurdog Shark	2.22	De Pinho et al., 2002
1997	South Brazil Coast	Dog Shark	1.9	De Pinho et al., 2002
1997	South Brazil Coast	Night Shark	1.77	De Pinho et al., 2002
1997	South Brazil Coast	Smooth Dogfish Shark	0.41	De Pinho et al., 2002
1997	South Brazil Coast	Narrowfin Smoothhound Shark	0.26	De Pinho et al., 2002
1990-2000	Gulf of Mexico	Blacktip Shark	0.86	Ache et al., 2000
1990-2000	Gulf of Mexico	Bonnethead Shark	0.51	Ache et al., 2000

Long-term Trends in Striped Bass

Mercury in striped bass is probably the most important indicator of mercury contamination in the Bay and Delta from a human health perspective. The importance of striped bass as an indicator is due to a combination of the high mercury concentrations that are common in their tissue, their abundance, and their great popularity among anglers. Like the other sport fish species of greatest concern with regard to mercury accumulation, striped bass are high trophic level predators and therefore highly susceptible to mercury accumulation. Striped bass are also good integrative indicators of mercury contamination in the Bay-Delta Estuary because of their use of the entire ecosystem, including both fresh and saline waters. Striped bass spend most of their lives in San Francisco Bay, but also move into freshwater and the coastal ocean. Recent research has shown that individual striped bass are quite variable in their use of Bay, freshwater, and ocean habitats (SFEI 2005, page 23). While all of this extensive movement makes striped bass good integrative indicators of long-term trends in the estuarine ecosystem, it makes them poor indicators of small scale spatial variation within the Bay-Delta.

A relatively extensive historical dataset exists for striped bass, allowing evaluation of trends over 33 years (Figure 4). The data are presented as estimated concentrations of a striped bass of a standard length of 55 cm in order to remove any bias that might occur from sampling different sized fish in different years. There is no increasing or decreasing trend seen in striped bass mercury concentrations over the period of record. Median concentrations for a standard sized fish were variable in the recent rounds of sampling, ranging from 0.28 $\mu\text{g/g}$ in 2000 to 0.46 $\mu\text{g/g}$ in 1997. Nevertheless, concentrations in 2003 were intermediate relative to other rounds of RMP sampling, and were also quite similar to concentrations measured from 1970 to 1972.

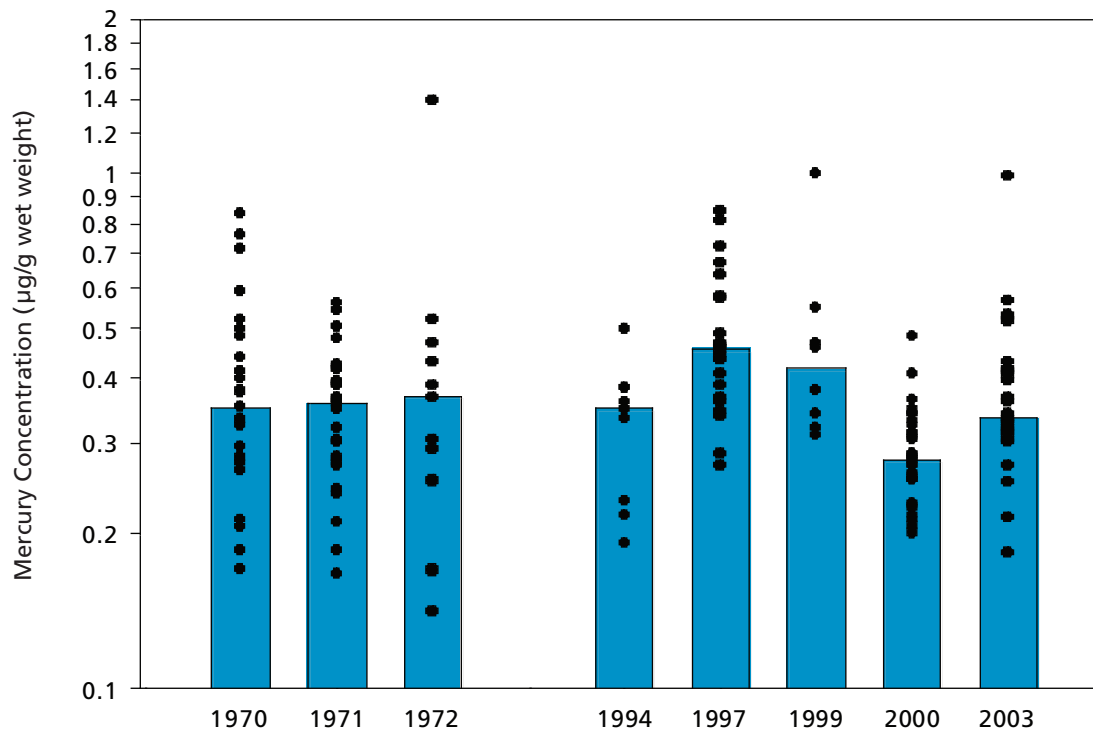


Figure 4. Mercury concentrations ($\mu\text{g/g}$) in striped bass from 1970-2003. Concentrations expressed as an average for a 55 cm fish (Greenfield et al., 2005). Bars indicate median for each year.

Polychlorinated Biphenyls (PCBs)

Background

Polychlorinated biphenyls (PCBs) are extremely persistent synthetic chemicals that were heavily used from the 1930s to the 1970s in electrical equipment and a wide variety of other applications. Awareness of their presence in the environment and their toxicity to humans and wildlife grew in the 1960s and 1970s, leading to a 1979 federal ban on their sale and production. Since the ban, concentrations in the Bay have gradually declined, but are still more than ten times higher than the threshold of concern for human health. In response to this problem, the SFBRWQCB has initiated a process to establish a PCB TMDL and implementation plan to accelerate the recovery of the Bay from decades of PCB contamination. Monitoring long-term trends of PCBs in Bay sport fish is essential to understanding the present rate of decline and the effectiveness of the PCB TMDL in reducing, and eventually eliminating, the impairment of the Bay by PCBs.

In spite of the fact that their use has been restricted for almost two decades, PCBs remain among the environmental contaminants of greatest concern because they are potent toxicants that are resistant to degradation and have a strong tendency to accumulate in biota. PCBs can cause toxic symptoms including developmental abnormalities and growth suppression, disruption of the endocrine system, impairment of immune function, and cancer. Of particular concern are the effects on development in infants whose mothers have been exposed before and during pregnancy. U.S. EPA classifies PCBs as a probable human carcinogen. PCBs and other similar organochlorines reach higher concentrations in higher levels of aquatic food chains. Consequently, predatory fish, birds, and mammals (including humans that consume fish) at the top of the food web are particularly vulnerable to the effects of PCB contamination.

Avoiding consumption of fatty tissues and species can reduce exposure to PCBs and other synthetic organic pollutants (such as legacy pesticides, dioxins, and PBDEs). PCBs, like many other synthetic organic pollutants, accumulate in fatty tissue. RMP Status and Trends monitoring has shown that fish species with higher fat content tend to accumulate higher PCB concentrations. Shiner surfperch and white croaker, species with relatively high fat content, had elevated PCB concentrations with all samples exceeding the health threshold in all years of RMP sport fish monitoring. In 1997, the RMP performed a study to evaluate the effect of removing skin from white croaker fillets (Davis et al. 2002). Substantially lower concentrations of trace organics were measured in the fillets with the skin removed. The average percent reduction for PCBs was 39%, with a range of 11% to 53%. These reductions were associated with decreased amounts of fat in the fillets without skin. Fat content was reduced by an average of 33% in the fillets without skin. Avoiding fat deposits and fatty organs such as the liver are other ways to reduce exposure to PCBs and other organic chemicals. Cooking methods such as baking or grilling that allow the juices to drain away and then discarding the juices also reduce exposure.

Additional background information on PCBs is available at the OEHHA website:

<http://www.oehha.ca.gov/fish/pdf/pcb-facts.pdf>.



The Latest Data

For PCBs, a screening value of 10 ng/g wet weight is being applied by the SFBRWQCB in the PCB TMDL. The most recent data (from 2003) show that PCB concentrations vary among species (*Tables 1 and 2, Figure 5*). Two sport fish species (white croaker and shiner surfperch) are key indicators of PCB impairment because they accumulate relatively high concentrations and are commonly found in nearshore areas easily accessed by subsistence fishers. These high concentrations are largely a function of the relatively high lipid content in these species. Median concentrations in these two species in the latest round of sampling in 2003 were 342 ng/g in white croaker and 217 ng/g in shiner surfperch, well over ten times higher than the 10 ng/g threshold of concern for human health. Other species with median concentrations consistently above the screening value over the four rounds of sampling were white sturgeon, striped bass, and jacksmelt. Overall, in 2003 44 of 51 measured samples (86%) of the Status and Trends species had concentrations higher than the screening value. The data for white croaker indicate that approximately a 97% reduction in PCB concentrations will be needed to eliminate the impairment in all species.

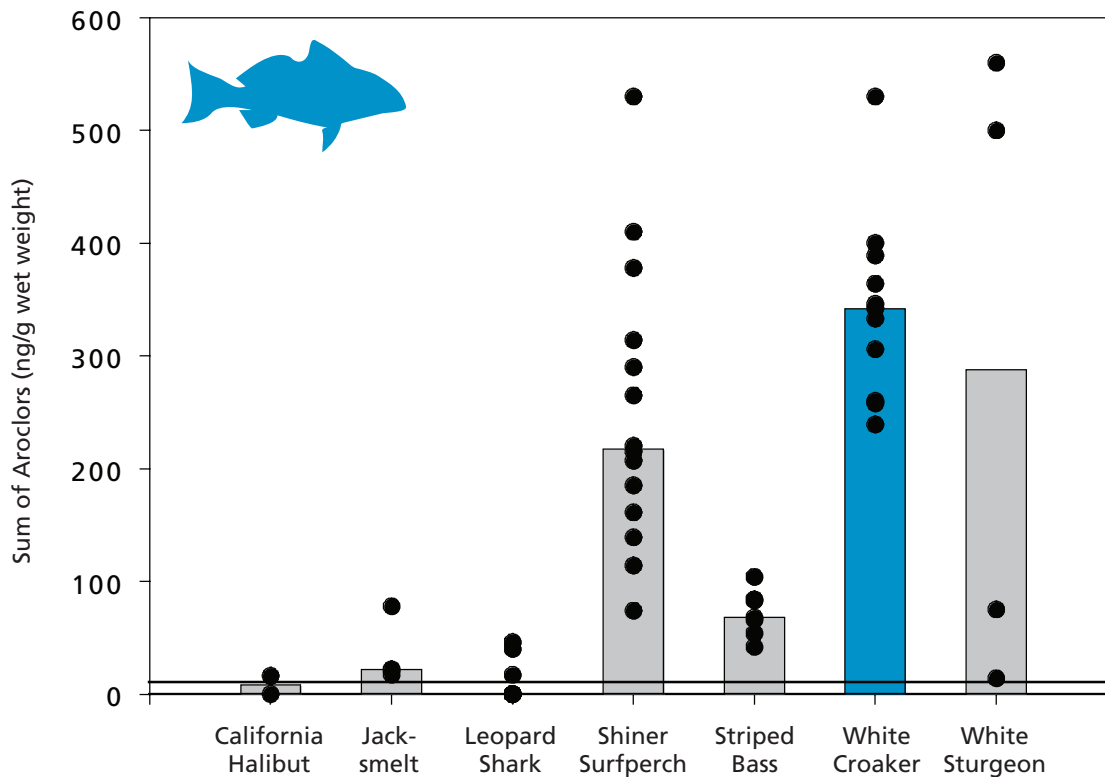


Figure 5. PCB concentrations (as Aroclors ng/g) in Bay fish, 2003. Points are concentrations in each composite sample analyzed. Bars indicate median concentrations. Horizontal line indicates screening value (10 ng/g). Fish figure and blue bar indicate the species with the highest median contaminant concentration.

Previous evaluations of RMP data and other data sources have not shown significant trends in fish tissue PCB concentrations since the mid 1980s. Comparison of data from the four sampling rounds (1994, 1997, 2000, 2003) found some significant variation among years (ANOVA ($p < 0.05$) on log transformed data followed by Least Significant Difference test, [Figure 6](#)). The data were adjusted for fat content, which varies from year to year and influences concentrations of PCBs and other organics. For leopard shark, white croaker, and striped bass 1994 was significantly elevated compared to other years, indicating that there may have been a decline since 1994. Nevertheless, overall since 1994 there was no clear general pattern of decline. PCB concentrations in 2003 were similar or higher than concentrations in 1997 and 2000 for striped bass, shiner surfperch, and white croaker.

Similar to mercury, long-term decreases in fish PCB concentrations are not expected due to the large reservoir of PCBs that persists in Bay sediments and continuing inputs from the watershed. A simple model of PCB fate in the Bay suggests that it will take approximately 35 years for median concentrations in all Bay fish to fall below the screening value even if all PCB inputs are eliminated (Davis 2004). It is known that PCBs are continuing to enter the Bay from urban runoff, Delta outflow, erosion and remobilization of buried sediment, and other pathways, so the modeling suggests that recovery is likely to take significantly longer than 35 years. Continued monitoring of the progression of concentrations in Bay fish species down toward the 10 ng/g screening value will be essential to eliminating PCB impairment of the Bay.

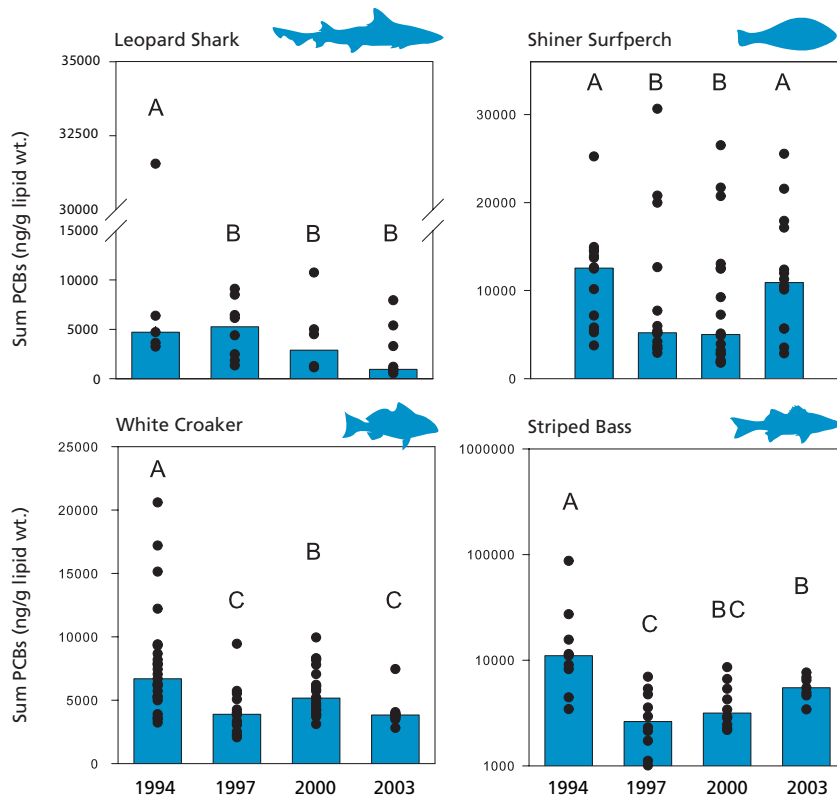


Figure 6. Long-term PCB trends from 1994-2003 for shiner surfperch, leopard shark, white croaker, and striped bass in lipid weight. Letters above each bar indicate statistically significant differences. Letters or grouping of letters that are different show years that are statistically different from other years. I.e. for striped bass, 2000 is statistically lower than 1994 (A different than B and C) but not statistically different from 1997 or 2003 (B and C contained in 1997 and 2003, respectively).

Legacy Pesticides (Dieldrin, DDT, and Chlordane)

Historical use of the legacy pesticides dieldrin, DDT, and chlordanes has resulted in contamination of the Bay and its watershed. These insecticides were widely used in both agricultural and domestic applications. Bans on the chemicals were implemented in the 1970s and 1980s. Simple fate models for the Bay (Connor et al. 2004), sport fish monitoring data (Greenfield et al. 2005), and mussel monitoring (Gunther et al. 1999) all indicate declining trends in legacy pesticides. Due to a combination of these declining concentrations and generally lower toxicity they are presently much less of a health concern than PCBs. Dieldrin is the most toxic legacy pesticide and poses the most persistent health concern. Trends observed for legacy pesticides indicate that all fish samples will soon be below the threshold for concern for DDT, while dieldrin will continue to be above thresholds in a small proportion of samples.

Dieldrin

Dieldrin concentrations exceeded the screening value of 2 ng/g in 8 of 55 (15%) of all samples. The concentrations above the screening value were observed in three species: white croaker (5 of 11 samples), white sturgeon (2 of 4 samples), and anchovy (1 of 2 samples) ([Table 2](#), [Figure 7](#)). The median concentration for white croaker was 1.85, approaching the screening value ([Table 1](#)). Medians for other species were all less than 1.3 ng/g.

Dieldrin concentrations have consistently exceeded screening values in the four rounds of sampling. However, the rate of exceedance appears to be on the decline. In 1994, 22 of 66 samples (33%) exceeded the screening

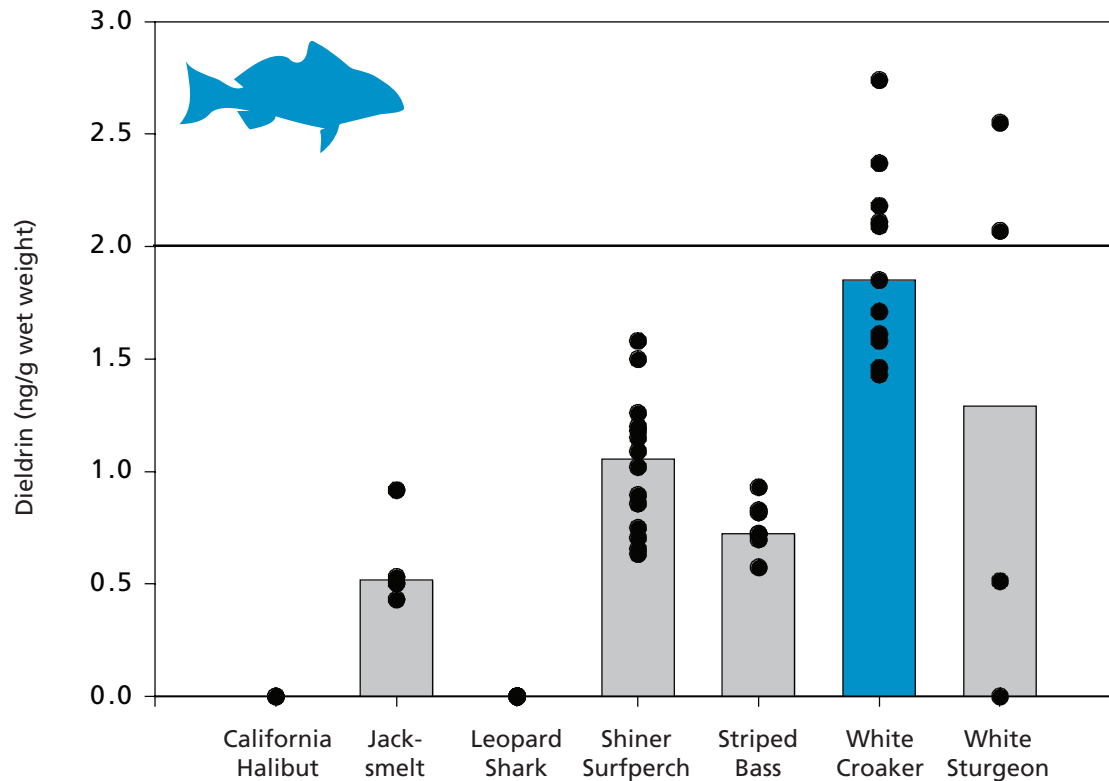


Figure 7. Dieldrin concentrations (ng/g) in Bay fish, 2003. Points are concentrations in each composite sample analyzed. Bars indicate median concentrations. Horizontal line indicates screening value (2 ng/g). Fish figure and blue bar indicate the species with the highest median contaminant concentration.

value, including 16 of 24 white croaker and 2 of 14 shiner surfperch. In 1997, 26 of 72 samples (36%) exceeded the screening value, including all 18 white croaker and 6 of 16 shiner surfperch. In 2000, 15 of 80 samples (19%) exceeded the screening value, including 12 of 24 white croaker and 3 of 18 shiner surfperch. In 2003 the lowest overall frequency of exceedance was observed, and the maximum concentration in shiner surfperch (1.58 ng/g) was below the screening value.

Dieldrin concentrations in Bay white croaker continue to pose a health concern, as they have during all four rounds of sampling.

DDT

In 2003 only one sample, a white sturgeon sampled from the South Bay, exceeded the DDT screening value (*Table 2, Figure 8*). This sample was also high in other organic contaminants such as PCBs and PBDEs. In previous rounds of sampling, white croaker was the only species that had concentrations exceeding 100 ng/g: 2 samples (of 66 total for all species) in 1994, 4 (of 72 total) in 1997, and 3 (of 80 total) in 2000. The maximum concentration in white croaker in 2003 was 65 ng/g. The highest median concentration for any species in 2003 was 53 ng/g for white sturgeon (*Table 1*), well below the 100 ng/g screening value. Statistical analysis of DDT concentrations (after adjustment for variation in lipid content among years) detected significant declines in leopard shark, striped bass, and white croaker from 1994 – 2003.

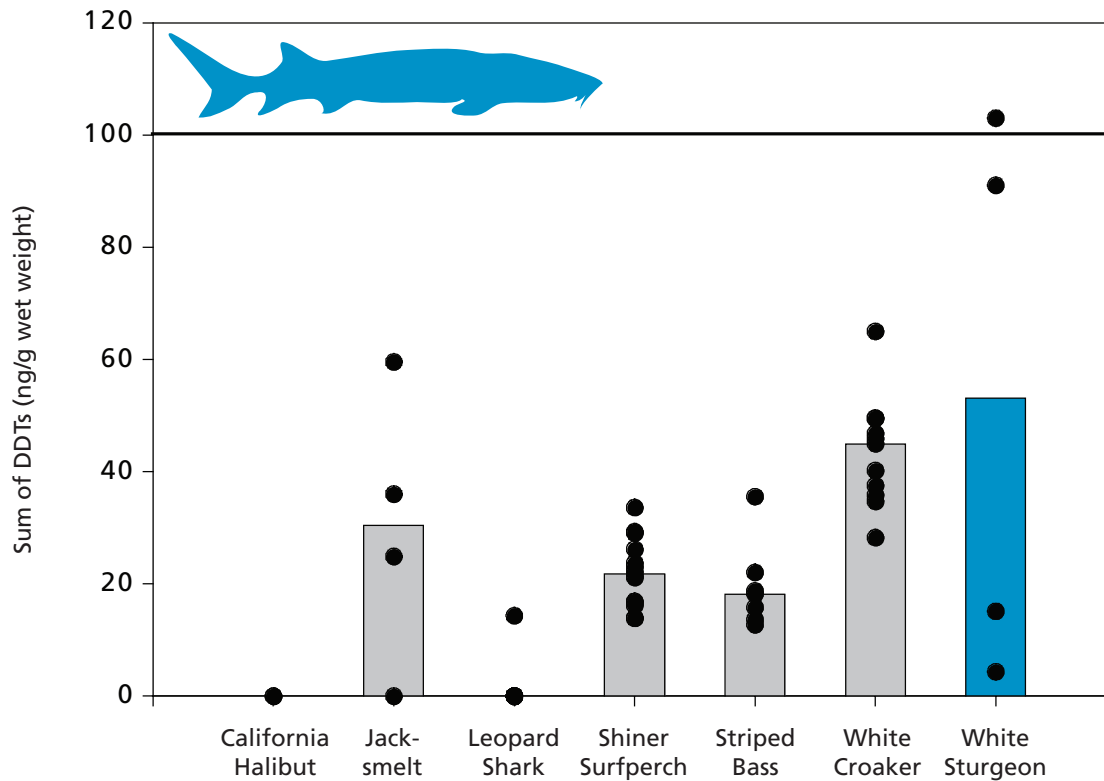


Figure 8. DDT concentrations (ng/g) in Bay fish, 2003. Points are concentrations in each composite sample analyzed. Bars indicate median concentrations. Horizontal line indicates screening value (100 ng/g). Fish figure and blue bar indicate the species with the highest median contaminant concentration.

Chlordane

There were no exceedances of the 30 ng/g chlordane screening value in any of the Status and Trends species sampled in 2003 ([Table 2](#)). The highest median concentration was 11 ng/g (in white sturgeon), well below the screening value ([Table 1](#)). The maximum concentration in a Status and Trends species was 24 ng/g in white sturgeon. Chlordanes also showed no screening value exceedances in 2000. Two samples exceeded 30 ng/g in 1994, and four samples in 1997. Statistical analysis of chlordane concentrations (adjusted for variation in lipid content among years) detected significant declines in leopard shark, shiner surfperch, and white croaker. Chlordane concentrations in Bay sport fish appear to not pose a concern for human health.

Polybrominated Diphenyl Ethers (PBDEs)

PBDEs are an emerging contaminant of concern in San Francisco Bay (Oros et al. 2005). They are currently on the SFBRWQCB's watch list of potential threats to Bay water quality and have recently been added to the list of pollutants monitored by the RMP in water, sediment, bivalves, fish, and cormorant eggs. PBDEs are a class of chemicals that are used as flame retardants in many consumer products such as furniture, computers and other electronics, plastics, and textiles. There has been growing concern about increasing PBDE concentrations in wildlife and humans worldwide. Concentrations of PBDEs in humans and wildlife in the Bay Area are among the highest that have been reported in the world and have also been on the increase. Like PCBs and legacy pesticides, PBDEs are persistent in the environment and readily accumulate in the food web. The California State Legislature passed a ban, effective in June 2006, on the use, sale and manufacturing of two mixtures of PBDEs ("penta" and "octa" mixes). A third mixture ("deca") does not bioaccumulate as strongly as the other mixtures and was not included in the ban. There is, however, some evidence that deca degrades to more bioaccumulative PBDEs in the environment.

The health impacts of PBDEs are not well characterized at present. Potential concerns include thyroid and estrogen hormone disruption, neurobehavioral toxicity, other developmental effects, and possibly cancer. Sensitive populations include pregnant women, developing fetuses, and infants. Screening values for PBDEs have not yet been established.

In RMP 2003 sampling, PBDEs were detected in almost all of the species sampled except for California halibut (*Figure 9*). The highest concentration (79 ng/g) was found in a white sturgeon sample from the South Bay. White sturgeon also had the highest median concentration (40 ng/g) of any species. White croaker had a median concentration of 28 ng/g, and shiner surfperch and striped bass both had a median of 15 ng/g. Median concentrations of PBDEs in Bay fish are now quantitatively comparable to those of DDTs. Median PCB concentrations are still about ten times higher than PBDEs.

Continued tracking of PBDE trends in Bay fish will be crucial in determining what effect, if any, the ban will have and if further management actions are necessary. RMP sampling in 2003 has provided a solid baseline for comparison with future data.



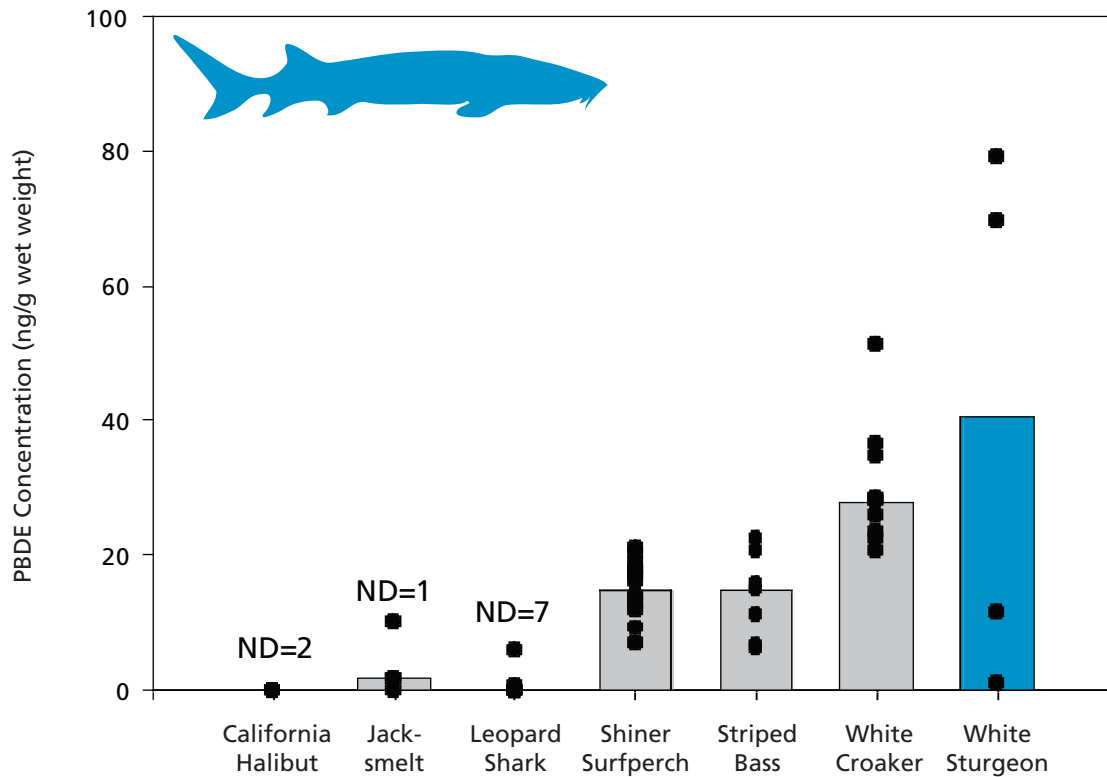













Figure 9. PBDE concentrations (ng/g) in Bay fish, 2003. Fish figure and blue bar indicate the species with the highest median contaminant concentration.

2003 Special Study – Preliminary Screening of Additional Species

In 2003 additional fish species were analyzed for PCBs and mercury. The sport fish species targeted in this effort (*Table 3*) were less frequently consumed, relative to the regular Status and Trends species, by Bay anglers in the survey conducted in 1998 and 1999 (SFEI 2000). Three species of small fish (anchovy, sardine, and herring) were also sampled in order to obtain a preliminary assessment of potential exposure of wildlife that consume these prey species. Since this was a screening level analysis, sample sizes were very small and sampling locations were limited. These data are only preliminary indications of concentrations in these species and should not be used to interpret safety for human consumption. The results primarily identify species where additional monitoring would be beneficial.

Sport Fish

Three species (black surfperch, brown rockfish, and Chinook salmon) did not exceed either the PCB or mercury screening value (*Table 3*). Barred surfperch, diamond turbot, brown smoothhound shark, starry flounder, and walleye surfperch had exceedances of the PCB screening value (*Table 3 and Figure 10*). Barred surfperch, diamond turbot, and brown smoothhound shark were the only species that exceeded the mercury screening value (*Table 3 and Figure 11*). For brown smoothhound shark, all nine samples exceeded the mercury screening value and the maximum concentration was 1.4 µg/g wet weight.

COMMON NAME		MERCURY*	PCBS
SCREENING VALUE		0.20 µG/G WW	10 NG/G WW
	ANCHOVY	0/2	2/2
	BARRED SURFPERCH	1/1	1/1
	BLACK SURFPERCH	0/3	0/3
	BROWN ROCKFISH	0/3	0/3
	HERRING	0/1	1/1
	CHINOOK SALMON	0/2	0/2
	DIAMOND TURBOT	1/1	1/1
	SARDINE	0/1	1/1
	SMOOTHBOUND SHARK	9/9	1/3
	STARRY FLOUNDER	0/2	1/2
	WALLEYE SURFPERCH	0/2	2/2

* TOTAL MAXIMUM DAILY LOAD (TMDL) SCREENING VALUE

Table 3. Number of samples above human health screening values for special study species.

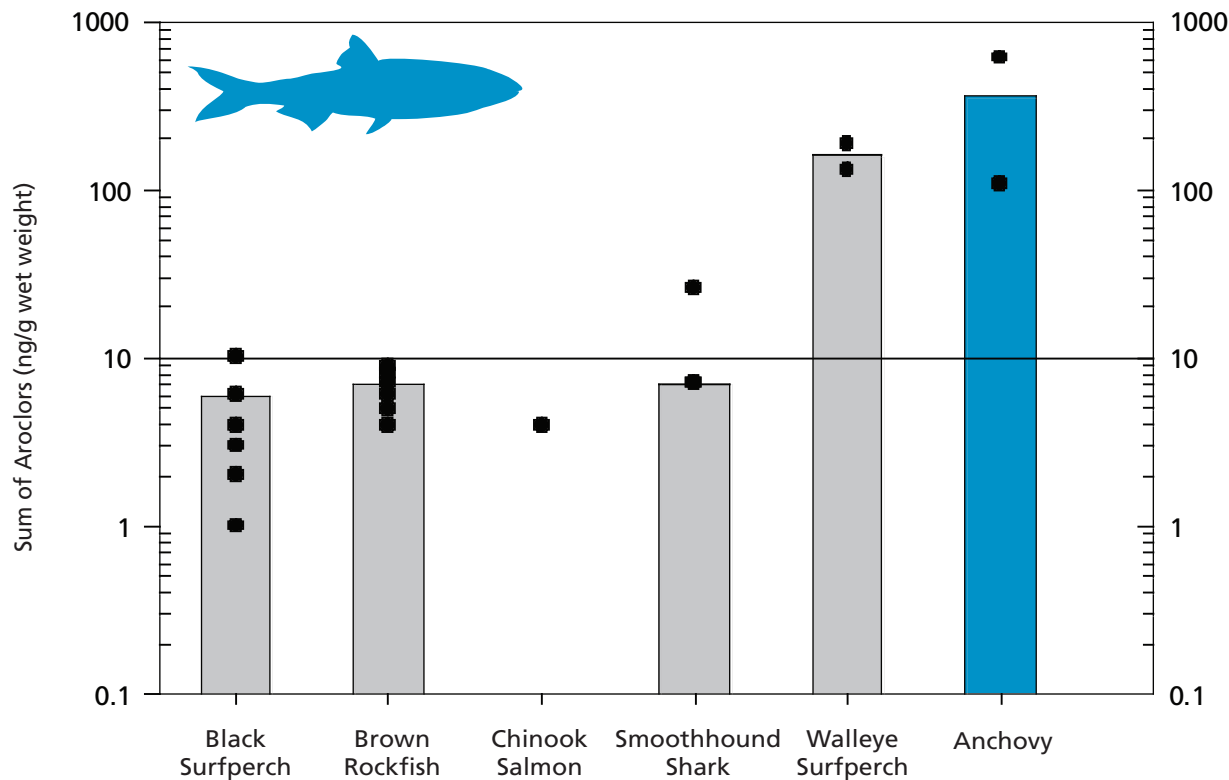


Figure 10. PCB concentrations (as Aroclors ng/g) for sport fish species in the special study. Horizontal line indicates screening value (10 ng/g). Fish figure and blue bar indicate the species with the highest median contaminant concentration.

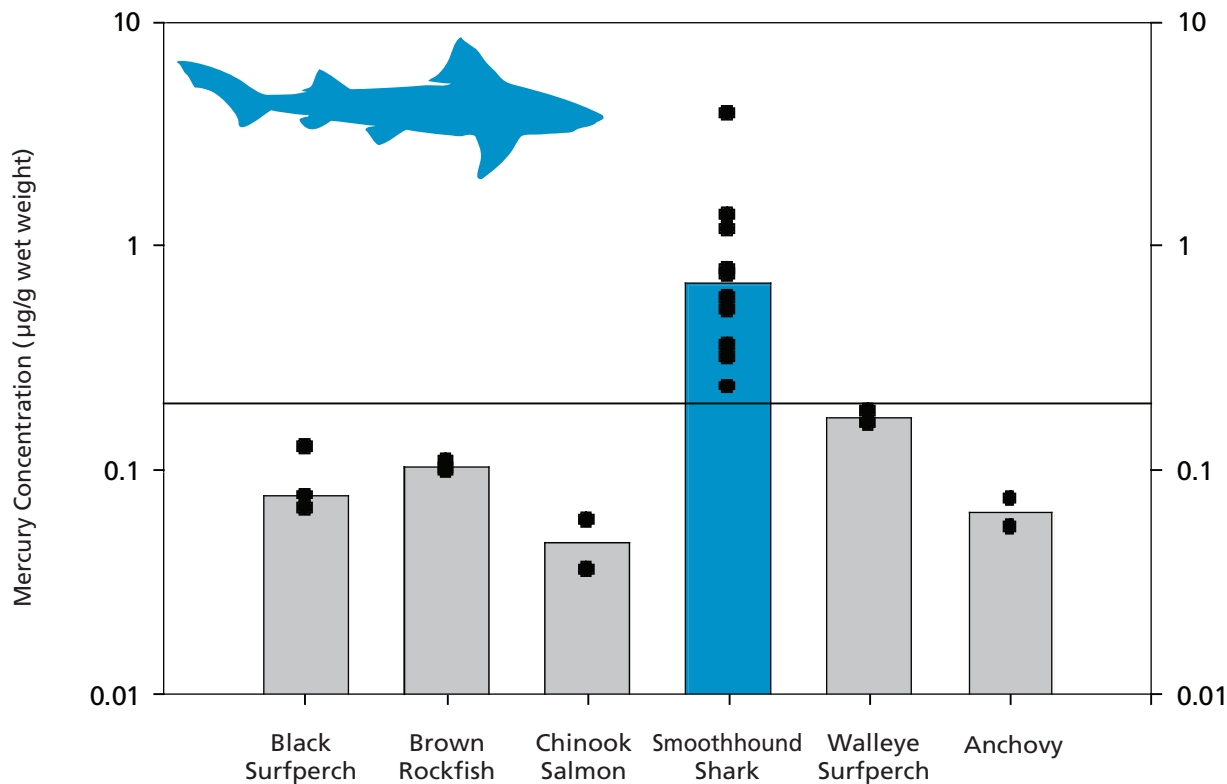


Figure 11. Mercury concentrations ($\mu\text{g/g}$) for sport fish species in the special study. Horizontal line indicates screening value ($0.20 \mu\text{g/g}$). Fish figure and blue bar indicate the species with the highest median contaminant concentration.

Prey Fish

Small fish are important prey items for Bay wildlife, including an endangered species. Pacific herring made up 21% and anchovy 14% of prey items consumed by endangered California least tern chicks nesting at Alameda Point (Elliot et al., 2004). These fish are also prominent in the diets of harbor seals and many species of fish-eating birds.

PCB ([Figure 12](#)) and other organics concentrations in prey fish were surprisingly high. Concentrations in anchovy were particularly high, including a maximum of 607 ng/g in a sample from the South Bay. This was the highest PCB concentration measured in any species in 2003. This anchovy sample (a composite of 8 fish) was very high in fat (9.4%), partially explaining the high PCB concentration. The other anchovy sample was lower in fat (1.9%, but still had a relatively high PCB concentration - 83 ng/g). One herring sample (a composite of 13 fish) measured 91 ng/g (0.9% fat), and one sardine sample (a composite of 10 fish) measured 32 ng/g (in spite of a high fat content - 14%). Concentrations of legacy pesticides and PBDEs showed a similar pattern among species, with relatively high concentrations in anchovy. PBDEs in the South Bay anchovy sample was 64 ng/g. Chlordane (28 ng/g) and dieldrin (7.2 ng/g) in this sample were the highest observed in any sample in 2003. The organics concentrations measured in these prey species are surprisingly high and worthy of further study.

Mercury concentrations in these prey fish samples were relatively low: not detectable in sardine, 0.06 and 0.07 in anchovy, and 0.02 in herring. Additional information on contaminant concentrations in small fish species would strengthen food web models that aim to predict wildlife contaminant concentrations based on contaminant levels in prey.

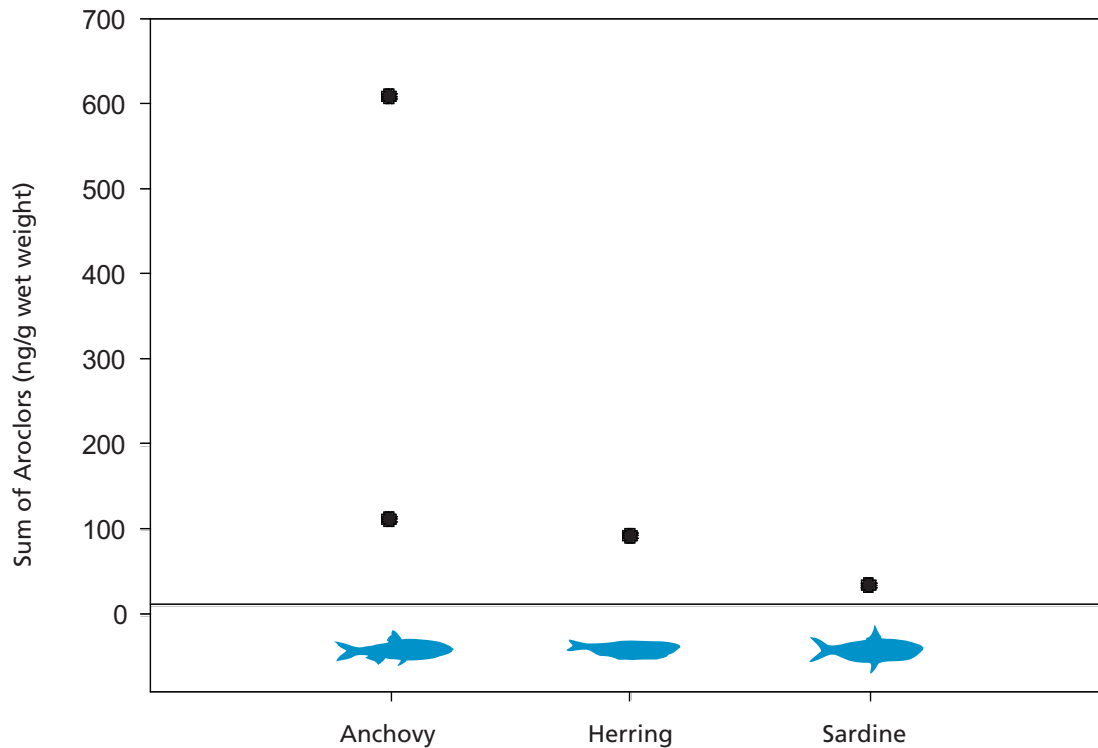


Figure 12. PCB concentrations (as Aroclors ng/g ww) in prey fish species, 2003.

FUTURE PLANS



Another round of RMP fish sampling will be performed in 2006. The 2006 sampling design will be modified from previous years in order to provide the information most needed by managers and to maximize the cost-effectiveness of this effort. In 2006, the RMP will focus on species that serve as indicators of impairment in the Bay. For mercury, the RMP will target striped bass and white sturgeon and for organic contaminants (PCBs, legacy pesticides, and PBDEs) we will target white croaker and shiner surfperch. The 2006 plan also includes continued monitoring of the special study species first analyzed in 2003. This will provide OEHHA information needed to develop consumption advice on other Bay sport fish species as well as potentially identifying other Bay species that may be lower in contaminants. The RMP will analyze the PBDE flame retardants in both Status and Trends and special study species.



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