# Bioaccumulation of Contaminants in Fish Tissues

Harbor Island Yacht Basin, looking west from Convair Lagoon

# *Chapter 5*
# Bioaccumulation of Contaminants in Fish Tissues

## INTRODUCTION

The bioaccumulation of contaminants in fishes from San Diego Bay is of great public concern since the Bay is a popular fishing location for many people, despite the prevalence of various types of pollutants (see USDoN, SWDIV and SDUPD 2000). Contaminant levels in the tissues of Bay fishes, however, have not been studied since the early 1990's (e.g., SDCDH 1990, McCain et al. 1992). To address these concerns, bottom dwelling (i.e., demersal) fishes were collected throughout San Diego Bay to assess more recent levels of contamination.

Contaminants can accumulate in the tissues of fish through various exposure pathways (Tetra Tech 1985). Exposure routes for demersal fishes include adsorption or absorption of dissolved chemical constituents from ambient waters, and the ingestion of pollutant-containing suspended particulate matter or sediment particles. Fish may also accumulate pollutants by directly consuming contaminated plant and animal food sources. Once incorporated into the tissues of a fish, a contaminant can be transferred to and bioconcentrated in upper trophic level predators, including other fish, birds, marine mammals, and humans.

This chapter presents an assessment of contaminant levels in the tissues of fish collected from San Diego Bay in the summer of 1998. These data will provide baseline information against which to measure future trends of contamination in Bay fishes. Contaminant levels in whole fish samples of California halibut from San Diego Bay were compared to a) predator protection thresholds established by Environment Canada (1997, 1998), and to b) halibut sampled in other southern California bays and harbors during the Bight'98 regional survey. In addition, samples of muscle tissue from various species of sport fish were analyzed to address human health concerns, since this is the tissue most often consumed by people.

## MATERIALS & METHODS

### Sample Collection and Processing

Five species of fish were collected at 24 stations in San Diego Bay during the summer of 1998 and analyzed for the accumulation of contaminants in their tissues (Figure 5.1, Table 5.1). Whole fish samples of California halibut (*Paralichthys californicus*) were collected at seven stations and analyzed for the presence of pesticides and polychlorinated biphenyl congeners (PCBs). Contaminant levels in these fish were compared to those for other bays and harbors in Southern California and to predator protection limits for mammals and birds. Muscle tissue samples were collected from sport fish at the remaining 17 stations in San Diego Bay and and analyzed for the presence of metals, pesticides and PCBs. The results of these analyses were compared to human health limits. The fish sampled for muscle tissues included California halibut, calico bass (*Paralabrax clathratus*), spotted sand bass (*Paralabrax maculatofasciatus*), barred sand bass (*Paralabrax nebulifer*), and yellowfin croaker (*Umbrina roncador*). Muscles tissues were analyzed for these five species because it is the tissue most often consumed by people, and for which the most consumption limits are available.

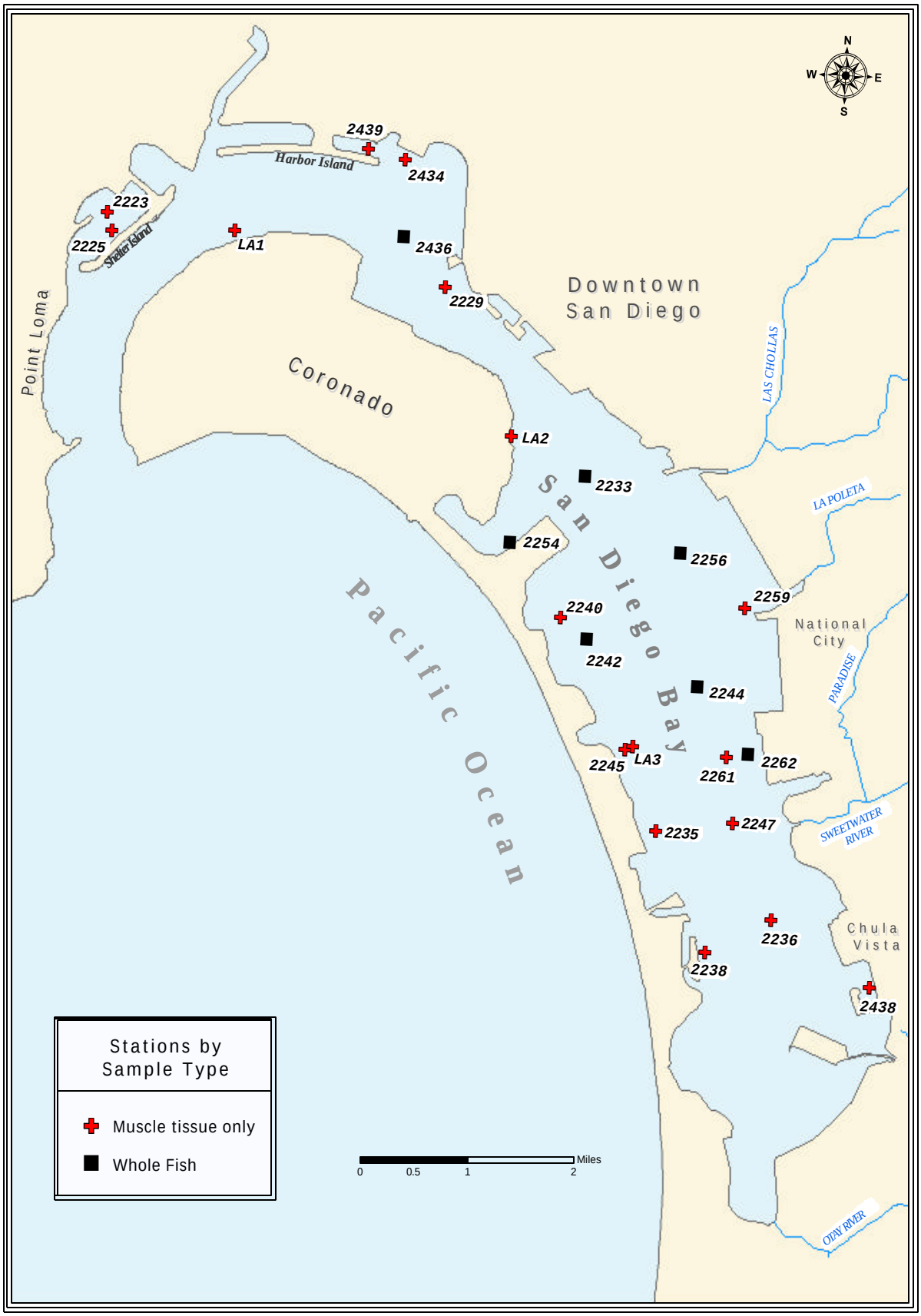


**Figure 5.1**

San Diego Bay fish tissue stations sampled during 1998.

## Table 5.1

Summary of species of fish sampled by tissue type at each San Diego Bay station during 1998. OT= otter trawl, RF= rig fishing.

| Station | Collection Method | Tissue | Species |
|---|---|---|---|
| 2233 | OT | Whole Fish | California halibut |
| 2242 | OT | Whole Fish | California halibut |
| 2244 | OT | Whole Fish | California halibut |
| 2254 | OT | Whole Fish | California halibut |
| 2256 | OT | Whole Fish | California halibut |
| 2262 | OT | Whole Fish | California halibut |
| 2436 | OT | Whole Fish | California halibut |
| 2223 | RF | Muscle | Spotted sand bass |
| 2225 | RF | Muscle | Spotted sand bass |
| 2229 | RF | Muscle | Barred sand bass |
| 2235 | RF | Muscle | Spotted sand bass |
| 2236 | RF | Muscle | Spotted sand bass |
| 2238 | RF | Muscle | Spotted sand bass |
| 2240 | RF | Muscle | Spotted sand bass |
| 2245 | RF | Muscle | Yellowfin croaker |
| 2247 | RF | Muscle | Spotted sand bass |
| 2259 | RF | Muscle | Barred sand bass |
| 2261 | RF | Muscle | Spotted sand bass |
| 2434 | RF | Muscle | Calico bass |
| 2438 | RF | Muscle | Spotted sand bass |
| 2439 | RF | Muscle | Spotted sand bass |
| LA1* | misc. | Muscle | California halibut |
| LA2* | misc. | Muscle | Spotted sand bass |
| LA3* | misc. | Muscle | Spotted sand bass |

* additional fish from Dr. Larry Allen, collected by various methods

California halibut for the whole fish samples were collected from otter trawls conducted as part of Bight'98 (see Chapter 4). Only fish in the 5-20 cm size-class range (standard length) were retained for analysis. After collection, all fish were wrapped in aluminum foil, placed into ziplock bags, and then transported to the lab and stored frozen until processed. Prior to processing, the fish were sorted into composite samples of six fish each. The fish were then partially defrosted, rinsed in deionized water to remove visible particles, and shaken dry. The standard length (cm) and weight (g) of each fish used in the composite samples were recorded (Appendix E.1). Additionally, individual fish weights were summed to give a total weight for each composite sample. The whole fish composites were homogenized in chilled blenders, which consisted of 1-liter glass containers with silicone rubber gaskets and aluminum foil-lined lids. A volume of deionized water equal to the composite weight was combined with the fish tissue to facilitate blending. The entire sample was then blended for less than two minutes to obtain a smooth homogenate. The homogenate was then placed in glass jars, sealed, labeled, and stored at -20$^{o}$C prior to chemical analysis for pesticides (e.g., DDT, chlordane) and PCB congeners (see Appendix E.2). All samples were delivered to the City of San Diego Wastewater Chemistry Laboratory within six months. All contaminant concentrations resulting from these analyses were doubled in order to account for the water added to each sample.

Muscle tissues were analyzed for sport fish considered representative of a typical sport fisher's catch using rod and reel type gear at most stations. However, Dr. Larry Allen used several methods to collect fish at the three sites designated LA1-LA3. Only fish > 11 cm in standard length were kept and processed. All fish were wrapped in aluminum foil, placed into ziplock bags, and then transported to the lab and stored frozen until processed. In the lab, various sport fish were sorted into composite samples containing a minimum of three fish each. The fish were then partially defrosted and cleaned with a paper towel to remove loose scales and excess mucus. The standard length (cm) and weight (g) of the fish used in each composite sample were recorded (Appendix E.1). Muscle tissues were subsequently dissected from all the fish included in each composite. These dissections were carried out on Teflon pads that were cleaned between samples. The muscle samples were then placed in glass jars, sealed, labeled, and stored at -20°C. All samples were delivered to the City of San Diego Wastewater Chemistry Laboratory within seven days of dissection for the subsequent analysis of priority pollutants, including metals, pesticides, and PCBs (Appendix E.3). A detailed description of all analytical protocols may be obtained from the City's Wastewater Chemistry Laboratory

## Data Analysis

Prior to any analysis, all values less than method detection limits (MDLs) were eliminated from the dataset. The MDLs for the contaminants analyzed in this study are listed in Appendices E.2 and E.3. Total DDT (tDDT) was calculated as the sum of DDT and its DDD and DDE derivatives. Total PCB (tPCB) was calculated as the sum of all PCB congeners. Metal and pesticide concentrations in the muscle tissues of fish were compared to national and international seafood action limits for humans (see Mearns et al. 1991).

Whole fish samples from San Diego Bay, Los Angeles/Long Beach Harbor, Marina Del Rey, Newport Harbor, and Ventura Harbor were compared to predator protection thresholds as determined by Environment Canada (1997, 1998). These thresholds are risk-based guidelines for marine mammals and birds, set at 14.0 ppb for tDDT and 0.79 ng (TEQ)/kg for tPCB, where TEQ is the toxic equivalent quotient. PCB TEQs were calculated separately for each sample as the sum of concentrations of the individual PCB congeners multiplied by their relative dioxin-like toxicity. The toxicity factors used in this study were those recommended by the World Health Organization for PCB congeners 77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, and 189, and differ for mammals and birds based on physiological differences (see Van den Berg et al. 1998).

# RESULTS

## Contaminants in Muscle Tissues of Fishes from San Diego Bay

### *Metals*

Trace metal contamination varied in the tissues of fishes captured in San Diego Bay. Detections rates exceeded 80% for mercury, zinc, iron and selenium, but were much lower (< 30%) for aluminum, arsenic, chromium and copper (Table 5.2). In general, most metals that were detected were present at relatively low concentrations. Only chromium and arsenic occurred at levels that reached or exceeded USFDA and international action limits. These standards represent thresholds that indicate undesirable concentrations in fish tissues and are used to prevent the sale of contaminated seafood (Mearns et al. 1991). Arsenic, for example, exceeded the median international standard in one sample of barred sand bass collected at station

## Table 5.2

Concentrations of metals (ppm) and pesticides (ppb) detected in fish muscle samples, listed by station and species. Values exceeding US FDA action levels, Median International Standards or Cal/EPA screening levels, are shown in bold. BSB = barred sand bass; CB = calico bass; CH = California halibut; SSB = spotted sand bass; YC = yellowfin croaker.

| | | Metals (ppm) | | | | | | | | Pesticides (ppb) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Station** | **Species** | **Al** | **As** | **Cr** | **Cu** | **Fe** | **Hg** | **Se** | **Zn** | **tDDT** | **tChlor** | **Dieldrin** |
| 2229 | BSB | —- | **4.8** | —- | —- | 6.0 | 0.028 | 0.20 | 2.02 | 5.68 | —- | —- |
| 2259 | BSB | —- | —- | —- | —- | 3.1 | 0.061 | 0.21 | 3.43 | 10.70 | —- | —- |
| 2434 | CB | —- | —- | —- | —- | 7.0 | 0.055 | 0.24 | 3.22 | 15.00 | —- | —- |
| LA1 | CH | —- | —- | 0.18 | 0.79 | 5.5 | 0.010 | —- | 3.86 | 3.27 | —- | —- |
| 2223 | SSB | —- | —- | —- | —- | 5.8 | 0.066 | 0.24 | 4.21 | 10.50 | —- | 0.46 |
| 2225 | SSB | —- | —- | —- | —- | 7.5 | 0.082 | 0.20 | 4.86 | 7.80 | —- | 1.17 |
| 2235 | SSB | 4.0 | —- | —- | 0.40 | 7.8 | 0.077 | 0.23 | 3.83 | 6.27 | —- | —- |
| 2236 | SSB | —- | —- | —- | —- | 7.0 | 0.078 | 0.20 | 2.69 | 5.03 | —- | —- |
| 2238 | SSB | —- | —- | —- | —- | 12.1 | 0.068 | 0.23 | 3.51 | 4.53 | —- | —- |
| 2240 | SSB | —- | —- | —- | —- | 7.8 | 0.041 | 0.20 | 3.73 | 4.65 | —- | —- |
| 2247 | SSB | —- | —- | —- | —- | 7.1 | 0.093 | 0.14 | 3.02 | —- | —- | —- |
| 2261 | SSB | —- | —- | —- | 1.05 | 9.2 | 0.047 | 0.13 | 4.27 | 7.57 | —- | —- |
| 2438 | SSB | —- | —- | **1.00** | —- | 9.7 | 0.039 | 0.24 | 4.39 | 6.12 | —- | —- |
| 2439 | SSB | —- | —- | —- | —- | 13.1 | 0.157 | 0.18 | 3.93 | 10.10 | —- | —- |
| LA2 | SSB | —- | —- | —- | 1.52 | 7.3 | 0.074 | 0.22 | 4.60 | 4.06 | —- | —- |
| LA3 | SSB | —- | —- | 0.50 | 2.57 | 10.8 | 0.032 | —- | 5.13 | —- | —- | —- |
| 2245 | YC | —- | —- | —- | —- | 6.7 | 0.192 | —- | 4.58 | 7.52 | 0.87 | |
| | All Species % Detect | 6 | 6 | 18 | 29 | 100 | 100 | 82 | 100 | 88 | 6 | 12 |
| US FDA Action Level * | | | | | | | 1.0 | | | 5000 | 300 | 300 |
| Median International Standard** | | | 1.4 | 1.0 | 20.0 | | 0.5 | 0.3 | 70.0 | 5000 | 100 | 400 |
| Cal/EPA screening level | | | | | | | | | | 100 | | |

*From Table 3-4 in Kyle 1998. Standards are action limits for commercial fin fish.
**From Table 2.3 in Mearns et al. 1991. All international standards are for shellfish, but are often applied to fish. All limits apply to the sale of seafood for human consumption.

2229 along the Silver Strand (Figure 5.1). The single elevated chromium value was recorded for a muscle sample from spotted sand bass collected at station 2438 inside the Chula Vista Marina.

### *Pesticides*

DDT was found in the muscle tissues of all species of fish collected in the Bay at an overall detection rate of 88% (Table 5.2). Concentrations ranged from 3.27 ppb in a California halibut sample to 15 ppb in a calico bass sample. The four highest DDT values occurred in fishes collected at stations 2434 and 2439 located near Convair Lagoon, at station 2259 near the NASSCO shipyards, and at station 2223 in the Shelter Island Yacht Basin (see Figure 5.1). Two other pesticides, chlordane and dieldrin, were also detected in muscle tissues, although less frequently than DDT. Dieldrin, for example, was found in two spotted sand bass samples collected

## Table 5.3

Concentrations (ppb) of PCBs detected in muscle tissue samples of fish collected in San Diego Bay during 1998. Data are presented for total PCBs (tPCB) and individual congeners. BSB = barred sand bass; CB = calico bass; CH = California halibut; SSB = spotted sand bass; YC = yellowfin croaker.

| | | | PCB Congeners (ppb) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Station** | **Species** | **tPCB** | **49** | **52** | **66** | **99** | **101** | **105** | **110** | **118** | **138** | **149** | **153** | **170** | **180** | **187** |
| 2229 | BSB | 43.6 | —- | —- | —- | —- | 7.9 | —- | —- | 8.1 | 9.6 | —- | 18.0 | —- | —- | —- |
| 2259 | BSB | 95.5 | —- | —- | —- | 8.0 | 11.0 | —- | —- | 11.0 | 15.0 | 8.3 | 27.0 | —- | 7.3 | 7.9 |
| 2434 | CB | 172.2 | 9.0 | 11.0 | 9.7 | 13.0 | 21.0 | —- | 11.0 | 18.0 | 18.0 | 12.0 | 32.0 | —- | 7.9 | 9.6 |
| LA1 | CH | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- |
| 2223 | SSB | 106.9 | —- | —- | —- | 13.0 | 10.0 | —- | —- | 16.5 | 18.5 | —- | 32.5 | —- | 8.3 | 8.2 |
| 2225 | SSB | 105.0 | —- | —- | —- | 11.0 | 12.0 | —- | —- | 17.0 | 17.0 | —- | 32.0 | —- | 7.4 | 8.6 |
| 2235 | SSB | 55.3 | —- | —- | —- | 7.9 | 7.6 | —- | —- | 7.8 | 11.0 | —- | 21.0 | —- | —- | —- |
| 2236 | SSB | 11.0 | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | 11.0 | —- | —- | —- |
| 2238 | SSB | 21.8 | —- | —- | —- | —- | —- | —- | —- | —- | 6.8 | —- | 15.0 | —- | —- | —- |
| 2240 | SSB | 46.4 | —- | —- | —- | —- | —- | —- | —- | 8.1 | 11.0 | —- | 21.0 | —- | —- | 6.3 |
| 2247 | SSB | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- |
| 2261 | SSB | 55.3 | —- | —- | —- | —- | 8.3 | —- | —- | 8.8 | 10.0 | —- | 22.0 | —- | —- | 6.2 |
| 2438 | SSB | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- |
| 2439 | SSB | 133.4 | 3.3 | 3.8 | 6.0 | 8.5 | 14.4 | 5.0 | 4.1 | 20.5 | 17.7 | 4.8 | 30.5 | 2.9 | 6.5 | 5.5 |
| LA2 | SSB | 109.6 | —- | —- | —- | 12.0 | 9.7 | —- | —- | 15.0 | 20.0 | —- | 36.0 | —- | 7.7 | 9.2 |
| LA3 | SSB | 7.6 | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | 7.6 | —- | —- | —- |
| 2245 | YC | 12.0 | —- | —- | —- | —- | —- | —- | —- | —- | —- | —- | 12.0 | —- | —- | —- |
| | All Species | | | | | | | | | | | | | | | |
| | % Detect | 82 | 12 | 12 | 12 | 41 | 53 | 6 | 12 | 59 | 65 | 18 | 82 | 6 | 35 | 47 |

at stations 2223 and 2225 in the Shelter Island Yacht Basin. Additionally, although chlordane is considered a contaminant of concern in San Diego Bay (see USDoN, SWDIV and SDUPD 2000), this pesticide was found in only one sample of yellowfin croaker collected at station 2245 near the Silver Strand. All pesticide concentrations were less than international, federal and state consumption limits.

***PCBs***

PCBs were found in the muscle tissues of almost all species of fish collected in the Bay (Table 5.3). The overall detection rate was 82%, and tPCB values ranged from 7.6 to 172.2 ppb. For most samples, tPCB was largely composed of the congeners 153, 138, 118, and 101. Samples with the highest concentrations tended to have the greatest number of congeners present. The highest tPCB concentrations occurred in calico bass and spotted sand bass samples collected at stations 2434 and 2439 near Convair Lagoon, an area known for high PCB sediment contamination (see Fairey et al. 1996).

Most tPCB concentrations reported herein were much higher than typically reported in the muscle tissues of flatfish, rockfish and sand bass sampled in offshore waters off of Point Loma and southern San Diego (City of San Diego 1996, 1997, 1998, 1999, 2000a, 2000b, 2000c, 2001a, 2001b, 2002a, 2002b). However, human health thresholds for PCB concentrations in muscle tissues have been established only for PCBs quantified as commercial mixtures (i.e., Aroclors), and therefore could not be applied directly to the congener data reported here.

## Contaminants in Whole Fish from San Diego Bay

***Pesticides***

DDT occurred in all California halibut whole fish samples collected in this study at concentrations ranging from 18 to 70 ppb (Table 5.4). The highest DDT concentration was found in fish collected at station 2233 located just south of the Coronado Bridge in the middle of the Bay. The lowest concentrations occurred in fish collected at stations 2254 and 2262 located along the edges of the Bay (see Figure 5.1). All values exceeded the predator risk threshold of 14 ppb for DDT (see Environment Canada 1997). No chlordane was detected in any of the whole fish samples analyzed during this study.

***PCBs***

PCBs were also detected in all of the California halibut samples collected in San Diego Bay (Table 5.4). Total PCB concentrations ranged from 63 to 323 ppb, with over 70% of the samples exceeding 200 ppb. The highest PCB value was found in fish collected at station 2242 located mid-channel across from the Naval Station San Diego (see Figure 5.1). The lowest PCB concentration was detected in fish collected at station 2262, which coincided with one of the lowest levels of DDT found in the halibut samples.

Total PCB was composed primarily of congeners 153, 138 and 101, all of which occurred in 100% of the whole fish samples (Table 5.4). PCB 118, the only detected congener with recognized dioxin-like toxicity (see Van den Berg et al. 1998), was among several other congeners detected in 86% of the fish. Each of the six halibut samples with PCB 118 present had PCB TEQs that were greater than the Environment Canada predator protection threshold value for mammals. Because PCB 118 is considered 10 times less toxic to birds than to mammals (Van den Berg et al. 1998), none of these samples exceeded the threshold for birds.

## Table 5.4

Concentrations (ppb) of total DDT and PCBs detected in whole fish samples of California halibut from San Diego Bay.

| | | | PCB Congeners | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | tDDT | tPCB | 99 | 101 | 110 | 118 | 138 | 149 | 151 | 153 | 180 | 187 |
| **2233** | 70 | 310 | 27 | 39 | 20 | 28 | 45 | 32 | 7 | 76 | 13 | 24 |
| **2242** | 40 | 323 | 26 | 36 | 18 | 30 | 52 | 30 | —- | 84 | 19 | 28 |
| **2244** | 32 | 240 | 20 | 32 | 18 | 22 | 34 | 24 | —- | 60 | 12 | 19 |
| **2254** | 18 | 248 | 23 | 24 | 14 | 28 | 39 | 21 | —- | 65 | 14 | 21 |
| **2256** | 42 | 254 | 22 | 32 | 16 | 24 | 36 | 26 | —- | 66 | 12 | 20 |
| **2262** | 19 | 63 | —- | 14 | —- | —- | 17 | —- | —- | 32 | —- | —- |
| **2436** | 36 | 161 | 17 | 24 | —- | 18 | 26 | 18 | —- | 44 | —- | 14 |
| **Freq (%)** | 100 | 100 | 86 | 100 | 71 | 86 | 100 | 86 | 14 | 100 | 71 | 86 |
| **Min** | 18 | 63 | 17 | 14 | 14 | 18 | 17 | 18 | 7 | 32 | 12 | 14 |
| **Max** | 70 | 323 | 27 | 39 | 20 | 30 | 52 | 32 | 7 | 84 | 19 | 28 |
| **Mean** | 37 | 226 | 22 | 29 | 17 | 25 | 36 | 25 | 7 | 61 | 14 | 21 |

### Comparison of San Diego Bay to Other Embayments

***Pesticides***

DDT was detected in 100% of the whole fish samples of California halibut collected from the different embayments sampled during Bight'98 (Table 5.5). The average tDDT concentration in halibut from San Diego Bay was about twice that of fish from Marina Del Rey, but substantially less than in fish collected in the Los Angeles/Long Beach, Newport, and Ventura harbors. The only sample that had a tDDT concentration less then the predator protection threshold for bird and mammal consumers occurred in Marina Del Rey. Although chlordane was found in halibut from Los Angeles/Long Beach Harbor, Marina Del Rey and Newport Harbor, this compound was not detected in any whole fish sample from San Diego Bay.

***PCBs***

PCBs were detected in 100% of the whole halibut samples from San Diego Bay, Marina Del Rey and Newport Harbor, in 40% of the samples from Los Angeles/Long Beach Harbor (Table 5.5). No PCBs were detected in the samples from Ventura Harbor . Fish from San Diego Bay averaged much higher concentrations of PCBs in their tissues than those from the other bays, which was probably due to historically acute PCB sediment contamination (USDoN, SWDIV and SDUPD 2000). None of the whole fish samples collected in any SCB embayment had PCB concentrations that exceeded the predator risk threshold for marine birds. In contrast, several values did exceed the threshold for marine mammals, including each of the samples from Newport and Ventura Harbors, 86% of the samples from San Diego Bay, and 20% of the samples from Los Angeles/Long Beach Harbor.

## SUMMARY & DISCUSSION

Fishes collected in San Diego Bay during 1998 contained many of the ‘contaminants of concern’ reported previously for sediments in the Bay (e.g., chromium, copper, lead, mercury, zinc, tributyltin, chlordane, PCBs) (USDoN, SWDIV and SDUPD 2000). PCBs and the metals mercury and zinc were detected in almost all

## Table 5.5

Concentrations (ppb) of pesticides and PCBs detected in whole fish samples from San Diego Bay compared to other bays and harbors sampled during Bight'98. Sample size in parenthases.

| | | SDBay (7) | Newport Harbor (1) | LA/LB Harbor (5) | Marina Del Rey (4) | Ventura Harbor (1) |
|---|---|---|---|---|---|---|
| Total DDT | %Detect | 100 | 100 | 100 | 100 | 100 |
| | range | 18-70 | na | 26-187 | 7-35 | na |
| | mean | 37 | 235 | 71 | 18 | 113 |
| Total PCB | %Detect | 100 | 100 | 40 | 100 | 0 |
| | range | 63-323 | na | 16-103 | 7-50 | —- |
| | mean | 228 | 35 | 60 | 23 | —- |
| Total Chlordane | %Detect | 0 | 100 | 20 | 25 | 0 |
| | range | —- | na | na | na | —- |
| | mean | —- | 5 | 5 | 2 | —- |
| Total DDT Threshold* | | | | | | |
| | %exceed | 100 | 100 | 100 | 50 | 100 |
| PCB Thresholds** | | | | | | |
| Mammals | %exceed | 86 | 100 | 20 | 0 | 0 |
| Birds | %exceed | 0 | 0 | 0 | 0 | 0 |

* = 14 ppb, predator protection threshold from Environment Canada 1997.
** = 0.00079 TEQ ppb predator protection threshold for mammals and birds, where TEQ calculated as summed concentration x toxicity of each congener, determined separately for mammals and birds based on different physiology (Environment Canada 1998, see also Bight'98 reports).

muscle tissue samples. In contrast, the other contaminants of concern were found much less frequently or not at all. Additional contaminants found in the muscles of Bay fishes included aluminum, arsenic, iron, selenium and the pesticide DDT. DDT and PCBs were also detected in all of the whole fish samples of California halibut collected in the Bay. Tissue contamination levels could not be associated with the sediments at specific collection sites since none of the species of fish analyzed demonstrate strong site fidelity, and because the overall sample area is relatively small.

Contaminant levels in muscle tissues and whole fish samples were assessed relative to two different types of thresholds in this study. In order to address human health concerns, concentrations of contaminants in the muscles of San Diego Bay fishes were compared to both national and international limits. Almost all of these values were below consumption limits. Arsenic and chromium were the only exceptions, with each exceeding the median international standard in a single sample. In contrast, concentrations of PCBs and DDT in whole fish samples were compared to the more recent mammal and bird predator protection thresholds (see Environment Canada 1997). All of these samples had PCB and DDT levels that exceeded the limits for mammals, while only concentrations of DDT exceeded the limit for birds.

Levels of PCB and DDT contamination in whole fish samples were compared among the various embayments sampled during Bight'98. Detection rates and concentrations of PCBs were much higher in

halibut samples from San Diego Bay than in the other bays and harbors. In contrast, DDT concentrations and detection rates were similar in fish from all of the southern California embayments.

It was not possible to determine temporal trends in contamination levels for San Diego Bay fishes. This was due to differences between this study and previous surveys in terms of analytical techniques, and the types of tissues and species analyzed. However, some comparisons were possible between this study in 1998 and a survey performed by the San Diego County Department of Health Services in 1988-1989 using muscle tissues from similar species of fish (SDCDH 1990). For example, arsenic levels were slightly higher, chromium levels were similar, and concentrations of DDT (i.e., p,p,-DDE in SDCDH 1990), mercury and selenium were lower in this survey than in 1989-1989. Comparisons were also possible between fishes collected in San Diego Bay and those collected in offshore coastal waters off San Diego. While levels of metals and pesticides were similar, PCB concentrations were substantially higher in the muscle tissues of fishes from San Diego Bay than typically reported for coastal flatfish, rockfish, and sand bass sampled off Point Loma and southern San Diego (e.g., City of San Diego 1996, 1997, 1998, 1999, 2000a, 2000b, 2000c, 2001a, 2001b, 2002a, 2002b).

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