Chapter 7: Bioaccumulation of Contaminants in Fish Tissues

INTRODUCTION

Bottom dwelling (i.e., demersal) fishes are collected as part of the Point Loma Ocean Outfall (PLOO) monitoring program to assess the accumulation of contaminants in their tissues. The bioaccumulation of contaminants in fish occurs through biological uptake and retention of chemical contaminants derived from various exposure pathways (see Tetra Tech 1985). Exposure routes for these fishes include the adsorption or absorption of dissolved chemical constituents from the water and the ingestion and assimilation of pollutants from food sources. They also accumulate pollutants by ingesting pollutant-containing suspended particulate matter or sediment particles. Demersal fish are useful in biomonitoring programs because of their proximity to bottom sediments. For this reason, levels of contaminants in tissues of these fish are often related to those found in the environment (Schiff and Allen 1997).

The bioaccumulation portion of the PLOO monitoring program consists of two components: (1) analysis of liver tissues from trawl-caught fishes; (2) analysis of muscle tissues from fishes collected by rig fishing. Fishes collected from trawls are considered representative of the demersal fish community, and certain species are targeted based on their ecological significance (i.e., prevalence). Chemical analyses are performed using livers from these fish because this is where contaminants typically concentrate due to the physiological role of this organ and the high lipid levels found there. In contrast, fishes targeted for collection by rig fishing are typical of a sport fisher’s catch. Muscle tissue is analyzed from these fishes because it is the part of a fish most often consumed by humans, and the results are therefore directly pertinent to human health.

All muscle and liver tissue samples were analyzed for contaminants as specified in the NPDES discharge permit governing the PLOO monitoring program. Most of these contaminants are also included in the NOAA National Status and Trends Program. NOAA initiated this program to detect changes in the environmental quality of our nation’s estuarine and coastal waters by tracking contaminants thought to be of concern (Lauenstein and Cantillo 1993). This chapter presents the results of all tissue analyses that were performed during 2004.

MATERIALS AND METHODS

Collection

Fishes were collected by trawl during October 2004 in four zones (Z1–Z4) and two rig fishing stations (RF1 and RF2) (Figure 7.1). Trawl-caught fishes were collected, measured and weighed following...
established guidelines as described in Chapter 6 of this report. Fishes were collected at rig fishing sites primarily using rod and reel fishing tackle following standard procedures (City of San Diego in prep). Fish traps were used at the rig fishing sites to facilitate the collection of fish. Only fish >12 cm standard length were retained for tissue analyses. These fish were sorted into composite samples, each containing a minimum of three individuals. The fish were then wrapped in aluminum foil, labeled, put in ziplock bags, and placed on dry ice for transport to the Marine Biology Laboratory freezer. The species that were analyzed from each station/zone are summarized in Table 7.1.

**Tissue Processing and Chemical Analyses**

All dissections were performed according to standard techniques for tissue analysis (see City of San Diego in prep). Each fish was partially defrosted and then cleaned with a paper towel to remove loose scales and excess mucus prior to dissection. The standard length (cm) and weight (g) of each fish were recorded (Appendix D.1). Dissections were carried out on Teflon pads that were cleaned between samples. Tissue samples were then placed in glass jars, sealed, labeled and stored in a freezer at -20°C prior to chemical analyses. All samples were subsequently delivered to the City of San Diego Wastewater Chemistry Laboratory within seven days of dissection.

### RESULTS

**Contaminants in Trawl-Caught Species**

#### Metals

Aluminum, arsenic, barium, cadmium, chromium, copper, iron, manganese, mercury, selenium, silver, tin, and zinc occurred frequently in the liver tissues of all trawl-caught species of fish (Table 7.2). Each of these metals was detected in over 60% of the samples, with variable concentrations. For example, iron occurred in all species at concentrations ranging from about 45 to 190 ppm.

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**Table 7.1**

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<tr>
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<th>Rep 2</th>
<th>Rep 3</th>
<th>Rep 4</th>
<th>Rep 5</th>
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<td>PS</td>
<td>PS</td>
<td>PS</td>
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<tr>
<td>RF 2</td>
<td>GR</td>
<td>MR</td>
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</table>

Species of fish collected for tissue analysis from each trawl zone (Z1–Z4) or rig fishing station (RF1–RF2) during October 2004. PS=Pacific sanddab; ES=English sole; LS=longfin sanddab; CR=copper rockfish; MR=mixed rockfish; GR=greenspotted rockfish.
Table 7.2
Concentrations (ppm) of metals detected in liver tissues from fish collected as part of the PLOO monitoring program during 2004. n=number of detected values.

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<thead>
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<th></th>
<th>Al</th>
<th>Sb</th>
<th>As</th>
<th>Ba</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Fe</th>
<th>Pb</th>
<th>Mn</th>
<th>Hg</th>
<th>Ni</th>
<th>Se</th>
<th>Ag</th>
<th>Sn</th>
<th>Zn</th>
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<td>6.7</td>
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<td>0.088</td>
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<td>3.65</td>
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<td>0.60</td>
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<tr>
<td>% Detected</td>
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<td>11</td>
<td>100</td>
<td>100</td>
<td>100</td>
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<td>4</td>
<td>100</td>
<td>96</td>
<td>96</td>
<td>100</td>
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</table>
In addition, the range of values from fish collected at stations closest to the discharge site (Zone 1) were similar to those from farther away (Zones 2–4) (Figure 7.2). Overall there was no clear relationship between contaminant levels and proximity to the outfall.

**Chlorinated Pesticides**

Four pesticides were detected in liver tissues from fishes collected in the Point Loma coastal region (Table 7.3). DDT was the most prevalent pesticide; it occurred in all samples with concentrations of total DDT ranging between 47 ppb and 2191 ppb. Chlordane (i.e., alpha(cis)-chlordane, gamma(trans)-chlordane, cis-nonachlor, and trans-nonachlor), hexachlorobenzene (HCB), and Mirex were also detected, although at concentrations less than 100 ppb. Of these constituents, alpha(cis)-chlordane, HCB and trans-nonachlor were the most common, with detection rates of 70% or greater. The four most frequently detected pesticides (or pesticide components) were plotted by zone to assess spatial patterns (Figure 7.3). DDT, alpha(cis)-chlordane, HCB, and trans-nonachlor were detected in fishes collected from all four zones. As with metals, there was no clear relationship between concentrations of these parameters and proximity to the outfall.

**PCBs**

Polychlorinated biphenyls (PCBs) occurred in all fish samples (Table 7.3 and Appendix D.3). Total
Table 7.3
Concentrations of chlorinated pesticides, PCBs, and lipids detected in liver tissues from fish collected as part of the PLOO monitoring program during 2004. HCB=hexachlorobenzene, A(c)C=alpha(cis) chlordane, G(t)C=gamma(trans)chlordane, CN=cis-nonachlor, TN=trans-nonachlor. Values are expressed in parts per billion (ppb) for all parameters except lipids, which are presented as percent weight (% wt). n=number of detected values.

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<thead>
<tr>
<th>Chlorinated Pesticides:</th>
<th>Total DDT</th>
<th>HCB</th>
<th>Mirex</th>
<th>Chlordane A(c)C</th>
<th>G(t)C</th>
<th>CN</th>
<th>TN</th>
<th>Total PCB</th>
<th>Lipids</th>
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</table>

ALL SPECIES

| % Detect. | 100 | 89  | 7   | 70  | 7   | 22  | 70  | 100 | 100 |

Figure 7.3
Concentrations of frequently detected chlorinated pesticides (or components) and total PCB (ppb) detected in liver tissues of fish as part of the PLOO monitoring program during 2004. Z1 represents the zone located closest to the discharge site.
**Table 7.4**  
Concentrations (ppm) of various metals and total DDT detected in muscle tissues from fish collected at PLOO rig fishing stations during 2004. Also included are US FDA action limits and median international standards. Bolded values exceed international standards.

<table>
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<th>As</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Pb</th>
<th>Hg</th>
<th>Se</th>
<th>Sn</th>
<th>Zn</th>
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<td>0.013</td>
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<td>—</td>
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<td>0.57</td>
<td>—</td>
<td>4.4</td>
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<td>nd</td>
<td>1</td>
<td>1</td>
<td>nd</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Min</td>
<td>1.9</td>
<td>—</td>
<td>0.19</td>
<td>0.14</td>
<td>—</td>
<td>0.291</td>
<td>0.20</td>
<td>0.24</td>
<td>3.3</td>
<td>0.013</td>
</tr>
<tr>
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<td>1.9</td>
<td>—</td>
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<td>0.14</td>
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**ALL SPECIES**

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<th>100</th>
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<th>100</th>
<th>100</th>
<th>50</th>
<th>100</th>
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US FDA Action Limit* | 1 | 5 |
Median International Standard* | 1.4 | 1.0 | 1.0 | 20.0 | 2.0 | 0.5 | 0.3 | 175.0 | 70.0 | 5.0 |

*From Table 2.3 in Mearns et al. 1991. USFDA action limit for total DDT is for fish muscle tissue, US FDA mercury action limits and all international standards are for shellfish, but are often applied to fish. All limits apply to the sale of seafood for human consumption.

PCB concentrations were variable and ranged from about 66 to 1800 ppb. No clear relationship was evident between concentrations of PCBs in fish livers and proximity to the outfall (Figure 7.3).

**Contaminants in Rig-Caught Fish**

Concentrations of contaminants in muscle tissue samples from rig-caught fishes were compared to national and international limits and standards to address human health concerns, both of which apply to the sale of seafood for human consumption (Mearns et al. 1991). In 2004, arsenic, chromium, copper, mercury, selenium, zinc, and DDT were detected in all of the muscle samples that were collected (Table 7.4). Of these, arsenic, mercury, and selenium occurred in some samples at concentrations that exceeded their median international standards. In addition, the maximum detected value of mercury in copper rockfish exceeded the United States Food and Drug Administration (FDA) action limit for this metal. All values of total DDT were below the FDA action limit.

Spatial patterns were assessed for total DDT and total PCB, as well as all metals that occurred
frequently in fish muscle tissues (Figure 7.4). A single sample from RF1 had the highest concentration of several parameters (e.g., mercury, selenium, zinc, DDT, PCB) (see Table 7.4). In addition, fish from both sites had concentrations of arsenic and selenium that exceeded the international standards. Although concentrations of all parameters varied, samples from the nearfield station (RF1) had values generally similar to those of the farfield station (RF2).

**SUMMARY AND CONCLUSIONS**

Demersal fish collected around the Point Loma Ocean Outfall in 2004 were characterized by contaminant loads within the range of those reported previously for other Southern California Bight (SCB) fish assemblages (see Mearns et al. 1991, Allen et al. 1998, 2002). In addition, concentrations of these contaminants were generally similar to those reported previously by the City of San Diego (City of San Diego 1996–2004).

The frequent occurrence of metals and chlorinated hydrocarbons in PLOO fish tissues may be due to many factors. Mearns et al. (1991) described the distribution of several contaminants, including arsenic, mercury, DDT, and PCBs as being ubiquitous in the SCB. In fact, many metals (e.g., aluminum and iron) occur naturally in the environment, although little information is available on their background levels in fish tissues. Brown et al. (1986) determined that no areas of the SCB are sufficiently free of chemical contaminants to be considered reference sites. This has been supported by more recent work regarding PCBs and DDTs (e.g., Allen et al. 1998).

Other factors that affect the accumulation and distribution of contaminants include the physiology and life history of different fish species. For example, exposure to contaminants can vary greatly between different species and also among individuals of the same species depending on migration habits (Otway 1991). Fish may be exposed to contaminants in one highly contaminated area and then move into an area that is less contaminated. This may explain why many of the pesticides and PCBs detected in fish tissues during 2004 were rarely detected or not detected at all in the sediments immediately surrounding the PLOO (see Chapter 4). In addition, differences in
feeding habits, age, reproductive status, and gender can affect the amount of contaminants a fish will retain (e.g., Connell 1987, Evans et al. 1993). These factors make comparisons of contaminants among species and between stations difficult.

Overall, there was no evidence that fishes collected in 2004 were contaminated by the discharge of waste water from the Point Loma Ocean Outfall. With one exception, concentrations of all mercury and DDT in muscle tissues from sport fish collected in the area were below FDA human consumption limits. Finally, there was no other indication of poor fish health in the region, such as the presence of fin rot or other physical anomalies (see Chapter 6).

LITERATURE CITED


Ocean Outfall, 2002. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.


City of San Diego. (in prep). EMTS Division Laboratory Quality Assurance Project Plan. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division. San Diego, CA.


