Chapter 7. Bioaccumulation of Contaminants in Fish Tissues

INTRODUCTION

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

The bioaccumulation portion of the SBOO monitoring program consists of two components: (1) liver tissues are analyzed for trawl-caught fishes; (2) muscle tissues are analyzed for fishes collected by rig fishing. Fishes collected from trawls are considered representative of the general demersal fish community, and certain species are targeted based on their ecological significance (i.e., prevalence in the community). Chemical analyses are performed using livers because it is typically the organ where contaminants concentrate. Fishes targeted for collection by rig fishing represent species from a typical sport fisher's catch, and are therefore of recreational and commercial importance. Muscle tissue is analyzed from these fish because it is the tissue most often consumed by humans, and therefore the results may have human health implications.

All muscle and liver samples were analyzed for contaminants as specified in the NPDES discharge permits governing the SBOO monitoring program. Most of these contaminants are also sampled for the National Oceanic and Atmospheric Administration (NOAA) National Status and Trends Program. NOAA initiated this program to detect changes in the environmental quality of the nation's estuarine and coastal waters by tracking contaminants thought to be of concern for the environment (Lauenstein and Cantillo 1993). This chapter presents the results of all tissue analyses that were performed during 2007.

MATERIALS AND METHODS

Field Collection

Fishes were collected during April and October of 2007 at seven trawl and two rig fishing stations (**Figure 7.1**). Trawl-caught fishes were collected, measured, and weighed following City of San Diego guidelines (see Chapter 6 for a description of

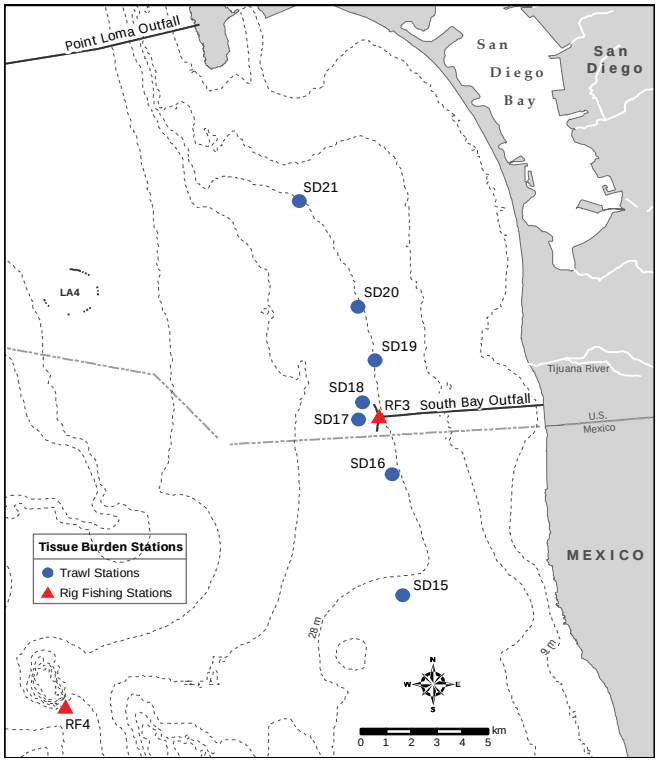

Figure 7.1
Otter trawl and rig fishing station locations for the South Bay Ocean Outfall Monitoring Program.

Table 7.1
Species of fish collected at each SBOO trawl and rig fishing station during April and October 2007.

Station	Rep 1	Rep 2	Rep 3
April 2007			
SD15	Hornyhead turbot	Pacific sanddab	(no sample)
SD16	Longfin sanddab	Hornyhead turbot	Hornyhead turbot
SD17	Longfin sanddab	Hornyhead turbot	English sole
SD18	English sole	Longfin sanddab	Pacific sanddab
SD19	Longfin sanddab	English sole	English sole
SD20	Hornyhead turbot	English sole	Longfin sanddab
SD21	English sole	English sole	Hornyhead turbot
RF3	Brown rockfish	Vermilion rockfish	Mixed rockfish
RF4	California scorpionfish	(no sample)	(no sample)
SD15	Hornyhead turbot	(no sample)	(no sample)
SD16	Longfin sanddab	Longfin sanddab	Longfin sanddab
SD17	Longfin sanddab	Longfin sanddab	Hornyhead turbot
SD18	Longfin sanddab	Longfin sanddab	Hornyhead turbot
SD19	Longfin sanddab	Hornyhead turbot	Longfin sanddab
SD20	Longfin sanddab	California scorpionfish	California scorpionfish
SD21	Longfin sanddab	Hornyhead turbot	Hornyhead turbot
RF3	Brown rockfish	Vermilion rockfish	Mixed rockfish*
RF4	California scorpionfish	California scorpionfish	California scorpionfish

* No PAHs were analyzed from this sample

collection methods). Fishes targeted at rig fishing sites were collected using rod and reel fishing tackle, and then measured and weighed. Species analyzed from each station are summarized in **Table 7.1**. The effort to collect targeted fishes was limited to five 10-minute trawls (bottom time) at each trawl station. Occasionally, insufficient numbers of target species were obtained despite this effort, thus resulting in reduced number of replicates at a station. Only fish ≥13 cm standard lengths were retained for tissue analyses. These fish were sorted into no more than three composite samples per station, each containing a minimum of three individuals. Composite samples are typically made up of a single species; the only exceptions are samples that consist of mixed species of rockfish. Fishes were then wrapped in aluminum foil, labeled, sealed in Ziplock® bags, placed on dry ice, transported to the City's Marine Biology Laboratory, and held in the freezer at -80˚C until dissection and tissue processing.

Tissue Processing and Chemical Analyses

All dissections were performed according to the following standard techniques for tissue analysis. 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 E.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 Services Laboratory within 10 days of dissection.

Tissue samples were analyzed for the chemical constituents specified by the NPDES permits under which this sampling was performed. Chemical

constituents analyzed included trace metals, chlorinated pesticides, polychlorinated biphynel compounds (PCBs), and polycyclic aromatic hydrocarbons (PAHs) (see **Appendix E.2**). Metals were measured as mg/kg or parts per million (ppm), while pesticides, PCBs, and PAHs were measured as µg/kg or parts per billion (ppb). Totals for DDT, PCB, BHC (=Lindane and derivatives) and chlordane were calculated as the sum of detected constituents (i.e., total PCB = sum of detected congeners). Values for each individual constituent are listed in **Appendix E.3**. This report includes estimated values for some parameters determined to be present in a sample with high confidence (i.e., peaks confirmed by mass-spectrometry), but at levels below the method detection limit (MDL). A detailed description of the analytical protocols may be obtained from the City of San Diego Wastewater Chemistry Services Laboratory (City of San Diego 2008).

Results

Contaminants in Trawl-Caught Fishes

Metals

Twelve metals, including antimony, arsenic, barium, cadmium, chromium, copper, iron, manganese, mercury, selenium, tin, and zinc occurred in ≥85% of the liver samples analyzed from trawl-caught fishes in 2007 (**Table 7.2**). Aluminum, beryllium, lead, nickel, silver, and thallium were also detected, but less frequently (i.e., detection rates of 18-69%). Concentrations of most metals were <10 ppm. Exceptions occurred for aluminum, arsenic, copper, iron, and zinc, which all had concentrations >15 ppm in at least one sample. Of all the metals detected, iron was present in the highest concentrations in all five species of fish analyzed.

Intra-species comparisons of frequently detected metals in liver tissues of fish from the two stations located nearest the SBOO (SD17, SD18) and those from stations located farther away to the south (SD15, SD16) or north (SD19–SD21) suggest that there was no clear relationship between contaminant loads and proximity to the outfall (**Figure 7.2**). Contaminant concentrations were fairly similar across all stations and most were close to or below the maximum levels detected in the same species prior to discharge. Arsenic occurred at concentrations above the pre-discharge maximums in several of the tissue samples. However, these relatively high concentration of arsenic occurred in multiple species throughout the region and also showed no pattern relative to the outfall.

Pesticides

Several chlorinated pesticides were detected during the 2007 trawl surveys (**Table 7.3**). Individual components of total chlordane and total DDT are listed in Appendix E.2, while detected values of all pesticides are included in Appendix E.3. DDT was detected in all samples with total DDT concentrations ranging from about 57 to 1059 ppb. Other pesticides that were detected included hexachlorobenzene (HCB) and chlordane, which occurred at maximum concentrations of 2.9 and 15.8 ppb, respectively. As with metals, there was no clear relationship between concentrations of these pesticides and proximity to the outfall (**Figure 7.3**). In addition, most pesticide concentrations were close to or below the maximum levels detected in the same species prior to wastewater discharge.

PAHs and PCBs

PAHs were not detected in fish liver samples during 2007. In contrast, PCBs occurred in every tissue sample. All detected PCB congeners are summarized in Appendix E.3. Total PCB concentrations were highly variable, ranging from about 21 to 545 ppb (Table 7.3). There was no clear relationship between PCB concentrations in fish livers and proximity to the outfall (Figure 7.3).

Contaminants in Fishes Collected by Rig Fishing

Arsenic, barium, chromium, copper, iron, manganese, mercury, selenium, tin, and zinc occurred in ≥75% of the muscle tissue samples collected from various rockfish at the two rig fishing stations in 2007 (**Table 7.4**). Aluminum, antimony,

Table 7.2

Metals detected in liver tissues from fishes collected at SBOO trawl stations during 2007. Values are expressed as parts per million (ppm); n=number of detected values, nd=not detected. See Appendix E.1 for names and periodic table symbols.

	Al	Sb	As	Ba	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
California scorpionfish																		
n (out of 2)	2	2	nd	2	nd	2	2	2	2	nd	2	2	2	2	2	2	2	2
Min	11.90	1.57	—	0.473	—	1.53	0.57	17.5	82.9	—	0.70	0.120	0.577	0.65	0.14	2.020	2.24	90.9
Max	19.60	1.68	—	0.584	—	3.29	0.62	17.7	127.0	—	0.80	0.140	0.769	0.72	0.15	2.260	2.31	103.0
Mean	15.75	1.62	—	0.528	—	2.41	0.60	17.6	104.9	—	0.75	0.130	0.673	0.68	0.14	2.140	2.27	96.9
English sole																		
n (out of 7)	4	5	7	7	5	7	7	7	7	4	7	7	nd	7	1	nd	7	7
Min	0.69	0.48	5.41	0.066	0.004	0.98	0.25	2.3	85.2	0.40	1.00	0.070	—	1.24	0.06	—	1.15	21.2
Max	12.50	1.31	45.40	0.103	0.015	1.88	0.46	11.3	256.0	1.45	2.34	0.147	—	1.72	0.06	—	1.38	47.0
Mean	6.53	0.83	18.96	0.081	0.010	1.27	0.35	6.4	198.9	0.84	1.73	0.099	—	1.53	0.06	—	1.25	35.4
Hornyhead turbot																		
n (out of 12)	8	11	12	12	5	12	12	12	12	nd	12	11	6	12	9	5	12	12
Min	0.85	0.55	2.48	0.056	0.003	2.77	0.28	4.8	29.7	—	0.91	0.084	0.260	0.58	0.07	0.853	1.13	35.1
Max	15.10	1.77	13.50	0.291	0.018	8.49	1.32	13.2	146.0	—	1.84	0.246	0.587	1.31	0.66	1.790	2.11	81.3
Mean	7.26	1.26	6.42	0.126	0.011	4.53	0.58	6.0	70.9	—	1.35	0.153	0.476	0.88	0.18	1.243	1.64	50.0
Longfin sanddab																		
n (out of 16)	12	16	16	16	5	16	16	16	16	3	16	11	12	16	2	10	16	16
Min	1.33	0.70	3.36	0.098	0.008	0.86	0.21	3.4	46.6	0.15	0.90	0.019	0.366	0.66	0.04	0.600	1.48	24.9
Max	28.40	2.38	22.10	0.518	0.025	3.59	0.95	9.8	323.0	0.60	3.14	0.095	4.500	1.56	0.07	2.740	2.89	68.0
Mean	16.19	1.65	7.13	0.272	0.014	1.92	0.60	5.3	104.7	0.42	1.31	0.050	1.031	0.98	0.05	1.721	2.30	31.9
Pacific sanddab																		
n (out of 2)	1	1	2	2	2	2	2	2	2	nd	2	2	nd	2	nd	nd	2	2
Min	10.50	0.60	3.06	0.072	0.014	3.42	0.29	3.6	138.0	—	1.21	0.086	—	0.89	—	—	1.69	30.1
Max	10.50	0.60	10.50	0.089	0.016	3.61	0.54	3.8	148.0	—	1.65	0.119	—	1.24	—	—	1.73	34.7
Mean	10.50	0.60	6.78	0.080	0.015	3.51	0.42	3.7	143.0	—	1.43	0.103	—	1.06	—	—	1.71	32.4
All species:																		
Detection rate (%)	69	90	95	100	44	100	100	100	100	18	100	85	51	100	36	44	100	100
Max value	28.40	2.38	45.40	0.584	0.025	8.49	1.32	17.7	323.0	1.45	3.14	0.246	4.500	1.72	0.66	2.740	2.89	103.0

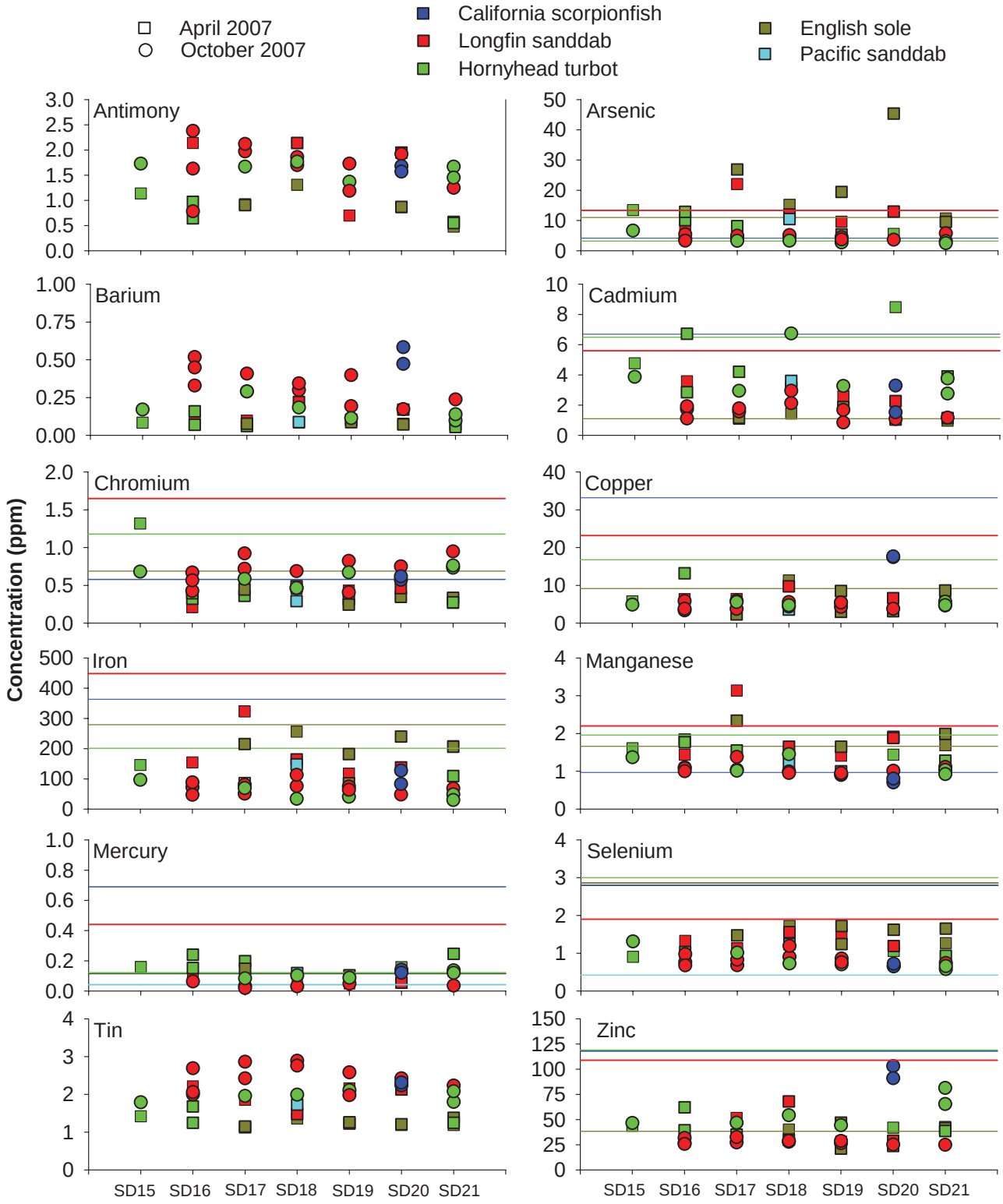

Figure 7.2

Concentrations of frequently detected metals in liver tissues of fishes collected from each SBOO trawl station during 2007. Reference lines are maximum values detected during the pre-discharge period (1995–1998); antimony, barium, and tin were not detected during the pre-discharge period because of substantially higher detection limits. Therefore, no reference lines are present for these contaminants.

Table 7.3

Concentrations of chlorinated pesticides, total PCB, and lipids detected in liver tissues from fishes collected at SBOO trawl stations during 2007. HCB=hexachlorobenzene; tChl=total chlordane; tDDT=total DDT; tPCB=total PCB. 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, nd=not detected.

	Pesticides				
	HCB	tChl	tDDT	tPCB	Lipids
Ca. scorpionfish					
n (out of 2)	2	2	2	2	2
Min	0.9	6.7	444.1	196.2	16.1
Max	1.0	11.7	487.7	273.0	18.7
Mean	0.9	9.2	465.9	234.6	17.4
English sole					
n (out of 7)	3	nd	7	7	7
Min	0.7	—	63.4	54.2	4.3
Max	1.2	—	631.3	187.8	7.9
Mean	0.9	—	224.3	96.0	5.7
Hornyhead turbot					
n (out of 12)	6	nd	12	12	12
Min	0.4	—	57.1	21.2	4.0
Max	0.8	—	146.0	82.2	10.9
Mean	0.6	—	97.9	43.1	6.7
Longfin sanddab					
n (out of 16)	16	15	16	16	16
Min	1.6	2.8	340.4	148.8	13.6
Max	2.9	15.8	1059.0	545.4	48.8
Mean	2.2	8.6	610.3	324.8	33.6
Pacific sanddab					
n (out of 2)	2	2	2	2	2
Min	1.6	4.4	326.2	148.1	12.4
Max	2.4	12.4	552.5	209.3	21.2
Mean	2.0	8.4	439.4	178.7	16.8
All species:					
Detection rate (%)	74	49	100	100	100
Max value	2.9	15.8	1059.0	545.4	48.8

beryllium, nickel, silver, and thallium were also detected, but less frequently (i.e., detection rates of 10-70%). Metals that were present in the highest concentrations were aluminum (16.1 ppm), iron (15.1 ppm), zinc (6.6 ppm) and arsenic (3.8 ppm). DDT and PCBs were detected in 100% of the muscle samples, while the pesticides HCB, BHC (lindane) and chlordane were detected in 50% or less of the samples (**Table 7.5**). Each of these contaminants was detected in relatively low concentrations, which ranged from 0.1 ppb for HCB to 19.4 ppb for total DDT.

To address human health concerns, contaminant concentrations found in muscle tissues were compared to both national and international limits and standards (Table 7.4, Table 7.5). The United States Food and Drug Administration (FDA) has set limits on the amount of mercury, total DDT, and chlordane in seafood that is to be sold for human consumption, while there are also international standards for acceptable concentrations of various metals (see Mearns et al. 1991). Of the contaminants detected in muscle tissues of fish collected as part of the SBOO monitoring program, only arsenic and selenium occurred in concentrations equal to or slightly higher than median international standards.

In addition to addressing health concerns, spatial patterns were analyzed for total DDT and total PCB, as well as for all metals that occurred frequently in muscle tissues (**Figure 7.4**). Overall, concentrations of DDT, PCB and various metals in the muscle tissue of fishes captured at both rig fishing stations were fairly similar, which suggests that there is no relationship with proximity to the outfall. Comparisons of contaminant loads in fishes from stations RF3 and RF4 should be considered with caution since different species of fish were collected at the two sites, and the bioaccumulation of contaminants may differ between species due to differences in physiology and diet. However, this potential problem may be minimal here as all fish specimens belong to the same family (Scorpaenidae), have similar life histories (i.e., bottom dwelling tertiary carnivores), and therefore likely have similar mechanisms of exposure to and uptake of contaminants (e.g., direct contact with sediments, similar food sources).

Summary and Conclusions

Twelve trace metals, DDT, and a combination of PCB congeners were each detected in ≥75% of the

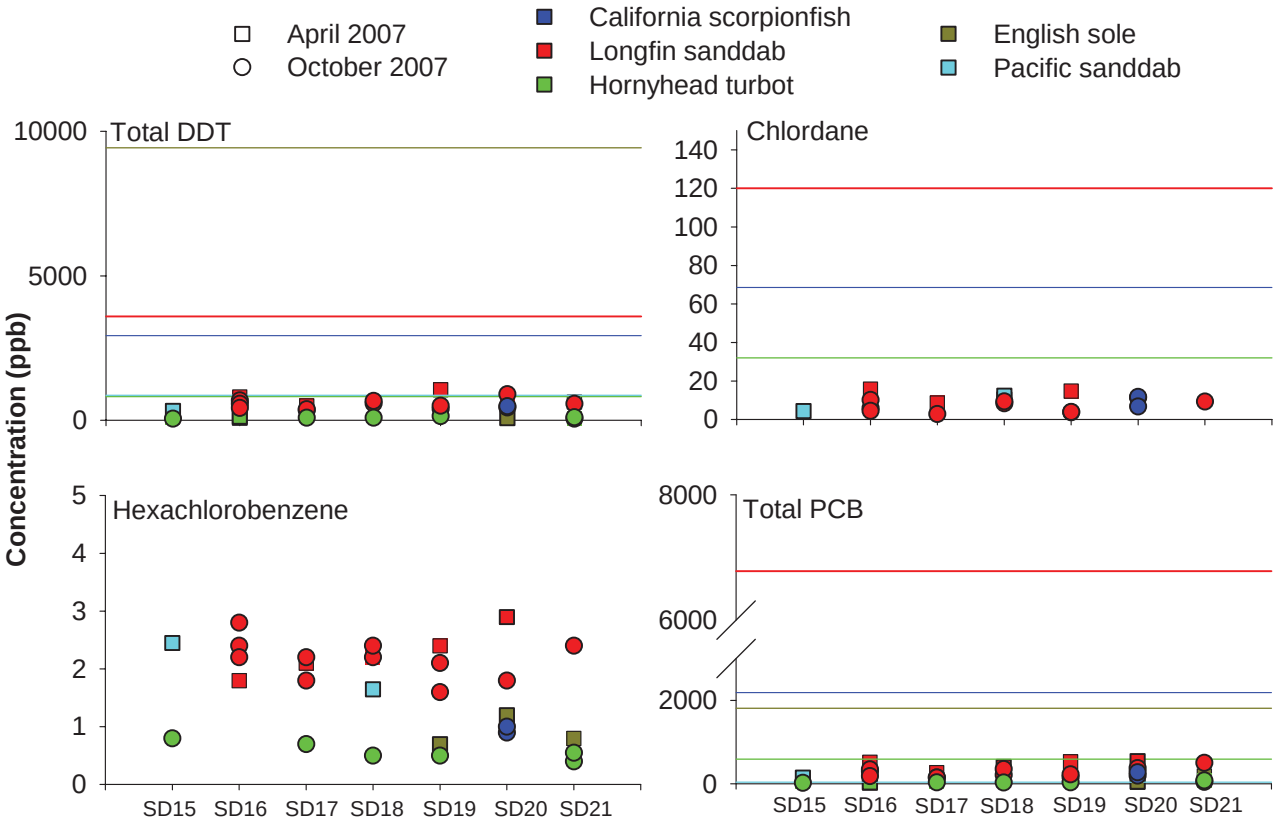

Figure 7.3

Concentrations of frequently detected chlorinated pesticides (total DDT, chlordane, hexachlorobenzene) and total PCBs in liver tissues of fishes collected from each SBOO trawl station during 2007. Reference lines are maximum values detected during the pre-discharge period (1995–1998); chlordane and hexachlorobenzene were not detected as frequently during the pre-discharge period because of substantially higher detection limits. Therefore, reference lines for these two contaminants are absent for some or all of the species.

liver tissue samples collected from five species of fish around the SBOO in 2007. All contaminant values were within the range of those reported previously for the Southern California Bight (SCB) (see Mearns et al. 1991, City of San Diego 1996–2001, Allen et al. 1998). Although several individual tissue samples contained concentrations of some metals that exceeded pre-discharge maximums, concentrations of most contaminants were not substantially different from pre-discharge levels (see City of San Diego 2000b). In addition, the few tissue samples that did exceed pre-discharge values were widely distributed among the sampled stations and showed no patterns that could be attributed to wastewater discharge via the SBOO.

The frequent occurrence of metals and chlorinated hydrocarbons in SBOO fish tissues may be due to multiple 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 occur naturally in the environment (see Chapters 4 and 8), although little information is available on 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, 2002). The lack of contaminant-free reference areas in the SCB clearly pertains to the South Bay region, as demonstrated by the presence of many contaminants in fish tissues prior to wastewater discharge (see City of San Diego 2000b).

Other factors that affect the accumulation and distribution of contaminants include the physiology and life history of different fish species. Exposure

Table 7.4

Metals detected in muscle tissues from fishes collected at SBOO rig fishing stations during 2007. Values are expressed as parts per million (ppm); n=number of detected values, nd=not detected. Data are compared to U.S. FDA action limits and median international standards for parameters where these exist. Bold values meet or exceed these standards. See Appendix E.1 for names and periodic table symbols.

	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
Brown rockfish																	
n (out of 2)	1	nd	2	2	1	1	2	1	2	2	2	1	2	nd	nd	2	2
Min	16.10	—	0.76	0.056	0.006	0.03	0.33	0.652	6.28	0.18	0.101	0.10	0.14	—	—	1.07	4.82
Max	16.10	—	**2.18**	0.128	0.006	0.03	0.38	0.652	7.48	0.21	0.125	0.10	0.15	—	—	1.76	6.16
Mean	16.10	—	**1.47**	0.092	0.006	0.03	0.36	0.652	6.88	0.19	0.113	0.10	0.15	—	—	1.41	5.49
California scorpionfish																	
n (out of 4)	4	nd	4	4	1	3	4	4	4	4	4	2	4	1	1	4	4
Min	8.17	—	**1.70**	0.077	0.007	0.04	0.26	0.150	5.09	0.13	0.147	0.12	0.22	0.06	0.91	1.13	4.41
Max	14.20	—	**3.79**	0.151	0.007	0.08	0.40	0.789	15.10	0.18	0.243	0.22	0.24	0.06	0.91	1.89	6.58
Mean	11.37	—	**2.62**	0.111	0.007	0.06	0.32	0.489	8.66	0.16	0.187	0.17	0.23	0.06	0.91	1.45	5.56
Mixed rockfish																	
n (out of 2)	1	1	2	2	1	1	2	1	2	2	2	nd	2	nd	nd	2	2
Min	8.73	0.55	1.20	0.050	0.010	0.06	0.18	0.529	1.93	0.11	0.060	—	0.16	—	—	0.83	3.50
Max	8.73	0.55	**1.68**	0.075	0.010	0.06	0.22	0.529	5.74	0.12	0.180	—	0.28	—	—	1.54	4.57
Mean	8.73	0.55	**1.44**	0.062	0.010	0.06	0.20	0.529	3.83	0.11	0.120	—	0.22	—	—	1.18	4.03
Vermilion rockfish																	
n (out of 2)	1	2	1	2	1	1	2	2	2	2	2	1	2	nd	1	2	2
Min	12.60	1.57	**1.69**	0.061	0.007	0.20	0.27	0.120	6.35	0.13	0.036	0.23	0.16	—	1.70	0.99	4.42
Max	12.60	1.75	**1.69**	0.202	0.007	0.20	0.46	0.355	7.85	0.21	0.060	0.23	**0.30**	—	1.70	2.43	5.55
Mean	12.60	1.66	**1.69**	0.131	0.007	0.20	0.37	0.237	7.10	0.17	0.048	0.23	0.23	—	1.70	1.71	4.98
All species:																	
Detection rate (%)	70	30	90	100	40	60	100	80	100	100	100	40	100	10	20	100	100
Max	16.10	1.75	3.79	0.202	0.010	0.20	0.46	0.789	15.10	0.21	0.243	0.23	0.30	0.06	1.70	2.43	6.58
US FDA action limit*											1.0						
Median IS*			1.4			1.0	1.0	20			0.5		0.3			175	70

* From Mearns et al. 1991. FDA mercury action limits and all international standards (IS) are for shellfish, but are often applied to fish. All limits apply to the sale of seafood for human consumption.

Table 7.5

Chlorinated pesticides, total PCB, and lipids detected in muscle tissues from fishes collected at SBOO rig fishing stations during 2007. tBHC=total BHC (lindane); tChlor= total chlordane; HCB=hexachlorobenzene; tDDT=total DDT; tPCB=total PCB. 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, nd=not detected. Data are compared to U.S. FDA action limits and median international standards for parameters where these exist.

	Pesticides					
	tBHC	tChlor	HCB	tDDT	tPCB	Lipids
Brown rockfish						
n (out of 2)	2	nd	nd	2	2	2
Min	0.5	—	—	1.2	0.2	0.3
Max	1.4	—	—	3.0	2.1	0.5
Mean	0.9	—	—	2.1	1.1	0.4
Ca. scorpionfish						
n (out of 4)	nd	1	3	4	4	4
Min	—	1.0	0.1	2.2	0.3	0.5
Max	—	1.0	0.2	19.4	6.5	2.3
Mean	—	1.0	0.1	8.2	3.1	1.3
Mixed rockfish						
n (out of 2)	2	nd	1	2	2	2
Min	0.9	—	0.1	1.2	0.2	0.3
Max	1.1	—	0.1	2.0	0.9	0.5
Mean	1.0	—	0.1	1.6	0.5	0.4
Vermilion rockfish						
n (out of 2)	1	nd	1	2	2	2
Min	1.4	—	0.4	1.6	0.7	0.3
Max	1.4	—	0.4	3.7	1.1	1.6
Mean	1.4	—	0.4	2.6	0.9	0.9
All species:						
Detection (%)	50	10	50	100	100	100
Max	1.4	1.0	0.4	19.4	6.5	2.3
FDA action limits*		300		5000		
Median IS*		100		5000		

* From Mearns et al. 1991. FDA action limits for total DDT and chlordane are for fish muscle tissue and all international standards (IS) are for shellfish, but are often applied to fish. All limits apply to the sale of seafood for human consumption.

to contaminants can vary greatly between different species and among individuals of the same species depending on migration habits (Otway 1991). Fishes may be exposed to contaminants in an area that is highly contaminated and then move into an area that is not. For example, California scorpionfish are known to migrate long distances (Hartmann 1987, Love et al. 1987). This is of particular concern for fishes collected in the vicinity of the SBOO, as there are many point and non-point sources that may contribute to contamination in the region (see Chapters 2–4); some monitoring stations are located near the Tijuana River, San Diego Bay, and dredged materials disposal sites, and input from these sources may affect fish in surrounding areas.

Overall, there was no evidence that fishes collected in 2007 were contaminated by the discharge of wastewater from the SBOO. While some muscle tissue samples from sport fish collected in the area had concentrations of arsenic and selenium above the median international standard for shellfish, concentrations of mercury and DDT 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, other indicators of disease, or any physical anomalies (see Chapter 6).

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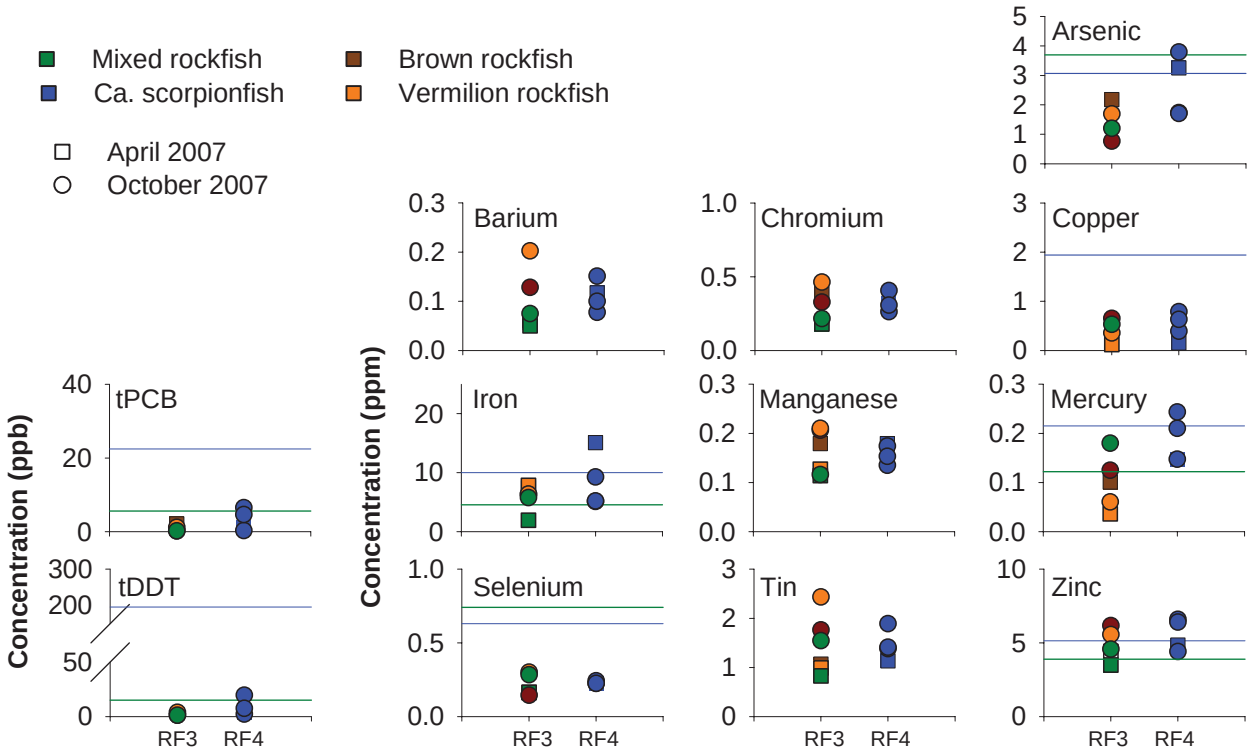

Figure 7.4

Concentrations of frequently detected metals, total DDT, and total PCB in muscle tissues of fishes collected from each SBOO rig fishing station during 2007. Reference lines are maximum values detected during the pre-discharge period (1995–1998) for California scorpionfish and mixed rockfish. Vermilion and brown rockfish were not collected during that period.

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