

CHAPTER 7

TISSUE CHEMISTRY

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INTRODUCTION

Measurement of chemical contaminants in the tissues of selected fish and invertebrates is required under the receiving water monitoring program of Hyperion Treatment Plant's NPDES Permit (see Chapter 1 Introduction). Under the guidelines of the permit, fish and the invertebrates were collected from Santa Monica Bay (SMB) by otter trawl and rig fishing. Trawled organisms are closely associated with the sea bottom throughout much of their lives. Thus, they are more likely to bioaccumulate pollutants from contaminated sediments (Thibodeaux and Bierman 2003) and their prey than are organisms living in the water column. The analyses of pollutants in rig-caught fish are important, as fishermen seek these species. Therefore, assessment of contaminant levels in edible tissue from these organisms is of considerable interest to the public.

Since 1987, as mandated by Hyperion's NPDES Permit, the City of Los Angeles has been monitoring selected priority pollutants in the tissues of fish and invertebrates from Santa Monica Bay (SMB). Since then, the tissue chemistry program for trawled fish has assessed the same target species (hornyhead turbot). For the rig-fish survey, several different species of sport fish were collected and their tissues analyzed during the period.

In addition to the City of Los Angeles's SMB monitoring program, there are other marine monitoring programs conducted in the Southern

California Bight (SCB). These programs include surveys of sediment chemistry, benthic macro fauna, water quality, fish, and bioaccumulation of contaminants in the tissues of marine organisms (NRC 1990a, 1990b). In 2003, the City of Los Angeles participated in the third comprehensive regional monitoring project in the Southern California Bight (Bight'03). The city will also participate in the planned Bight'08 project.

In April 2005, the Hyperion Treatment Plant received a new NPDES permit with a modified SMB monitoring program. The number of chemicals monitored in tissue under this permit was reduced to include only As, Se, Hg, DDT and its derivatives, and PCB and its derivatives since these chemicals are considered to be a health-risk to humans and they were consistently found in the previous tissue monitoring. This new monitoring program divides the old monitoring stations into three monitoring zones to ease sample collection and better represent the spatial trend of chemical bioaccumulation in fish tissue from SMB. The three zones are Zone 5 (north SMB), Zone 4 (south SMB), and the Nearfield Zone. Zone 5 is inshore of the 150-meter depth contour and extends from Point Dume Canyon to the south entrance of Marina del Rey. This zone includes stations C1, C3, and A1 of the previous permit. Zone 4, located inshore of the 150-meter depth contour, extends from the south entrance of Marina del Rey to the south end of the Redondo

Beach Pier. This zone includes stations A3 and C9a of the old permit. The Nearfield Zone is a 2-km radius around the 5-mile outfall and includes stations C6, D1, Z2, and Z3 of the old permit.

In this chapter, the results of selected priority pollutant analyses performed on tissues from selected fish captured by trawling and rig fishing from February 2005 to September 2006 are reported. Tissue data from prior years (2001 to 2004), including those of tissues collected through April 2005 were organized according to the zones delineated above and averaged for easier comparison to the tissue data collected from May 2005 to September 2006. The tissue contaminant results are assessed to determine their temporal (from either 2001 or 2002 to 2005 or 2006) and spatial distribution in the study area of SMB; they also are compared with US EPA/OEHHA (The State of California, Office of Environmental Health Hazard Assessment) screening values to identify contaminants that are of potential concern. The correlations of metal levels in trawl fish tissues and in sediment are briefly discussed.

MATERIALS AND METHODS

FIELD SAMPLING

Trawling was conducted using a 25-foot head rope length otter trawl. For a detailed description of this procedure see Chapter 6 (Trawl-Caught Fish and Invertebrates).

Trawled Fish and Invertebrates

The hornyhead turbot, *Pleuronichthys verticalis*, is targeted for priority pollutant analyses because it feeds on bottom-dwelling macrofauna and is generally found in high abundance along the 60-m depth contour in Santa Monica Bay. Also, because hornyhead turbot is in a reproductive state throughout the year (Goldberg 1982), there

may be less fluctuation in levels of lipids in which contaminants tend to accumulate.

Hyperion's 2005 NPDES Permit requires thirty hornyhead turbot to be collected annually from three trawl zones (Zone 5, Zone 4, and the Nearfield Zone; Figure 7-1). Ten muscle and liver tissue samples, from hornyhead turbot from each zone were composited into a single muscle and a single liver tissue representative sample. To obtain sufficient sample and to collect fish of a consistent age, individuals measuring between 15 and 23 cm are analyzed. During some sampling periods, sufficient numbers of size-class fish (15-23cm) were not collected. In this case, extra 20-minute trawls were conducted as good-faith efforts. If these good faith efforts failed to capture the required number of hornyhead turbot at each station, no further attempts were made. The 2005-06 tissue sample trawling effort is summarized in Table 7-1a. During 2005, both the winter and summer samples were collected. The winter samples were collected following the guidelines of the previous Hyperion NPDES permit; the summer samples were collected based on the zone concept of the new NPDES permit. During 2006, only one set of samples were collected as required by the newly adopted permit.

Rig-fishing

Sportfish were collected from (1) the Nearfield Zone, (2) Zone 5, and (3) Zone 4 in SMB using rod and reel fishing tackle. The choice of species for dissection was based on the abundance of species caught and their importance to the Santa Monica Bay sport fishery (Table 7-1b). Upon capture, each target fish was identified, examined for abnormalities, measured, and weighed. Selected species were dissected fresh onboard the monitoring vessel with procedures similar to those used by sport fishermen. The muscle tissue of each individual from the March 2005 samples was analyzed separately. Three replicates were required for each species collected at the 5-Mile Outfall based on the previous NPDES permit. For the August 2005 samples, muscle sample from ten individual fish for each species were

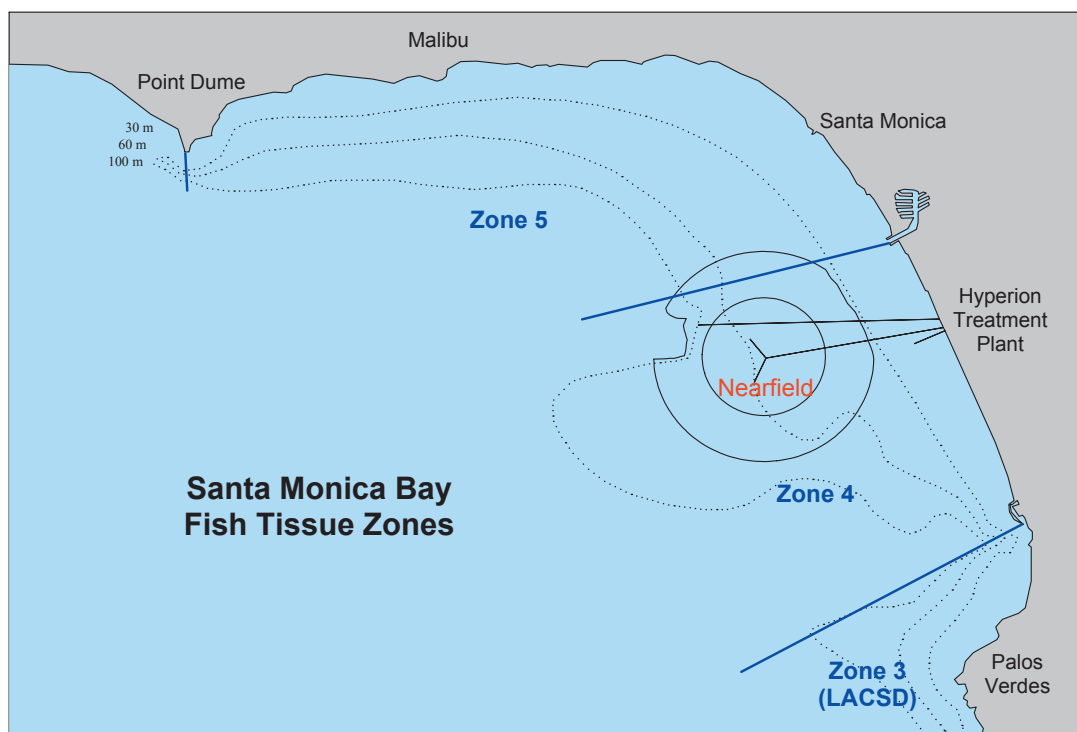


Figure 7-1. Fish tissue bioaccumulation zones for both Local Seafood Safety and Local Bioaccumulation Trends Surveys in Santa Monica Bay, 2005-2006.

composited to form a single muscle representative sample for the analyses.

LABORATORY ANALYSES

Specific details regarding priority pollutant tissue analyses are provided in Appendix C. For most heavy metal (except for mercury) analyses, tissues were acid digested in accordance with EPA Method 3050B (SW-846, 1986), then analyzed using an inductively coupled plasma (ICP) spectrophotometer by EPA Method 6010B (SW-846, 1986). Mercury in tissue was analyzed after the initial acid digestion by an automated cold vapor generated atomic absorption spectrophotometer by EPA Method 7471A (SW-846, 1986).

Hexane was used to extract organics from tissues and the extracts were concentrated prior to analysis (Appendix C). Prior to the adoption of the new NPDES permit in April of 2005, DDT and its derivatives, and polychlorinated biphenyls (PCB)

were analyzed using a Gas Chromatograph with electron capture detectors [GC-ECD] by EPA Methods 8081 and 8082, respectively (SW-846, 1986). After the adoption of the new permit, screening of forty-five PCB congeners were used for quantification for individual PCB congeners; these values are all estimates.

Cyanide was analyzed by EPA Method 9013 (EPA SW-846, 1986), and lipid content was gravimetrically measured with chloroform/methanol (2:1) extracts of tissue samples.

For samples analyzed in duplicate, the average of the duplicate results is reported. When the analytical result for a constituent was less than the method detection limit, zero was used in calculating the average.

Table 7-1a. Trawling effort for hornyhead turbot tissue analysis during 2005 and 2006.

	Station	2005		2006
		March	August	August
Trawl Fish (HHTB)	Zone 4: South SMB		1	1
	South SMB: C9a	2		
	Zone 5: North SMB		1	1
	North SMB: C1, C3	1		
	Nearfield		*	1
	C6, Z2	5		

*- No sample was collected during this period

RESULTS

HORNYHEAD TURBOT

The tissue samples collected were analyzed for three priority pollutant metals (arsenic, selenium, and mercury), DDT, PCB, and lipids. Cyanide was analyzed in only the March 2005 samples; it is not required by the new permit.

Cyanide was not detected in either the hornyhead turbot muscle or liver samples collected in March 2005.

As expected, As, Hg, and Se were detected in all muscle and liver samples collected in both the 2005 and 2006 (Tables 7-2a and 2-2b).

Of the six DDT and forty-five PCB derivatives analyzed from hornyhead turbot tissues during the 2005 and 2006 surveys, two DDT derivatives and

28 PCB congeners were detected in either muscle or liver in 2005 (Table 7-2a), and three DDT derivatives and 30 PCB congeners were detected in 2006 (Tables 7-2b).

The results of metal and organic pollutant results in hornyhead turbot muscle and liver tissues are discussed below.

Muscle Tissue

Metals

All three metals, arsenic (As), mercury (Hg), and selenium (Se) were detected in 100% of the hornyhead turbot muscle tissues sampled during the 2005 and 2006 surveys (Table 7-2a and 7-2b). The average concentrations of As and Se in muscle tissue samples decreased from 4.15 (mg/kg) in 2005 to 3.44 mg/kg in 2006 and from 1.55 mg/kg in 2005

Table 7-1b. Location and species of sportfish collected for tissue analyses during 2005 and 2006.

Species	Mar. 05	Aug. - Oct. 05	Aug. 06 (Not required for the 2nd year of new permit)
California scorpionfish	-----	Zone 4 (1), Zone 5 (1)	-----
Cabazon	Nearfield, 5M (3)	-----	-----
Vermilion rockfish	Nearfield, 5M (3)	Zone 4 (1)	-----
White croaker	Nearfield, 5M (3)	Zone 4 (1), Zone 5 (1)	-----
Blacksmith	-----	Zone 4 (1), Zone 5 (1)	-----
Barred sandbass	-----	Zone 4 (1), Zone 5 (1)	-----
Kelp bass	-----	Zone 5 (1)	-----
Black croaker	-----	Zone 5 (1)	-----
5M: 5-Mile			
-----: No Samples			
(): Number of composited samples			

to 0.96 mg/kg in 2006, respectively. However the average concentration of Hg increased slightly from 0.054 mg/kg in 2005 to 0.079 mg/kg in 2006.

The spatial and temporal trend analyses of As, Se, and Hg are shown in Figures 7-2 to 7-4. When no sample was collected or the result was under the detection limit or not available (for Se from 2002 to March 2005), the space is left blank in the figure. Except for sporadic fluctuation of the concentration of As and Hg in hornyhead turbot muscle collected at different zones and seasons, no clear spatial distribution pattern of either As or Hg was observed for the data collected from 2002 to 2006. For example, the maximum and the

minimum concentrations of As and Hg remain at approximately the same level for the three zones during 2002 to 2006. There was also no temporal trend observed for either As or Hg. Too few data points (two and three) are available for Se to really established either temporal or spatial trends.

Among the three metals, As had the highest concentrations, followed by Se, and Hg which had the lowest concentration throughout the years. The highest concentration of As, 7.76 mg/kg, was found in the muscle tissue of hornyhead turbot from the Zone 4 sample collected in February 2003. For Hg, the highest concentration, 0.12 mg/kg, was found in the August 2002 Zone 5 sample and the August 2005 Zone 4 sample. Since the analysis of

Table 7-2a. Metals, DDT, PCB, and their derivatives found in muscle and liver tissue of hornyhead turbot in Santa Monica Bay during 2005. Bolded numbers indicate DDT, PCB, and mercury levels that exceed the 0.560, 0.020, and 0.080 mg/kg OEHHA Screening Values (SV).

Constituents Detected	Muscle (n=10)			Liver (n=10)		
	Frequency %	Average (mg/kg)	Range (mg/kg)	Frequency %	Average (mg/kg)	Range (mg/kg)
Metals						
As	100	4.15	2.67 - 6.4	100	7.41	4.86 - 11.4
Se	100	1.55	1.5 - 1.6	100	7.20	6.8 - 7.6
Hg	100	0.054	0.03 - 0.12	100	0.14	0.07 - 0.24
Pesticides and PCBs:						
O,P'-DDE	10	0.0081	ND - 0.0647	40	0.093	ND - 0.69
P,P'-DDE	100	0.110	0.0065 - 0.879	100	2.17	0.0314 - 11.5
Total DDT		0.118			2.26	
PCB28	0	ND	ND	50	0.002	ND - 0.0044
PCB44	0	ND	ND	50	0.003	ND - 0.0056
PCB49	0	ND	ND	50	0.008	ND - 0.0152
PCB52	0	ND	ND	50	0.008	ND - 0.0164
PCB66	0	ND	ND	100	0.024	0.0142 - 0.034
PCB70	0	ND	ND	100	0.005	0.0031 - 0.0061
PCB74	0	ND	ND	100	0.012	0.0074 - 0.0165
PCB77	0	ND	ND	50	0.003	ND - 0.0054
PCB87	0	ND	ND	100	0.013	0.00649 - 0.0192
PCB99	0	ND	ND	50	0.022	ND - 0.0432
PCB101	0	ND	ND	100	0.040	0.0267 - 0.0535
PCB105	0	ND	ND	100	0.026	0.0158 - 0.0354
PCB110	0	ND	ND	100	0.023	0.0192 - 0.0276
PCB118	100	0.0020	0.00163 - 0.00254	100	0.063	0.0363 - 0.0897
PCB128	0	ND	ND	100	0.008	0.00493 - 0.0118
PCB138	100	0.0044	0.00314 - 0.00599	100	0.128	0.0767 - 0.179
PCB149	0	ND	ND	100	0.030	0.022 - 0.0373
PCB151	0	ND	ND	100	0.012	0.0089 - 0.0146
PCB153/168	0	ND	ND	100	0.109	0.0662 - 0.152
PCB156	0	ND	ND	50	0.006	ND - 0.0128
PCB157	0	ND	ND	50	0.002	ND - 0.00319
n: Number of samples analyzed			All numerical value for PCBs are estimated			
ND : Below Detection Limit			Other PCB and DDT derivatives not listed above are all ND			

Table 7-2a (continued). Metals, DDT, PCB and their derivatives found in muscle and liver tissue of hornyhead turbot in Santa Monica Bay during 2005. Bolded numbers indicate DDT, PCB, and mercury levels that exceeded the 0.560, 0.020, and 0.080 mg/kg OEHHA SV.

Constituents Detected	Muscle (n=10)			Liver (n=10)		
	Frequency %	Average (mg/kg)	Range (mg/kg)	Frequency %	Average (mg/kg)	Range (mg/kg)
PCB167	0	ND	ND	100	0.005	0.0033 - 0.0068
PCB170	0	ND	ND	100	0.020	0.0134 - 0.0263
PCB177	0	ND	ND	100	0.011	0.0085 - 0.014
PCB183	0	ND	ND	100	0.015	0.0104 - 0.0203
PCB187	0	ND	ND	100	0.034	0.0262 - 0.0423
PCB194	0	ND	ND	100	0.014	0.00915 - 0.0192
PCB201	0	ND	ND	100	0.021	0.0141 - 0.0285
Total PCB		0.01			0.67	
Lipids (%)	100	1.38	0.8 - 1.8	100	12.1	6.94 - 16.5
n: Number of samples analyzed			All numerical value for PCBs are estimated			
ND : Below Detection Limit			Other PCB and DDT derivatives not listed above are all ND			

Se is only required by the latest permit, only two sets (2005 and 2006) of data are available and the highest concentration was 1.6 mg/kg was from the August 2005 Zone 4 sample. The concentrations of both As and Se were about one order of magnitude higher than Hg and the concentration level of each individual metal was similar across all three zones.

Organics

The most frequently detected organic pesticides and PCB congeners in the muscle samples of hornyhead turbot during the 2005 survey were p,p'-DDE, PCB118, and PCB138. They were detected in all samples. The second most frequently detected organic constituent was o,p'-DDE which was detected in ten percent of the samples, (Table 7-2a). In 2006, p,p'-DDE, PCB138, and PCB153/168 were detected in all samples followed by PCB101, which was detected in thirty-three percent of the samples (Table 7-2b).

The average concentration of p,p'-DDE decreased from 0.110 mg/kg in 2005 to 0.054 mg/kg in 2006. The decrease in the average concentration of DDT derivatives is in contrast to the increase of % lipid in muscle tissue from the 2005 to the 2006 surveys (Table 7-2a and 7-2b). The concentrations of the other PCB congeners found in the 2005 (PCB118 - 0.0020 mg/kg and PCB138 - 0.0044 mg/kg) and in the 2006 surveys (PCB101 - 0.001 mg/kg, PCB138 - 0.004 mg/kg, and PCB 153/168 - 0.004 mg/kg,) approached their MDLs and seem insignificant.

The spatial and temporal distributions of total DDT and total PCB in fish tissue from 2002 to 2006 are shown in Figures 7-5 and 7-6, respectively.

The average concentrations of the DDT derivatives in muscle tissue of hornyhead turbot generally increased from the north zone (Zone 5) to the Nearfield Zone and are highest in the south zone (Zone 4, with a few exceptions, such as August

Table 7-2b. Metals, DDT, PCB and their derivatives found in muscle and liver tissue of hornyhead turbot in Santa Monica Bay during 2006. Bolded numbers indicate DDT, PCB, and mercury levels that exceed the 0.560, 0.020, and 0.080 mg/kg EPA/OEHHA SV.

Constituents Detected	Muscle (n=3)			Liver (n=3)		
	Frequency %	Average (mg/kg)	Range (mg/kg)	Frequency %	Average (mg/kg)	Range (mg/kg)
Metals						
As	100	3.44	2.84 - 4.03	100	5.58	3.13 - 8.58
Se	100	0.96	0.73 - 1.36	100	4.74	4.16 - 5.41
Hg	100	0.079	0.034 - 0.107	100	0.199	0.103 - 0.268
Pesticides and PCBs:						
O,P'-DDE	0	ND	ND	67	0.24	ND - 0.366
P,P'-DDE	100	0.054	0.046 - 0.068	100	2.76	0.872 - 4.2
P,P'-DDT	0	ND	ND	33	0.001	ND - 0.003
Total DDT		0.054			3.00	
PCB 28	0	ND	ND	67	0.005	ND - 0.010
PCB 44	0	ND	ND	67	0.002	ND - 0.005
PCB 49	0	ND	ND	100	0.014	0.005 - 0.021
PCB 52	0	ND	ND	67	0.018	ND - 0.032
PCB 66	0	ND	ND	67	0.034	ND - 0.065
PCB 70	0	ND	ND	100	0.008	0.002 - 0.015
PCB 74	0	ND	ND	100	0.015	0.004 - 0.025
PCB 87	0	ND	ND	33	0.009	ND - 0.028
PCB 99	0	ND	ND	67	0.043	ND - 0.083
PCB 101	33	0.001	ND - 0.002	100	0.076	0.021 - 0.131
PCB 105	0	ND	ND	100	0.045	0.013 - 0.079
PCB 110	0	ND	ND	100	0.056	0.017 - 0.099
PCB 118	0	ND	ND	100	0.104	0.029 - 0.161
PCB 119	0	ND	ND	67	0.003	ND - 0.005
PCB 128	0	ND	ND	100	0.024	0.006 - 0.043
PCB 138	100	0.004	0.003 - 0.005	100	0.190	0.068 - 0.261
PCB 149	0	ND	ND	100	0.062	0.020 - 0.104
n: Number of samples analyzed			All numerical value for PCBs are estimated			
ND : Below Detection Limit			Other PCB and DDT derivatives not listed above are all ND			

Table 7-2b (continued). Metals, DDT, PCB and their derivatives found in muscle and liver tissue of hornyhead turbot in Santa Monica Bay during 2006. Bolded numbers indicate DDT, PCB, and mercury levels that exceeded the 0.560, 0.020, and 0.080 mg/kg EPA/OEHHA SV.

Constituents Detected	Frequency %	Muscle (n=3)		Frequency %	Liver (n=3)	
		Average (mg/kg)	Range (mg/kg)		Average (mg/kg)	Range (mg/kg)
Pesticides and PCBs						
PCB 151	0	ND	ND	100	0.026	0.010 - 0.040
PCB 153/168	100	0.004	0.004 - 0.004	100	0.180	0.059 - 0.250
PCB 156	0	ND	ND	100	0.015	0.004 - 0.024
PCB 157	0	ND	ND	33	0.003	ND - 0.009
PCB 158	0	ND	ND	67	0.018	ND - 0.034
PCB 167	0	ND	ND	67	0.005	ND - 0.013
PCB 170	0	ND	ND	67	0.02	ND - 0.045
PCB 177	0	ND	ND	100	0.018	0.008 - 0.027
PCB 183	0	ND	ND	100	0.028	0.012 - 0.037
PCB 187	0	ND	ND	100	0.080	0.030 - 0.106
PCB 194	0	ND	ND	100	0.027	0.012 - 0.036
PCB 201	0	ND	ND	67	0.025	ND - 0.056
PCB 206	0	ND	ND	100	0.024	0.010 - 0.039
Total PCB		0.009			1.15	
Lipids (%)	100	2.41	1.14 - 3.36	100	16.3	15.9 - 16.9
n: Number of samples analyzed		All numerical value for PCBs are estimated				
ND : Below Detection Limit		Other PCB and DDT derivatives not listed above are all ND				

2002 in Zone 5 and March 2005 in the Nearfield Zone samples). Except for sporadic elevated concentrations, there were no well-established temporal trends for total DDT in the three zones for muscle tissue data from 2002 to 2006. Also with few exceptions, the variation in total DDT levels for each zone from 2002 to 2006 is rather insignificant. Only the March 2005 Nearfield sample and the June 2004 Zone 4 sample indicated a spike of total DDT (0.25 mg/kg) that is significantly higher than the remaining data.

Total PCB (PCB and its derivatives) was detected

most frequently from fish caught at the Nearfield Zone. In Zones 4 and 5, PCB derivatives were detected only twice each in the eight tissue samples collected between 2002 and 2005. However, during the 2006 survey when the procedure for the determination of PCB was changed to quantify each PCB derivative (or congener) instead of a collective set of PCB derivatives (Aroclors), PCB congeners were detected in all the tissue samples from the three zones. The highest concentration of total PCB in hornyhead turbot muscle tissue (0.183 mg/kg) was found in the Nearfield Zone March 2005 sample. There were too few total PCB data points

Figure 7-2. Aresenic concentrations (mg/kg) in muscle tissues of hornyhead turbot from all three zones during 2002 through 2006 surveys. No samples were collected from Zone 5 in August 2002 and from the Nearfield Zone in August 2005.

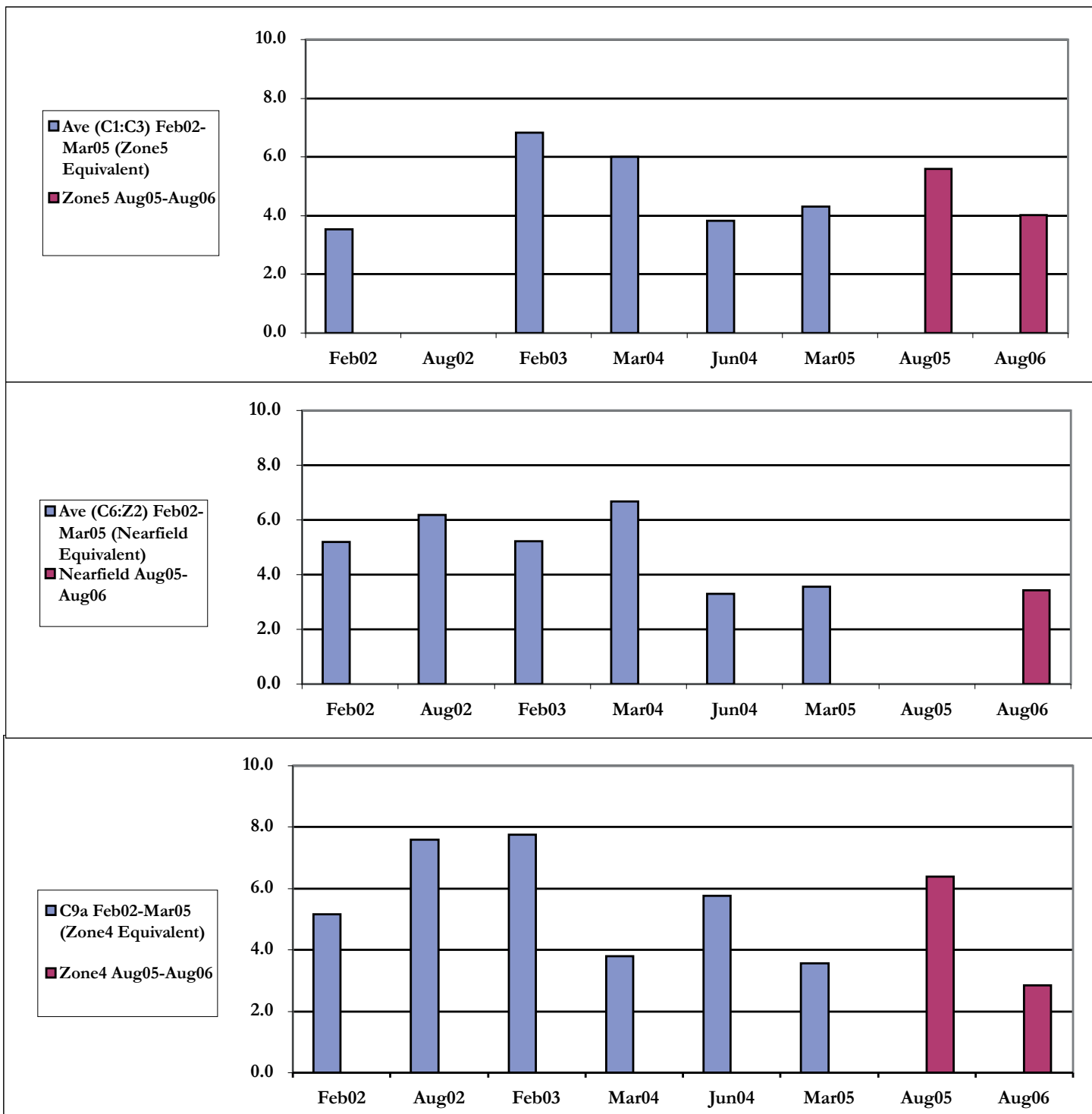


Figure 7-3. Selenium concentrations (mg/kg) in muscle tissues of hornyhead turbot from all three zones during 2005 and 2006 surveys. No sample was collected at the Nearfield Zone in August 2005. No selenium data available for all three zones from February 2002 to March 2005.

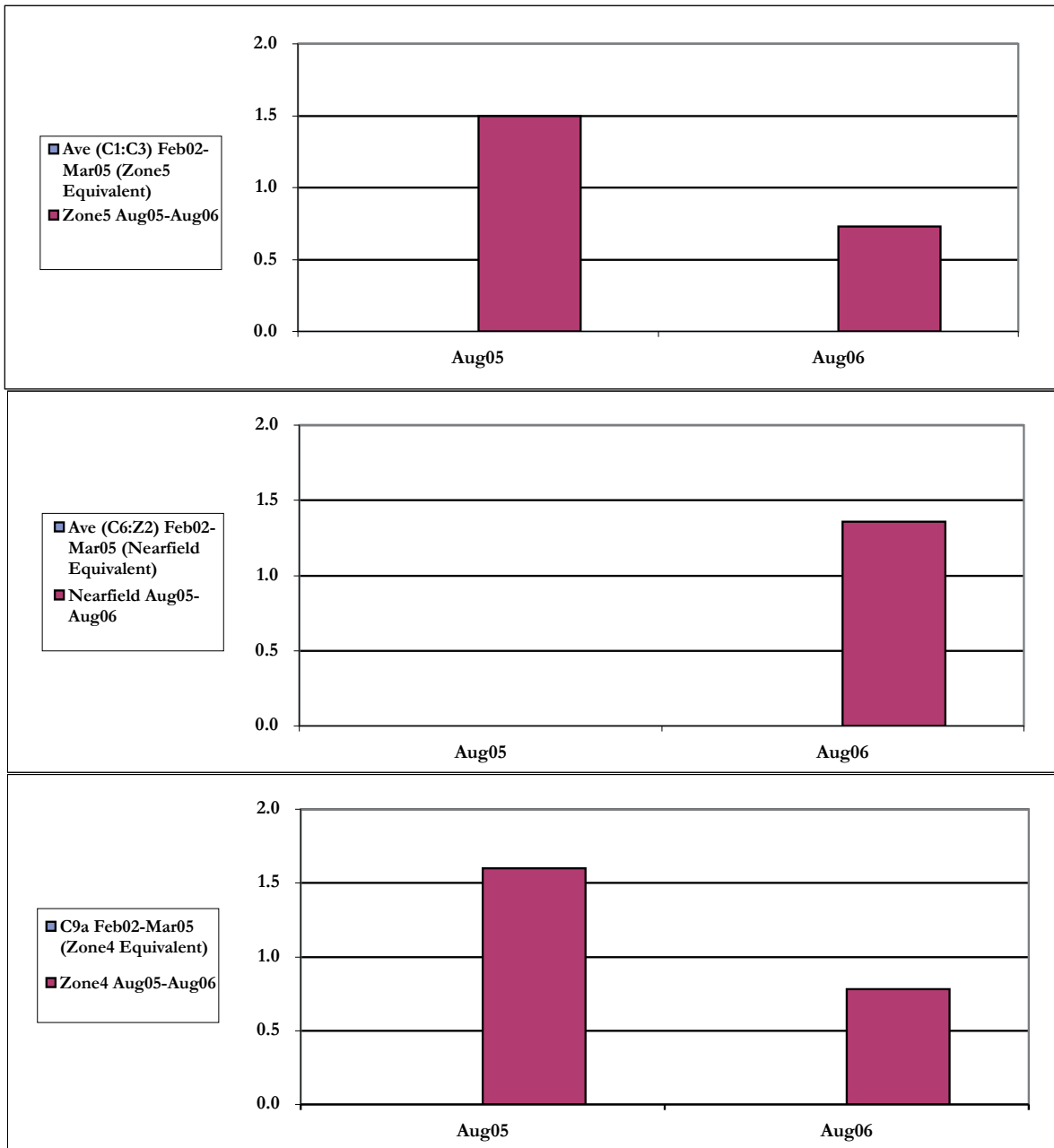


Figure 7-4. Mercury concentrations (mg/kg) in muscle tissues of hornyhead turbot from all three zones during 2002 through 2006 surveys. No sample was collected from the Nearfield Zone in August 2005.

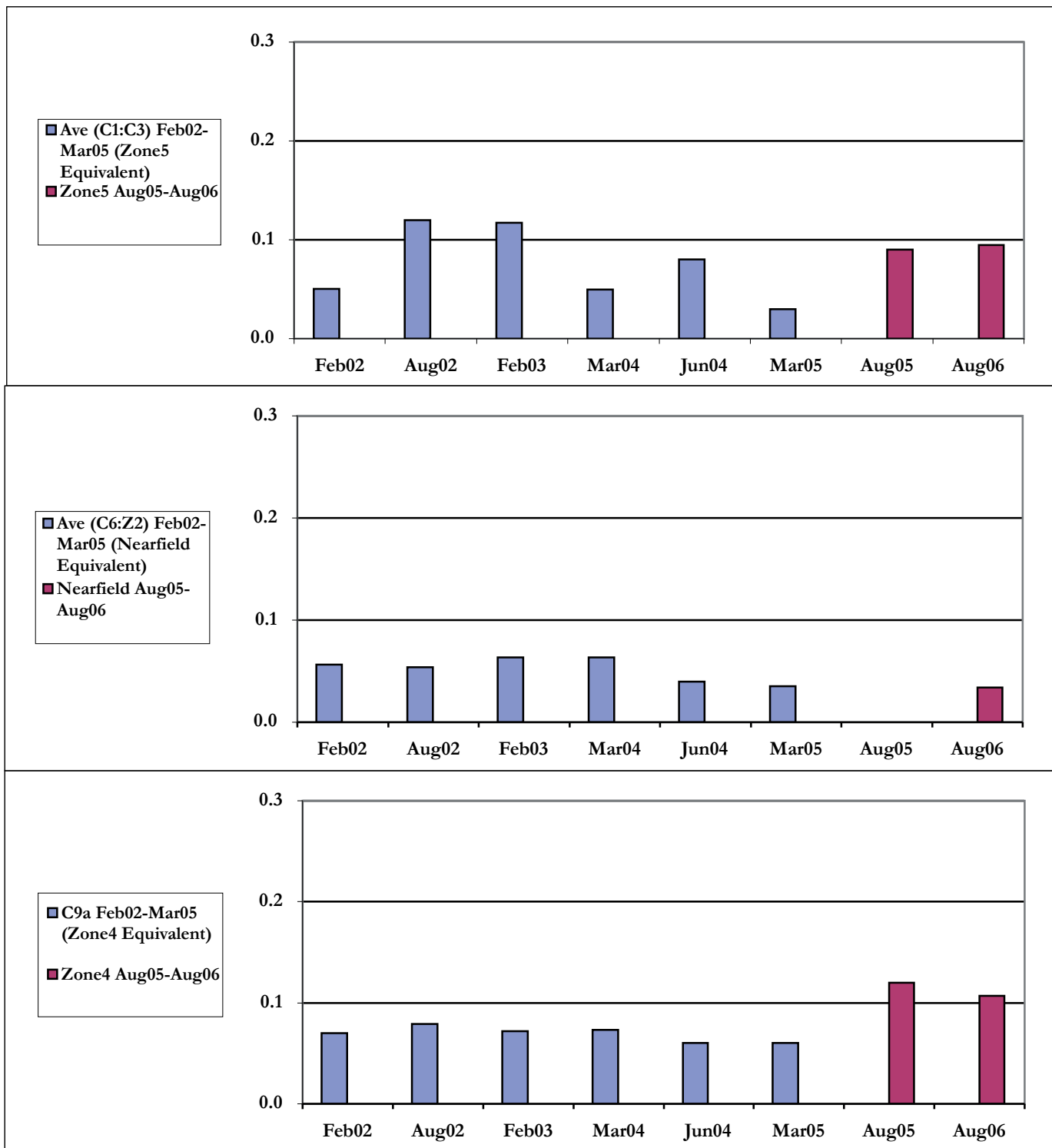


Figure 7-5. Concentrations (mg/kg) of total DDT in muscle tissues of hornyhead turbot at three zones during 2002 through 2006 surveys. No sample was collected from the Nearfield Zone in August 2005.

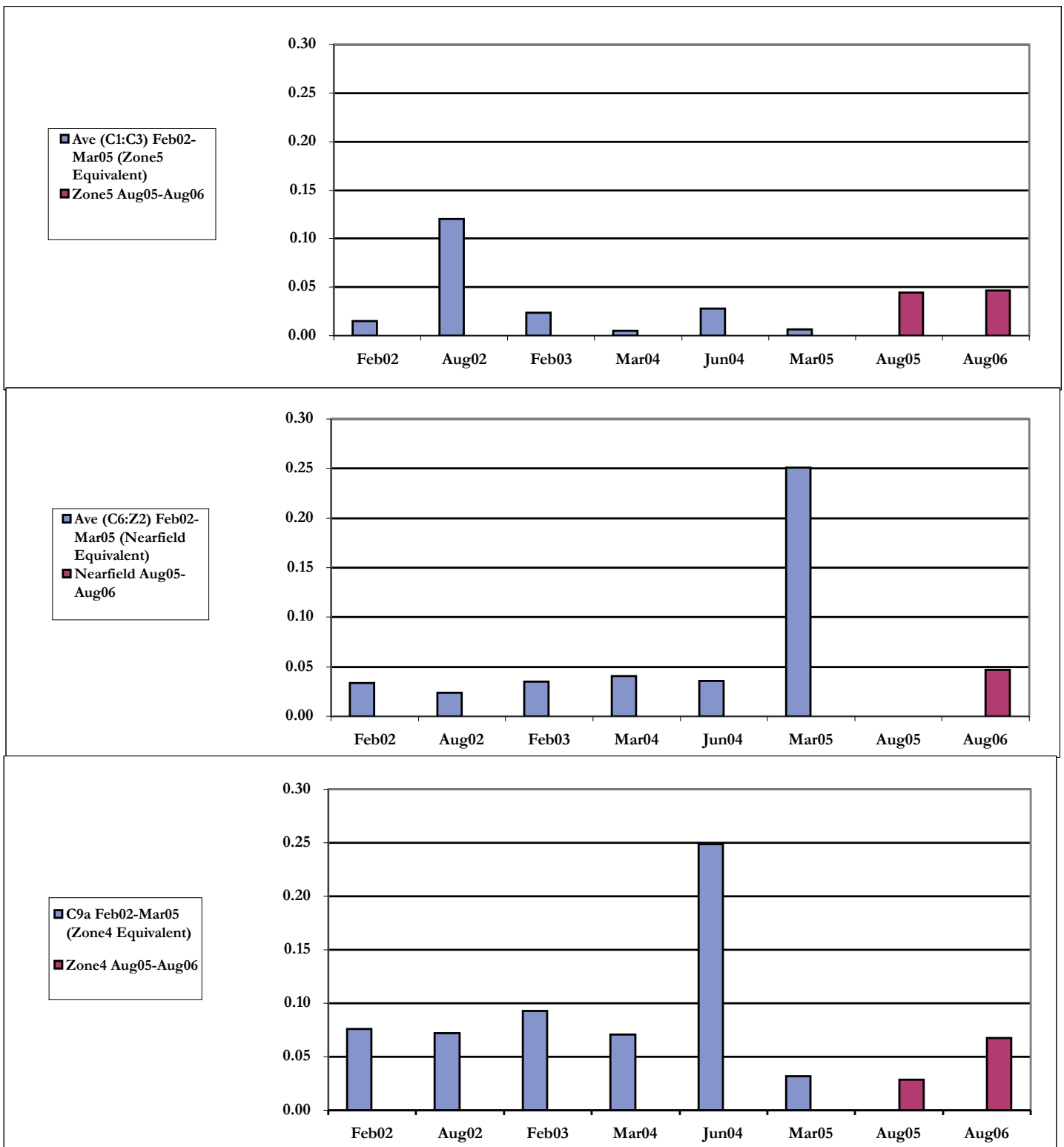


Figure 7-6. Concentrations (mg/kg) of total PCB in muscle tissues of hornyhead turbot at three zones during 2002 through 2006 surveys. No sample was collected from the Nearfield Zone in August 2005, Zone 5 in March 2005, or Zone 4 in March 2005.

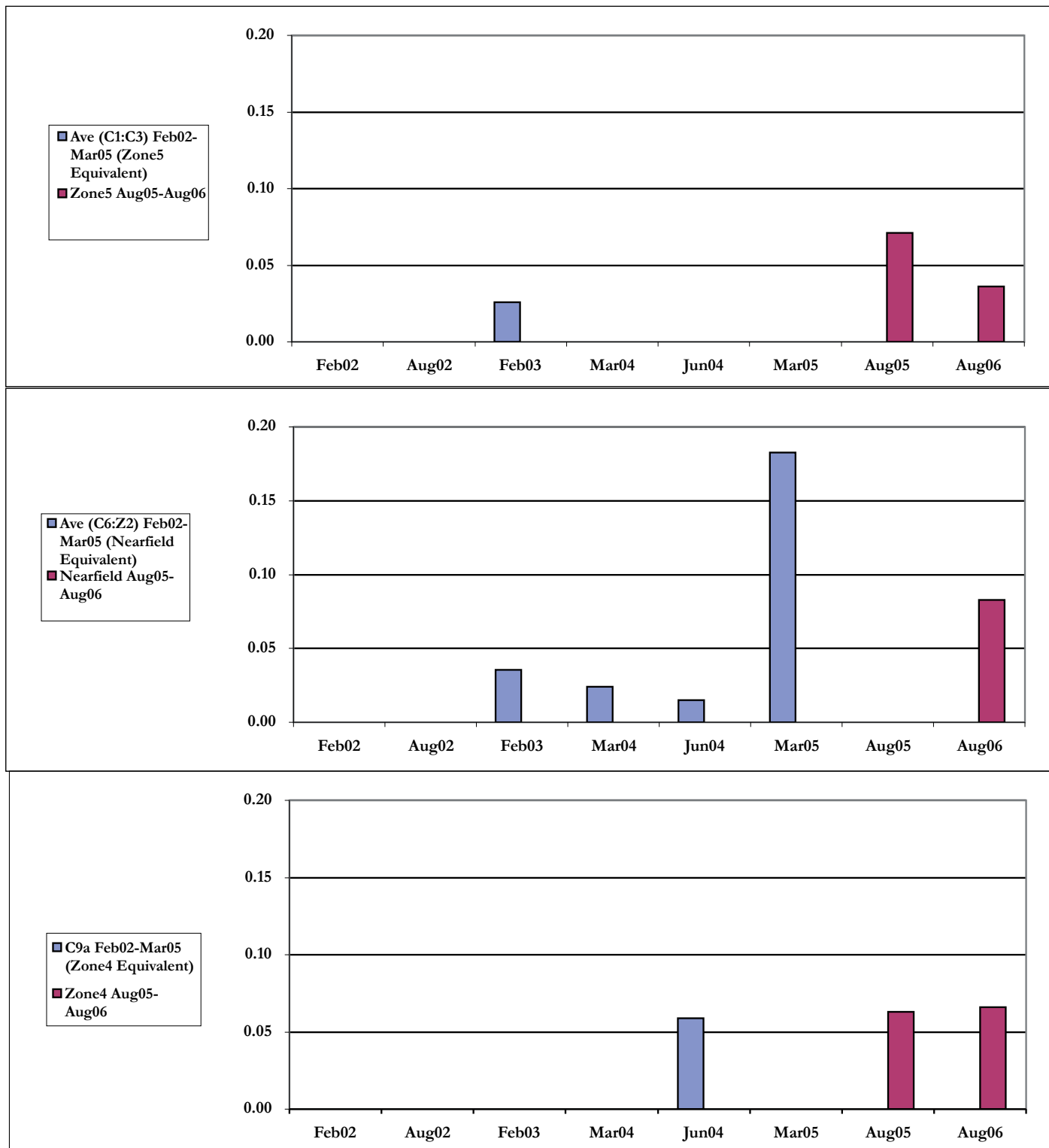
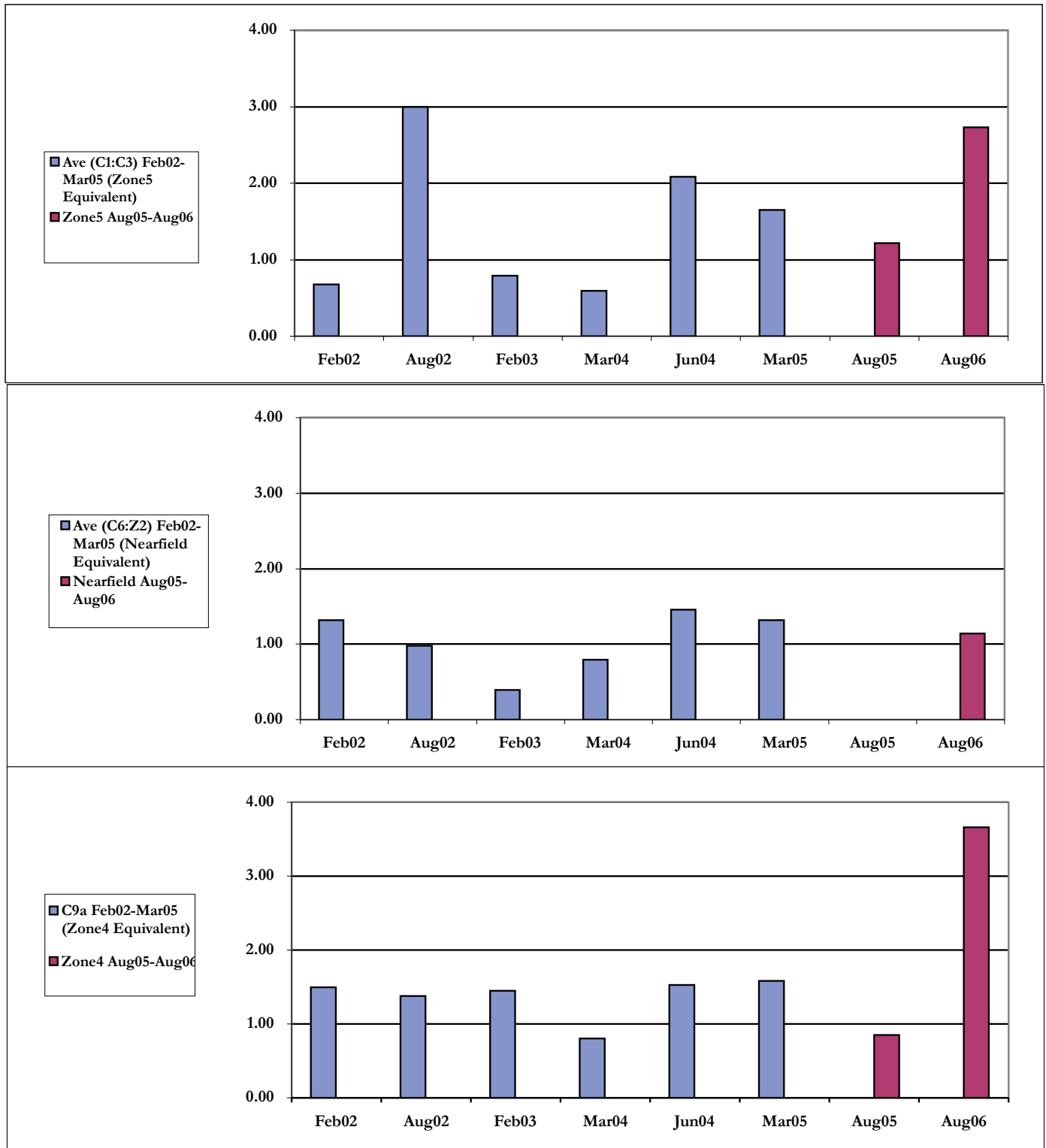


Figure 7-7. Concentrations of % lipid in muscle tissues of hornyhead turbot at three zones during the 2002 through 2006 surveys. No sample was collected at Nearfield Zone in August 2005.



from muscle tissue to indicate either the temporal or spatial trend during the 2002 to 2006 period.

The concentrations of lipids in muscle samples from 2002 to 2006 are presented in Figure 7-7. In fish muscle, the % lipid average value was 1.38% in 2005, and 2.41% in 2006 (Tables 7-2a and 7-2b). Percent lipid levels in samples collected during this period showed no systematic pattern and had poor correlation with total DDT and total PCB both spatially or temporally. Therefore, normalization of organic pollutant levels in muscle tissues with lipid levels could not be applied in a correlation study.

Liver Tissue

Metals

It was established during the past surveys that metals generally occurred more frequently and at higher concentrations in hornyhead turbot liver than in their muscle. The new NPDES permit requires analysis of only three metals, As, Se, and Hg in the fish tissue. The three metals were detected in all hornyhead turbot liver tissue samples in both 2005 and 2006. The average concentrations of As and Se in hornyhead turbot liver tissue samples collected in 2005 were higher than those collected in the 2006 survey as opposed to Hg where the average concentration of the 2006 survey was higher than the 2005 survey. The average concentration of As and Se in liver samples collected in 2005 were 7.41 and 7.20 mg/kg, respectively, compared with 5.58 and 4.74 mg/kg for the 2006 samples (Tables 7-2a, and 7-2b). The average concentrations of Hg in the 2005 and 2006 liver samples increased from 0.140 to 0.199 mg/kg; both are higher than the EPA/OEHHA SV level of 0.080 mg/kg. Among the three metals, As had the highest and Hg had the lowest average concentrations (Tables 7-2a, and 7-2b).

No systematic spatial or temporal distribution patterns of As and Hg concentrations were observed in liver samples collected during 2002-2006 period (Figures 7-8 and 7-10). Similarly, no spatial or

temporal pattern was observed for selenium (Figure 7-9).

Organics

As shown in Tables 7-2a and 7-2b, two DDT derivatives and twenty-eight PCB derivatives and three DDT derivatives and thirty PCB derivatives were detected in the liver tissue of the 2005 and the 2006 surveys, respectively. PCB77 was found in liver samples only in 2005, while p,p'-DDT and PCB 158 and PCB 206 were found in liver samples only in 2006. The average concentrations of the DDT derivatives and of the majority of the PCB congeners were higher in the 2006 than in the 2005 samples. In the 2005 liver samples, p,p'-DDE, total DDT, PCB congeners 66, 99,101,105, 110, 118,138,149, 153/168,187, 201 and total PCB exceeded the 0.560 mg/kg and 0.020 mg/kg screening values set for DDT and PCB respectively by EPA/OEHHA, while the concentrations of p,p'-DDE, total DDT, PCB congeners 66, 99, 101, 105, 110,118, 128, 138, 149, 151, 153/168, 183, 187, 194, 201, 206, and total PCB in 2006 liver samples were all higher than the 0.560 and 0.020 mg/kg screening values (Tables 7-2a and 7-2b).

Total DDT and total PCB have been consistently detected in liver samples during the last five years. Furthermore, concentrations have exhibited definite spatial trends in Santa Monica Bay (Figures 7-11 to 7-12). DDT concentrations in liver increased from Zone 5 (north SMB) to the Nearfield Zone (5-Mile Outfall) and to Zone 4 (south SMB). The average concentration of samples from Zone 5 (north SMB) differed significantly from those of the two remaining zones. The five highest average concentrations of DDT (over 4 mg/kg) were all found in liver samples from Zone 4 (south SMB) in March 2005, June 2004, February 2003, February 2002, and August 2006. PCB levels exhibited a similar pattern, but were highest at the Nearfield Zone (Figure 7-12). No clear temporal patterns of total DDT and PCB concentrations were observed in fish liver samples from Santa Monica Bay.

The concentrations of lipids in hornyhead turbot

Figure 7-8. Arsenic concentration (mg/kg) in liver tissues of hornyhead turbot at three zones during the 2002 through 2006 surveys. No samples at zone 5 in August 2002, and at Nearfield Zone in August 2005.

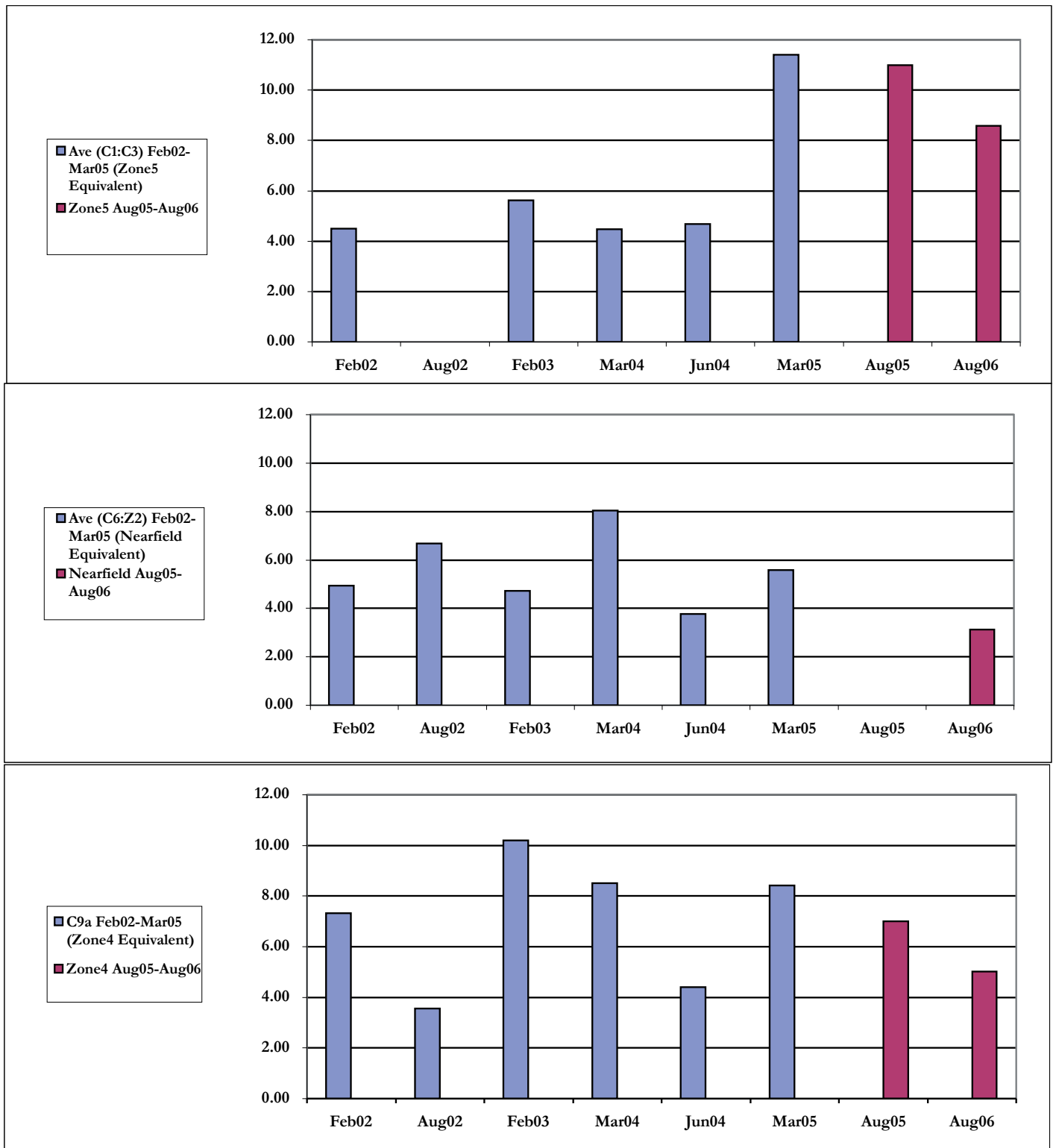


Figure 7-9. Selenium concentration (mg/kg) in liver tissues of hornyhead turbot at three zones during 2005 and 2006 surveys. No sample was collected from the Nearfield Zone in August 2005. Analysis of Se was required only after the issuance of the new permit in April 2005.

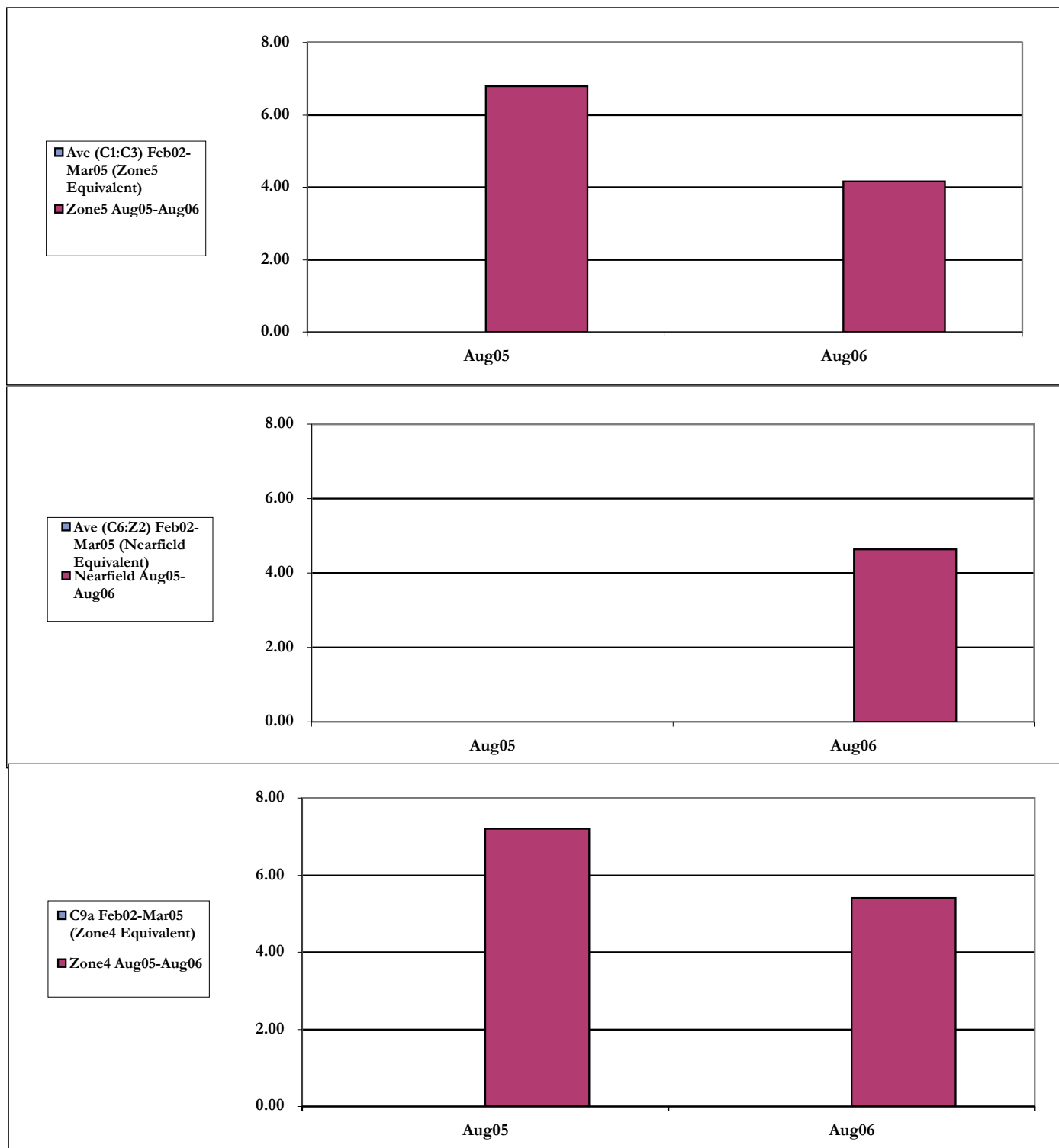


Figure 7-10. Mercury concentration (mg/kg) in liver tissues of hornyhead turbot at three zones during the 2002 through 2006 surveys. No sample was collected from the Nearfield Zone in August 2005.

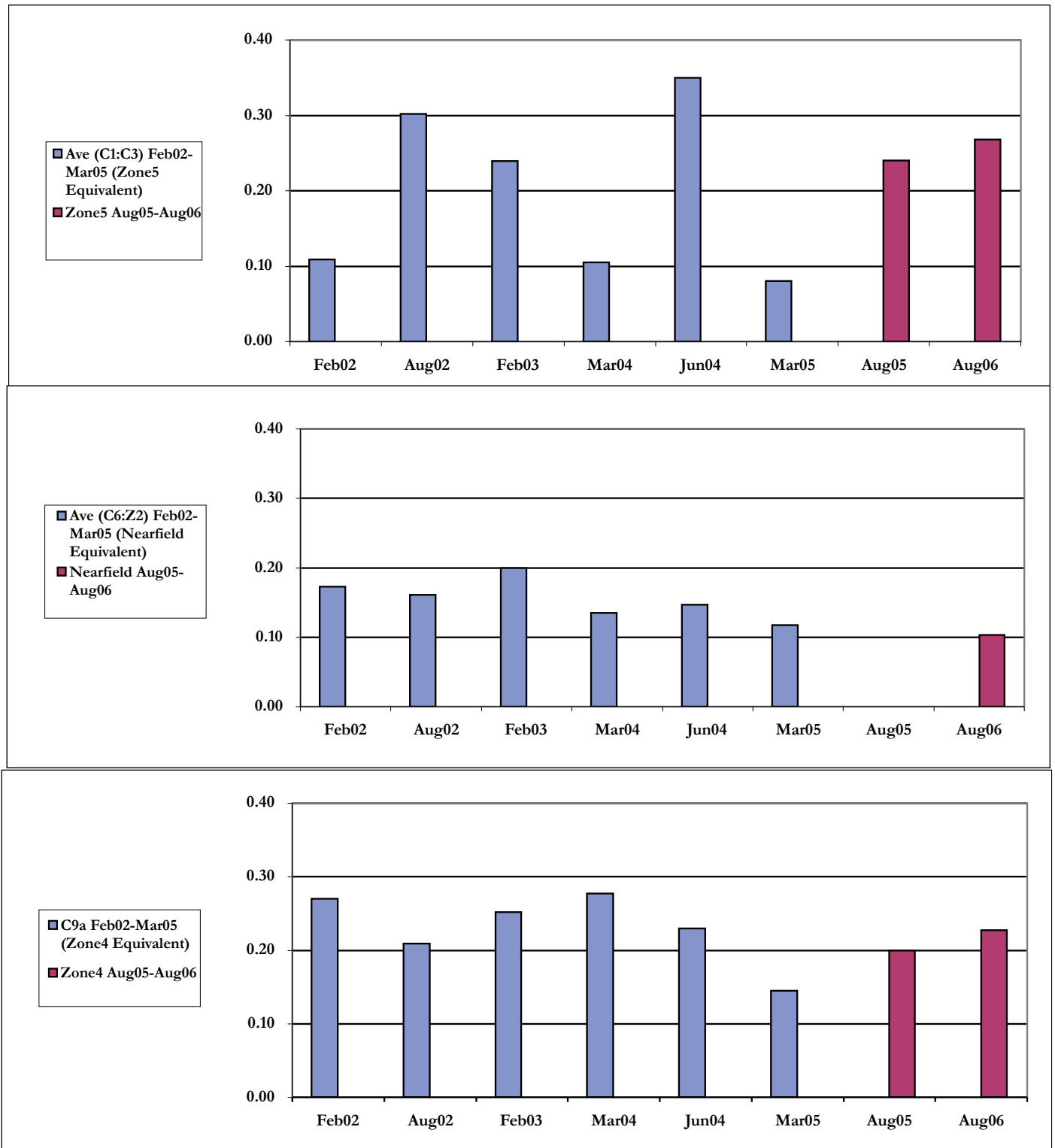


Figure 7-11. Concentration (mg/kg) of total DDT in liver tissues of hornyhead turbot from three zones during the 2002 through 2006 surveys. No sample was collected from the Nearfield Zone in August 2005.

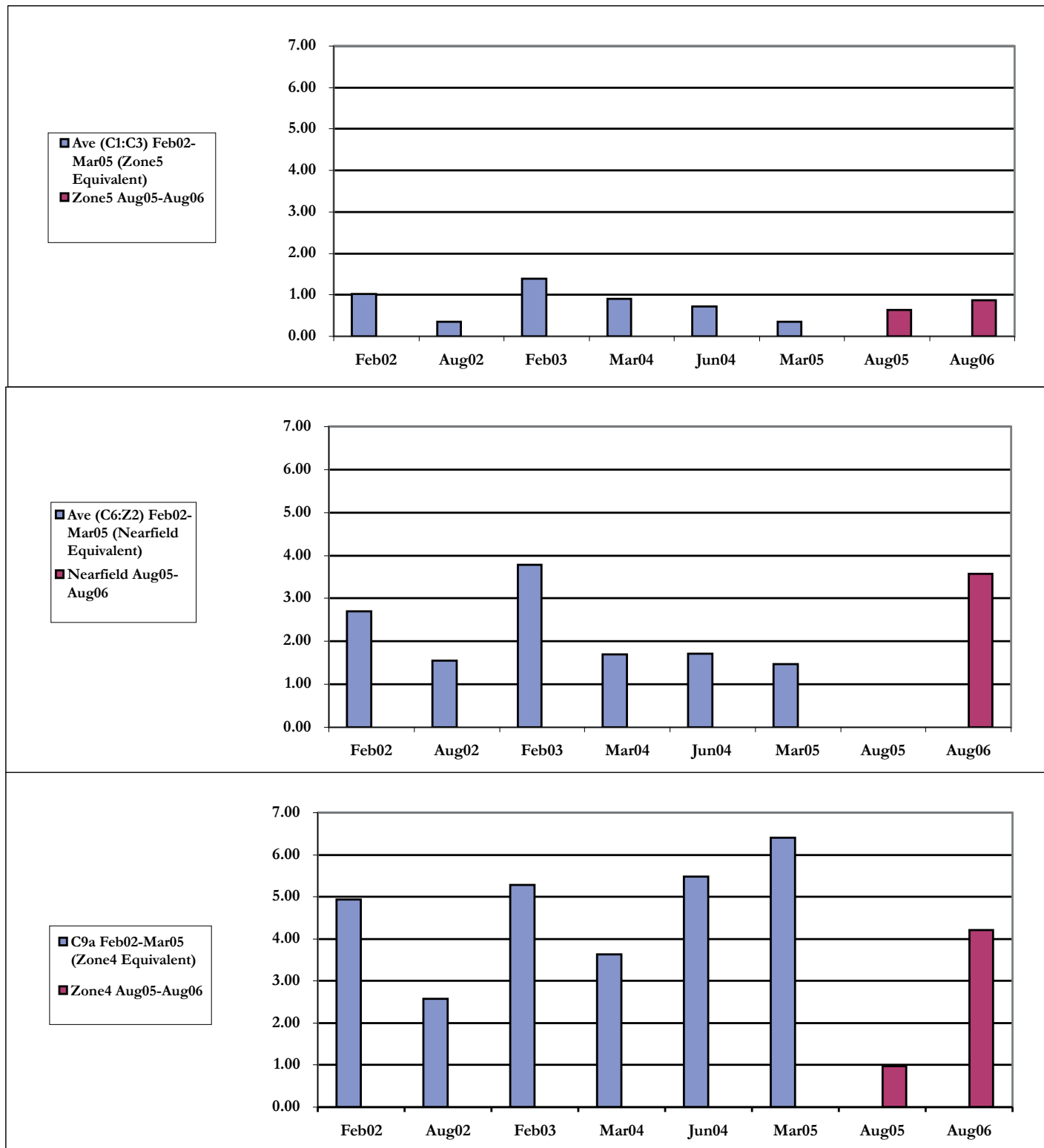


Figure 7-12. Concentration (mg/kg) of total PCB in liver tissues of hornyhead turbot from three zones during 2002 through 2006 surveys. No sample was collected from the Nearfield Zone in August 2005.

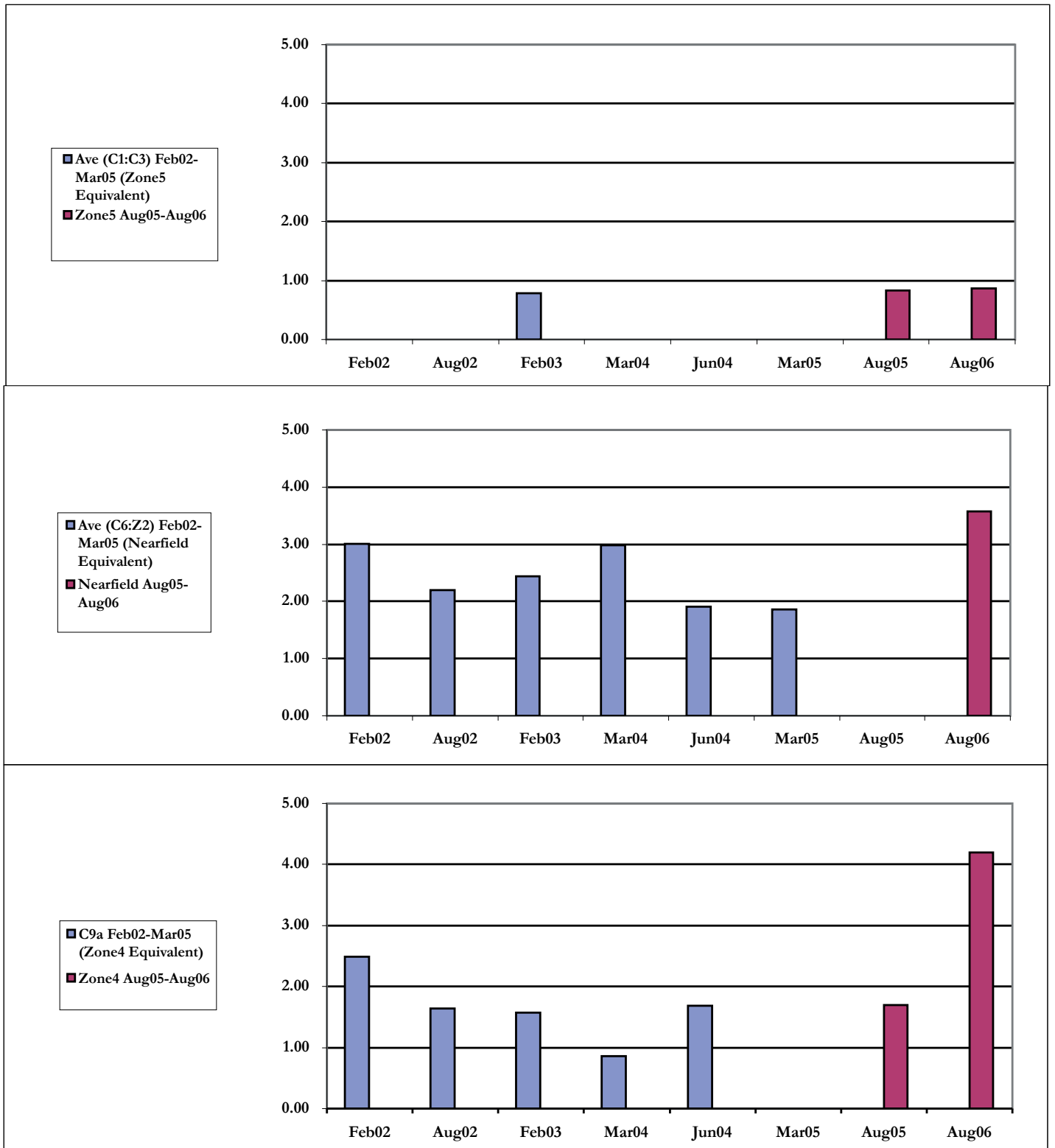
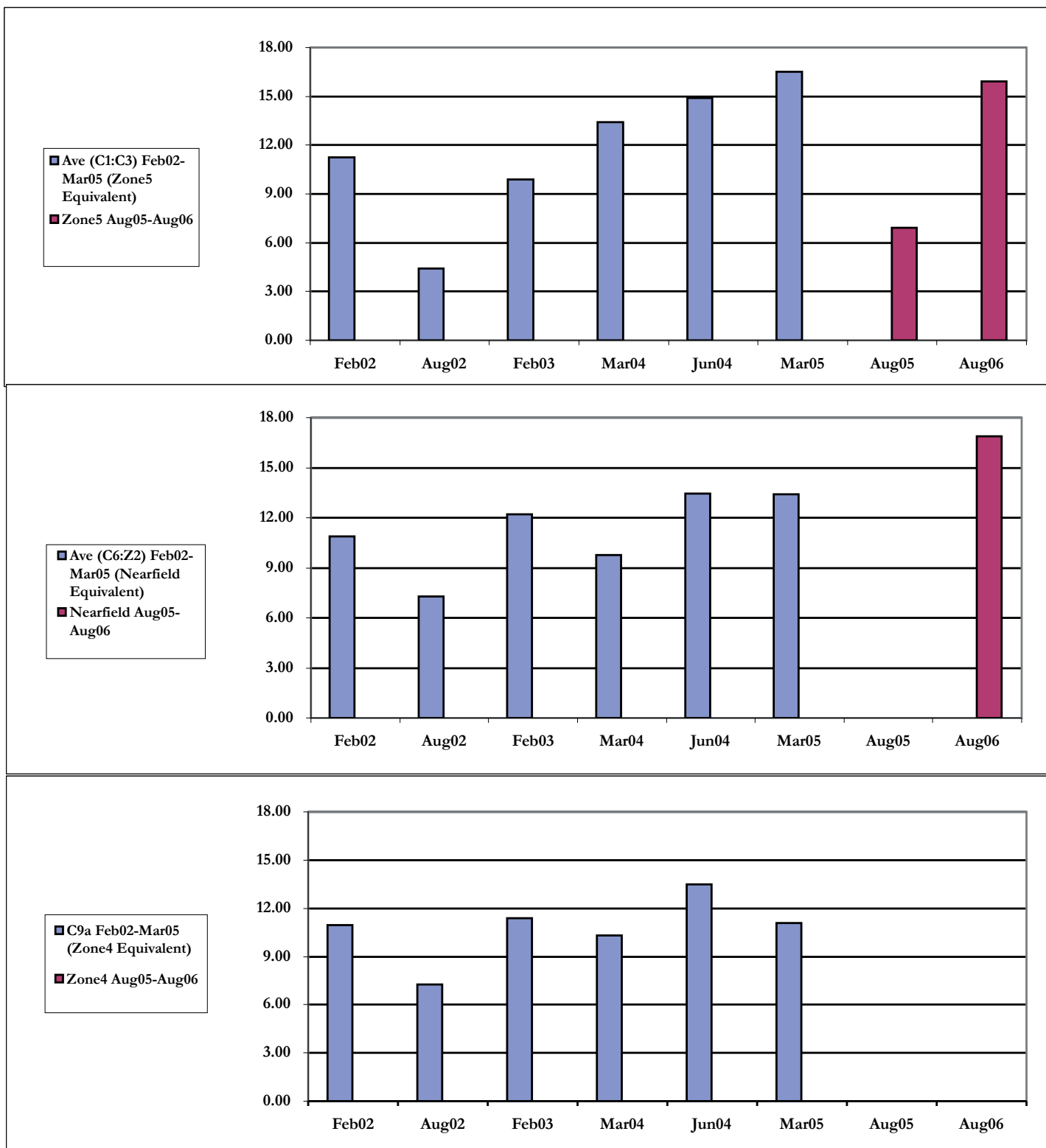


Figure 7-13. Concentration (mg/kg) of % lipid in liver tissues of hornyhead turbot from three zones during 2002 through 2006 surveys. No samples were collected from the Nearfield Zone in August 2005, or from Zone 4 (south SMB) in August 2005 and August 2006.



liver samples from 2002 to 2006 are presented in Figure 7-13. In hornyhead turbot liver samples, the average lipid concentration was 12.1 % in 2005 and 16.3 % in 2006 (Tables 7-2a and 7-2b). This is similar to the increase in the average concentrations of DDT and PCB derivatives in liver from the 2005 to the 2006 survey.

SPORTFISH

Three sport fish species were collected in March 2005 and seven sport fish species were collected in August and October of 2005 (Table 7-1b). No sport fish tissue analyses were required for 2006 by the new permit. The most frequently collected species during 2005 was the white croaker. Cyanide was analyzed in only the March 2005 samples; it is not required by the new permit. Cyanide was not detected in any of the samples tested. As and Hg were detected in all muscle samples of all sport fish species (Tables 7-3). Se was detected in all samples collected after March 2005. Se was not analyzed for samples collected in March 2005 because it was not required in the previous permit. The most frequently detected pesticides were p,p'-DDE and p,p'-DDD. Comparison of the frequency of the detected PCB derivatives was difficult since under the new permit the March 2005 samples had different requirements for PCB analysis than the samples collected thereafter.

Metals

Arsenic and mercury were detected in muscle tissues of all eight species of sport fish collected during 2005 (Tables 7-3). The average concentrations of arsenic, which varied among the different species, was highest in vermilion rockfish and cabezon (1.43 and 1.34 mg/kg respectively) and lowest in blacksmith and barred sand bass (0.3 and 0.4 mg/kg, respectively). Hg was detected in all eight species collected. Its average concentration ranged from 0.28 mg/kg in cabezon to 0.04 mg/kg in vermilion rockfish. Se was also detected in all seven species of fish analyzed (Se cabezon, collected in March 2005, was not analyzed) with a very narrow concentration

range from 0.5 mg/kg in vermilion rockfish to 0.3 mg/kg in white croaker, black croaker, barred sand bass, and kelp bass.

Since California scorpionfish and vermilion rockfish were the most frequently collected species from 2001 to 2005, (CLA, EMD 2002, 2004 and this report), the trend of tissue concentration of three metals (As, Se, and Hg) in these two species collected at the Nearfield Zone (5-Mile Outfall) was assessed (Figures 7-14 and 7-15). However, no temporal trend was observed. There also is not enough data for any individual species to determine the spatial trend of these metallic pollutants in their tissue.

Organics

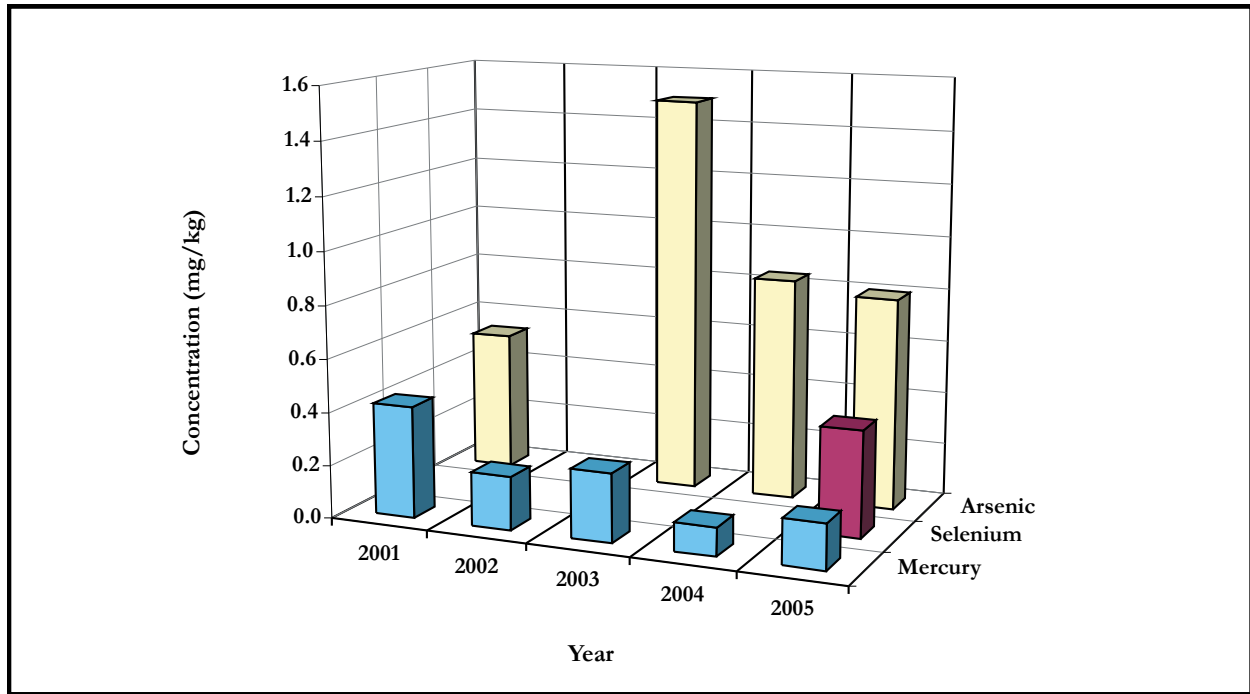
The organochlorine pesticides, p,p'-DDE and p,p'-DDD, were the most frequently detected organic pollutants in sport fish collected during the 2005 monitoring period (Table 7-4). p,p'-DDE was detected in seven out of eight species of the fish collected in 2005 and p,p'-DDD was detected in five of the eight species of fish. The highest average concentration of p,p'-DDE, 0.317 mg/kg, was found in the muscle of California scorpionfish followed by 0.246, and 0.109 mg/kg in the white croaker and barred sand bass muscle, respectively. The average concentrations of p,p'-DDD, found in muscle of the five fish species, were relatively low and ranged from 0.0002 mg/kg (vermilion rockfish) to 0.005 mg/kg (California scorpionfish).

Various PCB congeners were detected in white croaker, during spring and fall 2005 and in California scorpionfish, and barred sand bass during fall 2005 (Table 7-4). Muscle tissue of white croaker and California scorpionfish had relatively high total PCB concentrations (0.052 mg/kg for white croaker in March 2005, 0.0944 mg/kg for white croaker in October 2005, and 0.0778 mg/kg for California scorpionfish in August and October 2005). Greater numbers of PCB congeners were detected in white croaker and California scorpionfish than in any other species. No PCB derivatives were found in the muscle tissue of vermilion rockfish, cabezon, blacksmith, kelp bass and black croaker samples

Table 7-3. Arsenic, selenium, mercury, and cyanide in muscle tissue of sportfish from Santa Monica Bay during 2005. Units in mg/kg wet weight.

	VERMILION Mar. - Aug. 2005 n = 4 Mar(3), Aug(1)		CABEZON Mar. 2005 n = 3		WHITE CROAKER Mar. - Oct. 2005 n = 5 Mar(3), Aug(2)	
CONSTITUENTS	AVG (mg/kg)	RANGE (mg/kg)	AVG (mg/kg)	RANGE (mg/kg)	AVG (mg/kg)	RANGE (mg/kg)
As	1.43	1.2 - 1.58	1.34	1.00 - 1.96	0.52	0.26 - 0.88
Se	0.48	0.48 (one sample)	NA	NA	0.34	0.33 - 0.34
Hg	0.04	0.04 - 0.05	0.28	0.18 - 0.37	0.09	0.08 - 0.12
Cyanide	ND	ND	ND	ND	ND	ND
	CALIFORNIA SCORPIONFISH Aug. - Oct. 2005 n = 2		BLACK CROAKER Sep. 2005 n = 1		BARRED SANDBASS Aug. - Sep. 2005 n = 2	
CONSTITUENTS	AVG (mg/kg)	RANGE (mg/kg)	AVG (mg/kg)	RANGE (mg/kg)	AVG (mg/kg)	RANGE (mg/kg)
As	0.84	0.54 - 1.18	0.80	0.79 (one sample)	0.36	0.35 - 0.37
Se	0.44	0.42 - 0.46	0.27	0.27	0.32	0.30 - 0.33
Hg	0.17	0.14 - 0.19	0.30	0.30	0.20	0.22-0.18
Cyanide	ND	ND	ND	ND	ND	ND
	KELP BASS Sep. 2005 n = 1		BLACKSMITH Sep. - Oct. 2005 n = 2			
CONSTITUENTS	AVG (mg/kg)	RANGE (mg/kg)	AVG (mg/kg)	RANGE (mg/kg)		
DETECTED						
As	0.57	0.57 (one sample)	0.28	0.23 - 0.33		
Se	0.29	0.29	0.34	0.33 - 0.35		
Hg	0.08	0.08	0.05	0.03 - 0.06		
Cyanide	ND	ND	ND	ND		
n : Number of samples analyzed						
ND : Below Detection Limit						
NA : Not Analyzed						

Figure 7-14. Concentrations of arsenic, selenium, and mercury in muscle tissues of California scorpionfish at 5-Mile Outfall during the 2001 through 2005 surveys.



collected in 2005.

While the detected concentrations of DDT derivatives and PCBs were well below the DDT (5 mg/kg) and PCB (2 mg/kg) concentration levels set by the Food and Drug Administration (FDA), total PCB in white croaker and California scorpionfish exceeded the screening values of 0.020 mg/kg used by EPA and the California Office of Environmental Health Hazard Assessment for sport fish (Table 7-4).

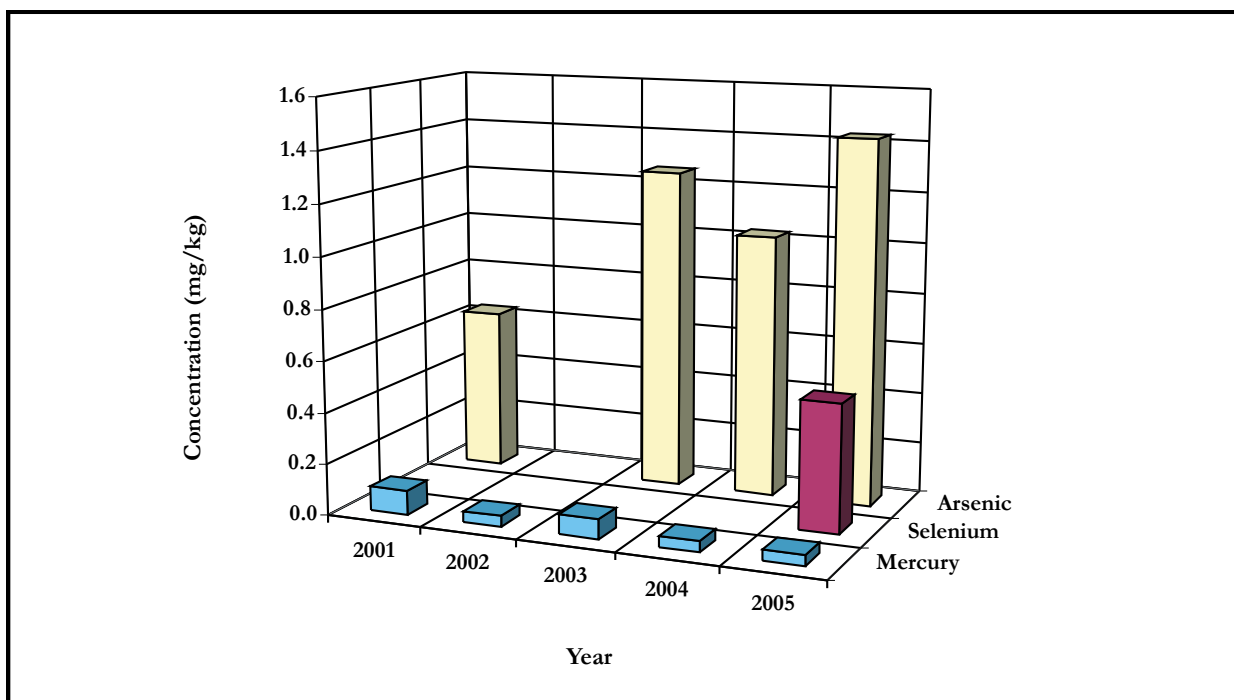
DISCUSSION

In general, tissue contaminant concentrations in 2005-2006 were similar to those measured in previous years (CLA, EMD 1989 - 2003). Bioturbation driven by the activity of bottom-living species was found to be responsible for a large fraction of pollutants released from sediment (Thibodeaux and Bierman 2003). However, metals measured in the tissues of fish did not necessarily correspond to areas where

sediment concentrations were high (Hoenicke 1993). Concentrations of arsenic and mercury in sediments, and in trawl fish from Zone 5 (North SMB), the Nearfield Zone (2-km radius around the 5-M Outfall), and Zone 4 (South SMB) were compared (Tables 7-5a and 7-5b). Similar to the finding of Hoenicke (Hoenicke, 1993), no significant correlation was observed between the sediment level and tissue bioaccumulation for these metals. For example, the arsenic and mercury levels of sediment in the Nearfield Zone are highest among the three zones (for 2005 - 4.32 and 0.383 mg/kg, and for 2006 - 4.88 mg/kg and 0.771 mg/kg, respectively), but the levels of arsenic in trawl muscle tissue from the Nearfield Zone was the lowest in 2005 and second lowest in 2006; mercury levels in muscle tissue from the Nearfield Zone was lowest both years. Also, there were no clear temporal trends in tissue metal contamination; differences over time were probably the result of natural variation.

The question of safe seafood consumption is of great concern with regard to the amounts of

Figure 7-15. Concentrations of arsenic, selenium, and mercury in muscle tissues of vermilion rockfish at 5-Mile Outfall during the 2001 through 2005 surveys.



trace contaminants in fish from the Bay. OEHHA reported assessing the risk to humans of eating fish caught at various locations in Southern California (OEHHA-1991/California EPA-2006)). The pollutants of greatest concern are the chlorinated hydrocarbons, mainly DDT and its breakdown products, and congeners of PCB.

The tissue concentrations of metals, particularly mercury are also of public health concern. The mercury level in fish tissue was compared with the “action levels” for fish consumption set by the Food and Drug Administration (FDA). Although it was detected in all sport fish tissue sampled in 2005, the mercury concentrations in all samples were well below both the FDA action level and the International Action Limit Median of 1.0 mg/kg. The FDA has not set the action level for Arsenic and Selenium. The Mercury concentrations were also below the California State Department of Health Services advisory limit of 0.5 mg/kg for sport fish (Tables 7-3).

Risk assessment of the consumption of fish tissue has evolved over time. The US EPA and OEHHA use the screening values (SVs) as specific Guidance Tissue Levels (GTLs) in screening surveys to determine whether any contaminants in fish are a potential human health concern in the sample water body. The US EPA recommends using the SVs to identify contaminants that are of potential concern and to select water bodies for further intensive monitoring (California EPA, 2006). The GTLs are established to provide local consumption advice in an attempt to prevent consumers from being exposed to more than the daily average daily reference dose for non-carcinogens or to a risk level greater than 0.0001 mg/kg for carcinogens. GTLs assume that the average serving size is a standard 8-ounce portion for adults who weigh 70 kg. The SVs for DDT, PCB, and mercury are 0.560, 0.020, and 0.080 mg/kg, respectively.

Many of the sport fish collected in 2005 could not meet the more restrictive SV recommended by OEHHA/EPA. In the 2005 survey, two sport fish

Table 7-4. Organic pollutants measured in sportfish from Santa Monica Bay during 2005. Bold numbers indicate DDT and PCB levels that exceeded the 0.560 and 0.020 mg/kg SV set by EPA/OEHHA.

Unit: mg/kg	VERMILION		CABEZON		WHITE CROAKER	
	Mar. - Aug. 2005		Mar. 2005		Mar. 2005	
	n = 4	Mar(3), Aug(1)	n = 3		n = 3	
CONSTITUENTS	AVG	RANGE	AVG	RANGE	AVG	RANGE
Pesticides and PCBs:						
O,P'-DDE	ND	ND	ND	ND	0.0022	ND - 0.0067
P,P'-DDD	0.0002	ND - 0.0006	ND	ND	0.0467	0.01333 - 0.0772
P,P'-DDE	0.040	0.0197 - 0.0658	0.0346	0.0239 - 0.0411	ND	ND
Total DDT	0.041		0.035		0.049	
PCB 1254	ND	ND	ND	ND	ND	ND
PCB 1260	ND	ND	ND	ND	0.0520	ND - 0.086
Total PCB	ND		ND		0.052	
Lipid %	2.16	1.76 - 2.64	2.06	1.97 - 2.15	0.0567	ND - 0.108
Unit: mg/kg	CALIFORNIA SCORPIONFISH		WHITE CROAKER		BLACKSMITH	
	Aug. - Oct. 2005		Oct. 2005		Sept. - Oct. 2005	
	n = 2		n = 2		n = 2	
CONSTITUENTS	AVG	RANGE	AVG	RANGE	AVG	RANGE
Pesticides and PCBs:						
O,P'-DDD	ND	ND	0.0024	ND - 0.0048	ND	ND
O,P'-DDE	ND	ND	ND	ND	ND	ND
P,P'-DDD	0.005	0.0015 - 0.0084	0.003	ND - 0.0054	0.00045	ND - 0.0009
P,P'-DDE	0.317	0.104 - 0.529	0.246	0.0885 - 0.404	0.048	0.0334 - 0.0634
Total DDT	0.321		0.251		0.049	
PCB70	0.00082	ND - 0.00163	0.00085	ND - 0.0017	ND	ND
PCB87	0.00146	ND - 0.00291	ND	ND	ND	ND
PCB99	0.01002	0.0041 - 0.0159	ND	ND	ND	ND
PCB101	0.00440	ND - 0.0088	0.00641	0.0056 - 0.0072	ND	ND
PCB105	0.00329	ND - 0.0066	0.00433	0.0036 - 0.0051	ND	ND
PCB 110	0.00566	0.0031 - 0.0082	0.00867	0.0048 - 0.0125	ND	ND
PCB118	0.00883	0.0038 - 0.0139	0.00893	0.0073 - 0.0106	ND	ND
PCB128	ND	ND	0.00182	ND - 0.0018	ND	ND
PCB138	0.01352	0.0083 - 0.0187	0.01432	0.0105 - 0.0181	ND	ND
PCB149	ND	ND	0.00771	0.0051 - 0.0103	ND	ND
n : Number of samples analyzed			All numerical value for PCBs are estimated			
ND : Below Detection Limit			Other PCB and DDT derivatives not listed above are all ND			

Table 7-4 (continued). Organic pollutants measured in sportfish from Santa Monica Bay during 2005. Bold numbers indicate DDT and PCB levels that exceeded the 0.560 and 0.020 mg/kg SV set by EPA/OEHHA.

Unit: mg/kg	CALIFORNIA SCORPIONFISH		WHITE CROAKER		BLACKSMITH	
	Aug. - Oct. 2005 n = 2		Oct. 2005 n = 2		Sept. - Oct. 2005 n = 2	
CONSTITUENTS	AVG	RANGE	AVG	RANGE	AVG	RANGE
Pesticides and PCBs:						
PCB151	0.00202	ND - 0.0040	0.00194	ND - 0.0039	ND	ND
PCB153/168	0.01466	0.0064 - 0.0229	0.01835	0.0120 - 0.0247	ND	ND
PCB170	0.00189	ND - 0.0038	0.00245	ND - 0.0049	ND	ND
PCB177	0.00123	ND - 0.0025	0.00186	ND - 0.0037	ND	ND
PCB180	0.00389	ND - 0.0078	0.00560	ND - 0.0112	ND	ND
PCB183	0.00114	ND - 0.00223	0.00185	ND - 0.0037	ND	ND
PCB187	0.00354	ND - 0.0071	0.00688	0.0037 - 0.0101	ND	ND
PCB201	0.00142	ND - 0.0028	0.00250	ND - 0.0050	ND	ND
Total PCB	0.0778		0.0944		ND	
Lipid %	1.975	1.86 - 2.09	2.38	1.97 - 2.79	2.28	2.17 - 2.38
Unit: mg/kg	BARRED SAND BASS		KELP BASS		BLACKCROAKER	
	Aug. - Sep. 2005 n = 2		Oct. 2005 n = 1		Sep. 2005 n = 1	
CONSTITUENTS	AVG	RANGE	AVG	RANGE	AVG	RANGE
Pesticides and PCBs:						
P,P'-DDD	0.0008	0.0008	ND	ND	ND	ND
P,P'-DDE	0.109	0.109	0.0413	0.0413	ND	ND
Total DDT	0.110		0.0413		ND	
PCB99	0.00173	ND - 0.0035	ND	ND	ND	ND
PCB118	0.00165	ND - 0.0033	ND	ND	ND	ND
PCB138	0.00394	ND - 0.0079	ND	ND	ND	ND
PCB149	0.00107	ND - 0.0021	ND	ND	ND	ND
PCB153/168	0.00370	ND - 0.0074	ND	ND	ND	ND
PCB187	0.00138	ND - 0.0027	ND	ND	ND	ND
Total PCB	0.0135		ND		ND	
Lipid %	1.87	1.87	1.87	1.87	ND	ND
n : Number of samples analyzed			All numerical value for PCBs are estimated			
ND : Below Detection Limit			Other PCB and DDT derivatives not listed above are all ND			

Table 7-5a. Correlation of arsenic and mercury concentrations (mg/kg) in muscle tissues of hornyhead turbot and in sediment during 2005 Santa Monica Bay monitoring.

	Zone 5		Nearfield		Zone 4	
	Sediment	Tissue	Sediment	Tissue	Sediment	Tissue
Arsenic	3.75	4.96	2.67	3.61	5.27	4.51
Mercury	0.114	0.060	0.122	0.04	0.56	0.080
ND - Below Detection Limit						

For sediment:

Zone 5 including station C1, C3

Nearfield including station C6, D1, Z2

Zone 4 including station C8, C9a, E6

species, California scorpionfish and white croaker, had average concentrations of total PCB higher than 0.020 mg/kg (Table 7-4). Also, California scorpionfish, white croaker, cabezon, black croaker, and barred sand bass had average concentrations mercury higher than the 0.080 mg/kg SV (Table 7-3).

people and the high levels of total DDT and total PCB are a health concern.

The data reported herein are helping to build our knowledge of contaminants in sport fish from the Bay. Such data may be used to further refine levels of risk associated with consumption of these fish, and when appropriate, to modify health advisories. The existing monitoring performed by the City should be supplemented by additional collections of sport fish from piers and jetties. Several of these species (e.g., croaker and scorpionfish) are consumed by

Table 7-5b. Correlation of arsenic and mercury concentrations (mg/kg) in muscle tissues of hornyhead turbot and in sediment during 2006 Santa Monica Bay monitoring.

	Zone 5		Nearfield		Zone 4	
	Sediment	Tissue	Sediment	Tissue	Sediment	Tissue
Arsenic	3.38	4.03	3.69	3.44	5.64	2.84
Mercury	0.097	0.095	0.125	0.034	0.142	0.107
ND - Below Detection Limit						

For sediment:

Zone 5 including station C1, C3

Nearfield including station C6, D1, Z2

Zone 4 including station C8, C9a, E6

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