CHAPTER 8
Bioaccumulation

Cover photos

Upper left: Hornyhead Turbot (*Pleuronichthys verticalis*)

Lower right: Barred Sand Bass (*Paralabrax nebulifer*) near the seafloor

Chapter 8 Bioaccumulation

INTRODUCTION

The Los Angeles County Sanitation Districts (Sanitation Districts) own and operate the Joint Water Pollution Control Plant (JWPCP), which discharges secondary treated effluent into the Pacific Ocean pursuant to the Waste Discharge Requirements and National Pollutant Discharge Elimination System (NPDES) permit issued by the Los Angeles Regional Water Quality Control Board (LARWQCB; Order No. R4-2017-0180, NPDES No. CA0053813; Appendix 1.1). Monitoring and reporting requirements for the NPDES permit are specified in the Monitoring and Reporting Program (MRP) portion of the NPDES permit. The MRP specifies several monitoring elements for the JWPCP, including receiving water (i.e. ocean) monitoring.

The chemical analysis of bioaccumulative contaminants in fish tissues is a vital aspect of ocean monitoring programs. The bioaccumulation monitoring program assesses the temporal and spatial trends in the assimilation and accumulation of contaminants into fish from the coastal region. Contaminants may enter these organisms by uptake from the water, by ingestion of contaminated sediment particles, or by consumption of contaminated prey (Tetra Tech 1985). Chemical compounds with a non-polar structure typically accumulate and concentrate in the fat tissue of fish (Gossett et al. 1982; Clarke et al. 1990). This chapter describes the bioaccumulation of contaminants in fishes caught locally and provides results that are essential to evaluate the ecological and human health risks posed to humans, marine mammals, birds, or other predators from consumption of these fish species.

History of bioaccumulation studies

Fish sample collections and analyses for bioaccumulative contaminants in Southern California began in the early 1970s with comprehensive reports issued by the National Oceanic and Atmospheric Administration (Mearns et al. 1991) and MBC Applied Environmental Sciences and Applied Management Planning Group in 1994 (MBC 1994). These reports document that higher levels of dichloro-diphenyl-trichloroethane (DDTs) and polychlorinated biphenyl (PCBs, **Table 8.1**) were detected in fish tissue near the JWPCP outfalls operated by the Sanitation Districts and the Hyperion wastewater outfalls operated by the City of Los Angeles. Tissue contaminant levels decreased with distance from the outfall areas. These reports also indicated that by the mid-1980s, there had been a sharp decrease in DDTs and PCBs concentrations in fish muscle tissue concentrations. A detailed review of the early pilot studies and regional bioaccumulation monitoring focused on seafood contamination can be found in **Appendix 8.1**, together with a review of studies on wildlife risk from contaminated fish.

Despite the observed decline of DDTs and PCBs in the early 1990s, contaminants within some marine species were still high enough to prompt the Los Angeles County Department of Health Services to post public warnings along the Santa Monica Bay and the Palos Verdes Peninsula to discourage human consumption of White Croaker (**Appendix 8.2**). The California Department of Public Health (CDPH, formerly California Department of Health Services), Office of Environmental Health Hazard Assessment (OEHHA) also issued fish consumption guidelines within this region, recommending no consumption of White Croaker and limited consumption of other species caught in the Palos Verdes area. These advisories have been in place to warn fishers to avoid or limit consumption of certain fish species since 1985. In the early 1990s, the California Department of Fish and Wildlife (CDFW, formerly California Department of Fish and Game) closed the White Croaker commercial fishery along a portion of the Palos Verdes Peninsula (**Appendix 8.3**), a measure that remains in effect today.

In June 2009, the OEHHA revised the "Safe Eating Guidelines" based on a large study conducted during 2002-2004 by the United States Environmental Protection Agency (EPA) and the Montrose Settlements Restoration Program (USEPA/USDOC 2007). A total of 1,373 fish from 22 species groups were collected along the coastal waters of Southern California from Ventura Harbor to San Mateo Point. Results from

Table 8.1 Definitions for DDTs and PCBs

Corresponding definitions of text and NPDES permit references used for DDTs and PCBs within the chapter.

Text reference	Permit reference	Defining compounds
DDTs	DDT derivatives	4,4'-DDT; 2,4'-DDT; 4,4'-DDE; 2,4'-DDE, 4,4'-DDD, 2,4'-DDD
Total DDTs	Total DDT	Sum of detectable DDTs
PCBs	Aroclors	Aroclor-1016, Aroclor-1221, Aroclor-1232, Aroclor-1242, Aroclor-1248, Aroclor-1254, Aroclor-1260
PCB congeners	PCB derivatives	PCB congeners 18, 28, 37, 44, 49, 52, 66, 70, 74, 77, 81, 87, 99, 101, 105, 110, 114, 118, 119, 123, 126, 128, 138, 149, 151, 153, 156, 157, 158, 167, 168, 169, 170, 177, 180, 183, 187, 189, 194, 201, 206
Total PCBs	Total PCB	Sum of detectable PCB (Aroclors)

this study indicated that several species contained DDTs, PCBs, and mercury at levels that were concerning to consumers and as a result, the OEHHA issued a set of revised consumption guidelines for this region (**Appendix 8.4**).

Bioaccumulation monitoring requirements

The MRP for the JWPCP NPDES permit requires the Sanitation Districts to participate in four Bioaccumulation and Seafood Safety Monitoring programs. A brief discussion of each program is described below.

The Local Bioaccumulation Survey is conducted annually by sampling Hornyhead Turbot (*Pleuronichthys verticalis*) liver and muscle tissues and White Croaker (*Genyonemus lineatus*) muscle tissue off the Palos Verdes Peninsula. These species serve as sentinel fishes for tissue contamination levels of DDTs and PCBs. The primary purpose of this effort is to determine if the fish tissue contamination in the vicinity of the outfall is changing over time.

The Local Seafood Safety Survey is conducted biennially to evaluate human health risks associated with the consumption of locally caught sport fish. The main purpose of this survey is to determine the status and trends of tissue contaminant concentrations in locally caught sport fish as they relate to human health risk. The survey design is based upon the Santa Monica Bay Restoration Commission Comprehensive Monitoring Program (SMBRP 2000) and examines a wider variety of fish species and contaminants than the Local Bioaccumulation Survey. These results are provided to the CDFW, the Bioaccumulation Oversight Group (BOG) of the Surface Water Ambient Monitoring Program (SWAMP), and OEHHA, who is charged with providing fish consumption advisories to the public.

The third bioaccumulation monitoring program requirement is to participate in Regional Seafood Safety Surveys. The objective of these surveys is to determine whether any unexpected changes in contaminant levels have occurred in species or sites not targeted by Local Seafood Safety Surveys. This study is expected to be conducted at least once every ten years under the direction of OEHHA or a regional steering committee. When such surveys are scheduled, the NPDES permit requires that the Sanitation Districts contribute staff and resources for planning, sampling, analyses, and data management associated with the project.

The last Regional Seafood Safety Survey was conducted as part of the 2018 Bight Regional Monitoring (Bight'18). In this statewide study, 230 fish representing 22 species were collected by CDFW from 26 locations on the California coast, including the SCB. The Sanitation Districts' staff served on the Bight'18 Sediment Quality Committee and participated in the implementation of the Regional Seafood Safety Survey by performing chemical analyses on some of the tissue samples (Bight'18, *in prep.*).

The final fish tissue bioaccumulation monitoring requirement is to participate in Regional Bioaccumulation/Predator Risk Surveys. The primary objective of these surveys is to provide data that can be used to estimate the health risk to marine birds, mammals, and other wildlife that consume fish from the Southern California Bight (SCB). Similar to the Regional Seafood Safety Surveys, these efforts are organized by a regional steering committee and expected to occur every ten years. When such surveys are scheduled, the NPDES permit requires that the Sanitation Districts provide staff and resources for planning, sampling, analyses, and data management associated with the project.

Consistent with this requirement, the last Regional Bioaccumulation/Predator Risk Survey was conducted as part of the 2013 Bight Regional Monitoring (Bight'13). The Bight'13 Contaminant Impact Assessment Committee initiated a study to collect and analyze marine bird eggs from four species: Caspian tern (pelagic forager), cormorant (benthic forager), western gull (mixed forager) and California least tern for legacy contaminants (DDTs, PCBs and chlordanes), constituents of emerging concern (CECs), and metals (Clatterbuck et al., 2016). The Sanitation Districts' staff provided resources in the associated planning, chemistry, and bioaccumulation technical committees and participated in the pilot marine bird eggs analysis and laboratory inter-calibration process.

Chapter overview

This chapter provides results for the Local Bioaccumulation Surveys from 2018 and 2019 and the Local Seafood Safety Survey results from 2018. Consistent with the objectives of these two monitoring requirements, the Local Bioaccumulation Surveys data are analyzed and discussed in terms of spatial (proximity to the JWPCP outfall discharge) and temporal relationships between fish tissue contamination levels while the seafood safety results are provided in relation to existing OEHHA human health risk screening values.

This chapter is one component of the 2018 -2019 JWPCP Biennial Receiving Water Monitoring Report (LACSD 2020a). The complete report includes results and analyses for all JWPCP NPDES receiving water monitoring requirements as well as the associated appendices. Electronic copies of the complete 2018-2019 JWPCP Biennial Receiving Water Monitoring Report can be downloaded at the Sanitation Districts' website, www.lacsd.org.

MATERIALS AND METHODS

Field sampling

Fish are collected from three zones along the Palos Verdes Peninsula (**Figure 8.1)** consistent with the Local Bioaccumulation and Local Seafood Safety Surveys defined in the MRP. The three zones create a non-overlapping spatial gradient originating at the JWPCP discharge and extending down current of the outfall. The Outfall Zone (Zone 1) is inshore of the 150-meter depth contour and between White Point and Bunker Point. The Intermediate Zone (Zone 2) is inshore of the 150-meter depth contour between Portuguese Point and a line bearing 270 degrees off near Point Vicente and encompasses the Marine Protected Areas (MPAs) established in 2012. The Distant Zone (Zone 3) is inshore of the 150-meter depth contour between Palos Verdes Point and the south end of the Redondo Beach Pier.

A summary of the sampling parameters for these surveys, including targeted fish species, size ranges, tissue types, sampling periods, fishing methods, and collection depths, are presented in **Table 8.2**. Further details regarding the field sampling associated with the 2018-2019 surveys are discussed below.

Local Bioaccumulation Survey

White Croaker and Hornyhead Turbot for the Local Bioaccumulation Trends Survey are collected using an otter trawl. Consistent with previous trend surveys, sampling is initially targeted along the 61-meter isobath. If insufficient numbers of the target species are found at this depth, the trawls are moved incrementally inshore or offshore until ten consistent sized specimens of target species fish are collected from each zone. The specimens are individually wrapped, labeled, and frozen immediately after collection according to standard operating procedures (**Appendix 8.5**) for subsequent tissue processing and analysis in the laboratory.

In 2018, White Croaker samples were collected by otter trawl at night on the 7th and the 9th of November. For the 2019 effort, White Croaker samples were collected during night trawls between the 6th and the 7th of November. Hornyhead Turbot specimens were collected concurrently with trawls conducted for the Local Demersal Fish and Invertebrate Surveys (Chapter 6) between the 13th and the 20th of August and between the 12th and the 15th of August for the 2018 and 2019 surveys, respectively.

Local Seafood Safety Survey

The species targeted for the Local Seafood Safety Survey are representative of fish commonly caught and consumed by local fishers including benthic rockfish (Vermilion Rockfish, *Sebastes miniatus*), Kelp Bass (*Paralabrax clathratus*), Barred Sand Bass (*Paralabrax nebulifer*), surfperches (Black Perch, *Embiotoca jacksoni*), and White Croaker. Fishes are collected in relatively shallow water depth, where fishers would typically catch these species. In accordance with the JWPCP NPDES permit requirement, ten fish of each species are collected from each zone during the survey. The target size range for each species is based upon applicable

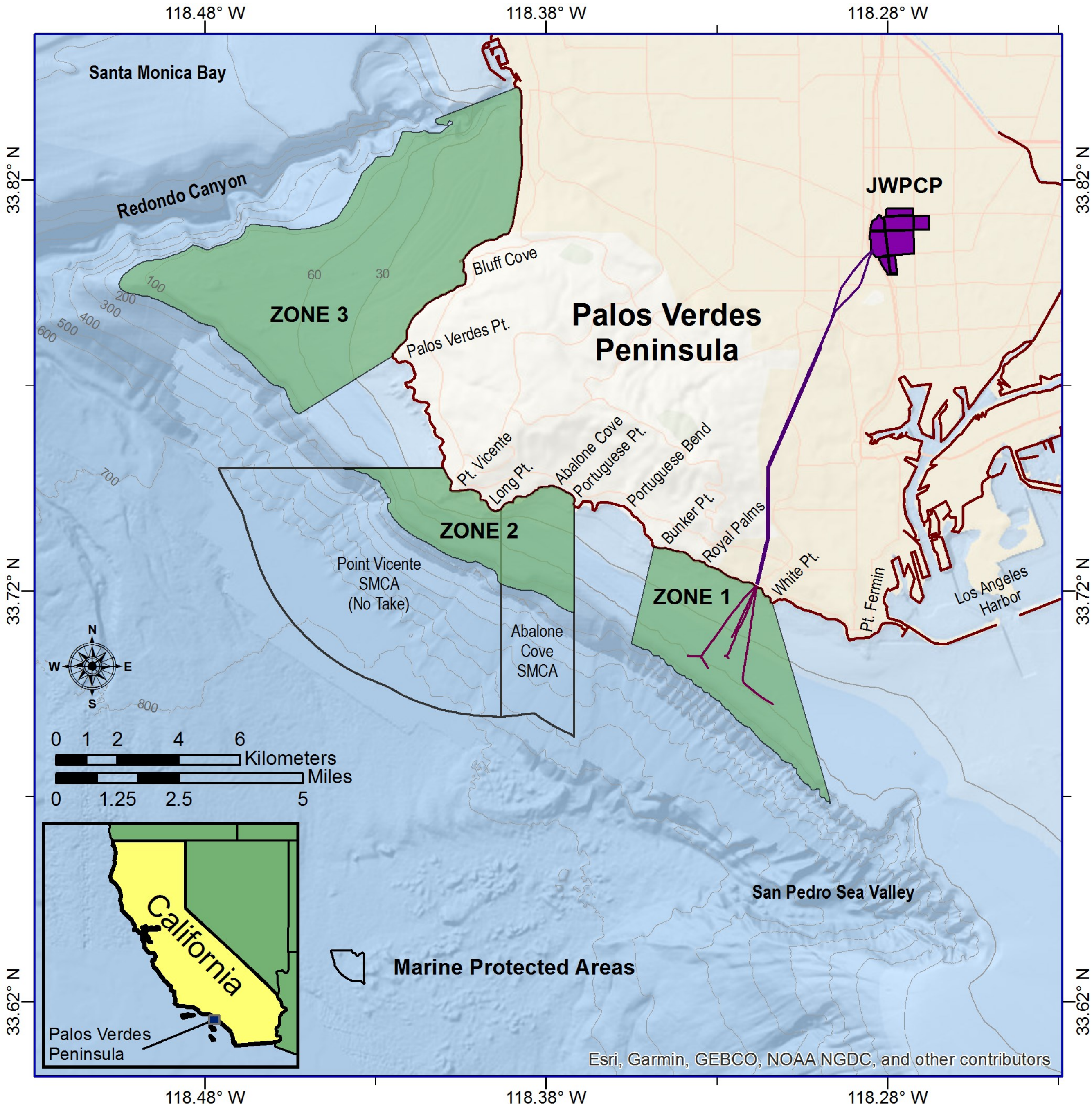

Figure 8.1 Fish Tissue Bioaccumulation Sampling Zones

Map of sampling zones associated with the local fish contamination trends and seafood safety monitoring programs.

Table 8.2 Targeted Fish Tissue Sampling Parameters

Summary of field sampling parameters and techniques for fish tissue contamination monitoring. Samples of Hornyhead Turbot, White Croaker, Vermilion Rockfish, Kelp Bass and Black Perch are composites of muscle or liver tissue from 10 individual fish. SL=standard length, T=trawl, NT=night trawl, H=hook and line, F=fish trap, S=spear.

Species	Size class (mm SL)	Tissue(s)	Sampling period	Fishing method(s)	Collection depth
Local Bioaccumulation Trends Monitoring (annually)					
Hornyhead Turbot (*Pleuronichthys verticalis*)	150-199	Muscle/Liver	Aug	T	22-62 m
White Croaker (*Genyonemus lineatus*)	174-200	Muscle	Nov	NT	43-57 m
Local Seafood Safety Survey (biennially, even numbered years)					
Vermilion Rockfish *(Sebastes miniatus)*	211-279	Muscle	Jul-Dec	H,F,S	24-86 m
Kelp Bass *(Paralabrax clathratus*)	284-378	Muscle	Jul-Dec	H,F,S	9-32 m
Barred Sand Bass (*Paralabrax nebulifer*)	285-370	Muscle	Aug-Dec	H,F,S	9-64 m
Black Perch (*Embiotoca jacksoni*)	180-235	Muscle	Aug-Nov	H,F,S	9-48 m
White Croaker (*Genyonemus lineatus*)	174-200	Muscle	Nov	NT	43-57 m

legal-size limits for the species, examination of available size frequency distribution data for the region, and USEPA guidance (USEPA 2000). Each individual fish is measured, wrapped, labeled, and frozen immediately according to standard operating procedures (**Appendix 8.6**) for subsequent tissue processing and analysis in the laboratory.

During the 2018 Local Seafood Safety Survey, all fish were collected by hook and line, fish trap and spear except White Croaker which was collected via trawl at night (Table 8.2). Vermilion Rockfish were collected between July 2nd and December 27th. Kelp Bass were collected from July 12th to December 18th. Black Perch were captured between August 27th and November 13th. Barred Sand Bass were caught from August 31st to December 27th. White Croaker used to monitor seafood safety were the same fish collected during the 2018 Local Bioaccumulation Survey discussed previously.

Tissue processing and analysis

All tissue sampling and fish tissue resections/processing were performed at the Sanitation Districts' Marine Biology Laboratory according to standard operating procedures. The tissue collection, homogenization procedures, and the analytical requirements for the Local Trends and Seafood Safety Surveys differed as described below.

Tissue sampling and homogenization procedures in the Local Bioaccumulation Surveys were consistent with previous trend monitoring procedures established in the early 1990s (Appendix 8.5). Specifically, skinless muscle tissue samples were obtained from the dorso-lateral musculature of each fish and weighed. The weight of all muscle tissue from each species' composite sample was standardized to the smallest mass and combined to form a single composite sample. This process ensured that each fish contributed the same amount of tissue to the composite. Composite samples of liver tissue from Hornyhead Turbots were created in the same manner. The composite samples were homogenized and extracted according to the Environmental Laboratory Accreditation Program (ELAP, **Appendix 8.7**) approved standard operating procedures prior to chemical analysis.

Consistent with the objectives of the Local Seafood Safety Survey, skinless muscle tissue samples were obtained by filleting the fish in a manner typical of sport fishers (Appendix 8.6). These “fisherman’s fillets” were homogenized individually to obtain a well-mixed sample representative of the average concentration in the fillet. Equal masses of homogenate from each fish of a particular species and zone were combined to form a single composite sample (Appendix 8.6). This sample was then extracted according to approved standard operating procedures prior to chemical analysis.

The analytical parameters measured in the Local Bioaccumulation Surveys include percent moisture, percent lipids, DDTs, total DDTs, PCBs as Aroclors, PCBs as congeners, total PCBs as Aroclors, and total PCBs as congeners. The Local Seafood Safety Survey samples were analyzed for the same parameters, with the addition of total mercury, arsenic and selenium.

Data analysis

Local Bioaccumulation Survey

Analysis of the Local Bioaccumulation Survey data is focused on the spatial distribution and historical trend of DDTs and PCBs in target tissues of sentinel species collected from the Outfall (Zone 1), Intermediate (Zone 2), and Distant Zones (Zone 3). All DDT and PCB data used to evaluate local trends are lipid-normalized to account for variations in tissue lipid content that may bias comparisons of tissue contamination between zones and over time. The spatial distributions of DDTs and PCBs in fish tissue between the three zones are displayed graphically for each survey year.

Historical trends include data for Hornyhead Turbot muscle and liver tissues from 2006 to 2019 and for White Croaker muscle tissue from 1990 to 2019, except 2014 when the LARWQCB granted a variance due to the sampling effort for the EPA Palos Verdes Shelf Superfund site remediation (USEPA, 2018). A longer data record for White Croaker exists in Zone 1, but methodological inconsistencies and the limited number of samples makes use of these data inappropriate for historical trends (LACSD 2006).

Mean lipid-normalized total DDTs and total PCBs data for each survey year are grouped by decade (1990s, 2000s and 2010s) to account for year-to-year random variability. Although treatment periods were used for historical trend analysis in other chapters of this report, decadal averages were used for the historical trends analysis in the bioaccumulation program analyses for two reasons. First, the significant discharge of DDTs and PCBs to the Palos Verdes shelf sediments ceased in the early 1970s due to source control efforts, not improved treatment. Presenting the historical trends data using treatment period would misinterpret any change in tissue concentration as being related to treatment. Second, Hornyhead Turbot data has only been collected (2006) since the plant was upgraded to full secondary treatment (late 2002) making a treatment based historical trend impossible.

The historical Local Bioaccumulation Survey data were analyzed for significant spatial and temporal changes using two-way analysis of variance (ANOVA; alpha = 0.05). Significant differences detected between zones and decades were further evaluated using a Student-Newman-Keuls multi-comparison all pairwise procedure (two-tailed, alpha = 0.05) to identify which zones or decades were significantly different from each other. Since the Hornyhead Turbot data only includes two decades, no multiple comparison tests were necessary to identify significant differences.

Local Seafood Safety Survey

Local Seafood Safety Survey results are displayed graphically by each zone and as an average for the entire PVS. Unlike the Local Bioaccumulation Surveys described previously, results of the Local Seafood Safety Survey were not lipid-normalized to reflect the concentration of contaminants associated with the consumption of the fish caught from that area in 2018. Where available, threshold values (OEHHA 2008) for fish tissue contamination developed for the protection of human health are also included in the figures to provide context for the results in terms of health risk.

RESULTS

All targeted fish species for the 2018 and 2019 Local Bioaccumulation Survey and the 2018 Local Seafood Safety Survey were collected from every zone within the parameters listed in Table 8.2. Data summary reports consisting of complete data sets for the 2018 and 2019 surveys were submitted to the LARWQCB electronically by September 1 of 2019 (LACSD 2019) and 2020 (LACSD 2020b), respectively.

Local Bioaccumulation Survey

Results for lipid-normalized total DDTs and total PCBs from the 2018 and 2019 Local Bioaccumulation Trends Surveys are provided in **Figure 8.2** and **Appendix 8.8**. Lipid-normalized total DDT concentrations in Hornyhead Turbot ranged from 145 (Zone 3, muscle) to 3,048 µg/kg wet weight (Zone 1, liver) in 2018 and from 209 (Zone 3, muscle) to 2,648 µg/kg wet weight (Zone 1, liver) in 2019. The concentration of total lipid normalized DDTs in White Croaker ranged from 250 (Zone 2) to 408 µg/kg wet weight (Zone 1) in 2018 and from 147 (Zone 3) to 459 µg/kg wet weight (Zone 1) in 2019. The prevailing forms of DDTs found in all years, species, tissues and zones were 4,4'-DDE and 2,4'-DDE. DDDs were consistently detected in the fish tissue although at much lower levels than DDE. 2,4'-DDT was not detected in muscle tissues of White Croaker and Hornyhead Turbot from all zones. 4,4'-DDT was not detected in White Croaker muscle tissue and Hornyhead Turbot liver and muscle tissue from the Intermediate Zone (Zone 2) and Distant Zone (Zone 3).

PCBs were detected in all samples for White Croaker and Hornyhead Turbot, except for Hornyhead Turbot muscle tissue in Zone 3, which was under reportable levels in 2018. Lipid-normalized total PCBs in Hornyhead Turbot ranged from none detected (Zone 3, muscle) to 412 (Zone 1, liver) µg/kg wet weight in 2018 and between 85 (Zone 3, muscle) and 530 (Zone 1, liver) µg/kg wet weight in 2019. The lipid-normalized concentration of total PCBs in White Croaker muscle ranged from 64.2 (Zone 3) to 75.7 µg/kg wet weight (Zone 1) in 2018 and from 59.0 (Zone 2) to 95.2 µg/kg wet weight (Zone 1) in 2019. The prevailing forms of PCBs found in all years, species, tissues and zones were Aroclor 1254 and Aroclor 1260. The lipid normalized total PCB congeners for Hornyhead Turbot liver tissue range from 64.7 (Zone 3) to 167.5 µg/kg wet weight (Zone 1) in 2018 and from 58.0 (Zone 3) to 235.2 µg/kg wet weight (Zone 3) in 2019. The prevailing forms of PCB congeners during the 2018-2019 surveys were PCB congeners 66, 118, 138 and 153. Results for total DDTs, total PCBs and PCB congeners in White Croaker and Hornyhead Turbot tissues are listed in Appendix 8.8.

Local Seafood Safety Survey

Table 8.3 summarizes the results from the 2018 Local Seafood Safety Survey. White Croaker had the highest concentrations of DDTs and PCBs. The PCB results for Black Perch and Kelp Bass were below the reporting limits at all three zones; in Zone 3, PCBs were detected only in White Croaker. Similar to the Local Bioaccumulation Survey results, the primary form of DDTs in these samples was 4,4'-DDE while Aroclors 1254 and 1260 were almost exclusively associated with PCB contamination. Analysis of PCB congeners found that only White Croaker and Barred Sand Bass had detectable concentrations, while PCB congeners PCB-138 and 153 were the most prevalent.

Metal analyses in the 2018 Local Seafood Safety Survey found that the highest mean levels of mercury, arsenic and selenium were in the Barred Sand Bass in Zone 3 (339 µg/kg wet weight), the Vermilion Rockfish in Zone 2 (3,910 µg/kg wet weight) and the Vermilion Rockfish in Zone 1 (548 µg/kg wet weight), respectively. The least contaminated fish species in terms of mercury and arsenic were the Black Perch in Zone 1 (48.8 µg/kg wet weight) and the Kelp Bass in Zone 1 (862 µg/kg wet weight), respectively. Selenium levels were not detected for Black Perch in Zones 1 and 2.

DISCUSSION

The main objectives of the fish bioaccumulation monitoring requirements in the MRP are to identify the spatial and historical trends in fish contamination levels near the discharge and provide information relevant to assessing the health risk of locally caught sport fish consumed by humans and wildlife. During the 2018-2019 monitoring period, the Sanitation Districts collected fish samples to access local trends and human health risk objectives. Results of the Regional Predator Risk Survey conducted as a part of the Bight'13 Regional Monitoring Program can be downloaded at [the website for the Southern California Coastal Water Research Project](#).

Current condition

The current pattern of fish tissue contamination with DDTs and PCBs is a gradient with the highest concentrations found near the outfall (Zone 1) and decreasing down current (Figure 8.2, Appendix 8.8). The gradient pattern is consistent across years (2018-2019), species, tissues, and chemical constituents, except for a minor deviation observed between Zone 2 and Zone 3 for DDTs in White Croaker muscle tissue

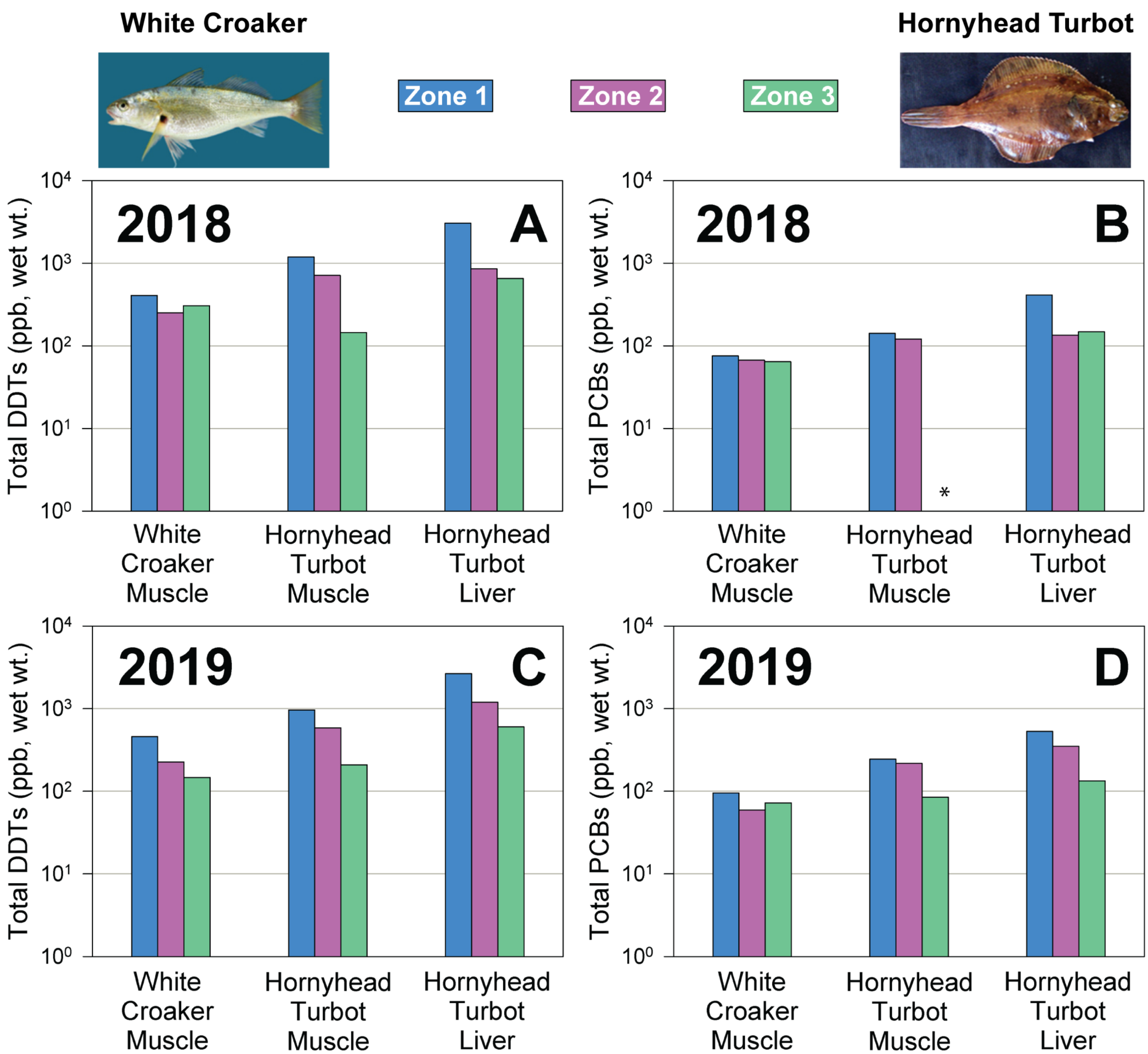

Figure 8.2 Spatial Trends in Fish Tissue Contamination

Spatial trends in lipid normalized total DDTs and total PCBs in fish tissues collected from the Palos Verdes shelf in 2018 (A and B) and 2019 (C and D). Asterisk (*) denotes analytical results below the reporting limit (10 ug/kg wet weight).

(2018), and for PCBs in Hornyhead Turbot liver tissue (2018) and White Croaker muscle tissue (2019), likely due to sampling variability. This same general pattern has been reported previously (LACSD 2008, LACSD 2010, LACSD 2012, LACSD 2014a, LACSD 2016, LACSD 2018) and is consistent with the documented discharge of DDTs and PCBs through the White Point outfall prior to the 1970s (Chapter 1).

This outfall-centric gradient of fish contamination with DDTs and PCBs is even more pronounced with an analysis of data collected since the 1990s. (**Figure 8.3, Appendix 8.9**). Regardless of species, tissue type, or chemical class, mean contamination levels are significantly higher in the Outfall Zone (1) in comparison to the other two zones. Although not always statistically significant, mean fish tissue contamination in the Intermediate Zone (2) is always greater than in the Distant Zone (3). These spatial trends in fish tissue contamination are consistent with the gradient of total DDTs and PCBs in sediments found along the Palos Verdes shelf (Chapter 4).

Historical trends

From the early 1990s, analyses of DDTs and PCBs in White Croaker muscle tissue have been measured repeatedly in three zones along the Palos Verdes shelf. The limited number of fish collected per zone each year combined with normal between-fish variability in contamination observed in this species (LACSD 2005) makes year-to-year comparisons for historical trends potentially misleading. Therefore, historical trends have been examined by comparing White Croaker muscle tissue contamination levels in the 1990s, 2000s, and the 2010s. In 2006, the Hornyhead Turbot was added as a bioaccumulation indicator species to the JWPCP NPDES permit. Therefore, historical trends analysis for hornyhead turbot is only presented for the past two decadal periods (2000s and 2010s).

Significant declines in the concentrations of total DDTs and PCBs in White Croaker muscle were observed between the 1990s and the subsequent two decadal periods (**Figure 8.4**, Appendix 8.9). Mean levels of contamination in

Table 8.3 Local Seafood Safety Data Summary

Fish tissue contamination data summary from the 2018 local seafood safety survey. Asterisk(*) denotes samples with total PCBs and Selenium are below the reporting limit (RL) of 10 and 200 µg/kg wet weight, respectively.

Species	Zone	Total DDTs (ppb)	Total PCBs (ppb)	Mercury (ppb)	Selenium (ppb)	Arsenic (ppb)	Total Lipids (%)	Moisture (%)
White Croaker (*Genyonemus lineatus*)	1	1,950	554	70.4	544	1,840	7.20	72.5
	2	795	301	85.8	522	1,820	4.30	75.6
	3	874	395	102	386	1,970	5.80	74.8
Barred Sand Bass (*Paralabrax nebulifer*)	1	314	91.9	242	438	1,480	1.10	76.4
	2	107	66.5	221	294	1,320	0.49	78.4
	3	233	*	339	313	1,340	0.36	77.7
Vermilion Rockfish (*Sebastes miniatus*)	1	110	17.8	53.7	548	2,160	0.67	77.8
	2	51.1	*	133	304	3,910	0.64	78.2
	3	44.4	*	58.6	303	3,580	1.20	78.4
Black Perch (*Embiotoca jacksoni*)	1	43.9	*	48.8	*	1,550	3.50	78.2
	2	49.5	*	56.1	*	1,630	0.73	77.9
	3	116	*	129	266	1,670	0.34	79.4
Kelp Bass (*Paralabrax clathratus*)	1	54.2	*	175	328	862	0.39	78.6
	2	40.7	*	237	313	1,140	0.74	78.1
	3	38.9	*	277	292	1,550	0.52	78.3

White Croaker have also significantly decreased between the 2000s and 2010s for DDTs and PCBs.

No statistically significant decreases in DDT and PCB contamination were observed between the 2000 and 2010 decadal periods in Hornyhead Turbot liver and muscle tissues. Although a slight decrease in concentrations of DDTs and PCBs for Hornyhead Turbot liver tissue between 2000s and 2010s was observed, the decline was not statistically significant (Figure 8.4). The lack of a statistically significant trend in Hornyhead Turbot contamination may be due to insufficient sample size, as the Sanitation Districts only began to collect this species in 2006.

However, the results from White Croaker clearly demonstrate that a historical trend of declining tissue contamination levels. This trend appears to be associated with declining concentrations of total DDTs and PCBs in surficial sediments along the Palos Verdes shelf over the past forty years (Chapter 4). Several processes are responsible for these declines in sediment contamination, such as continual flux and transport of sediment porewater into the water column (Fernandez et al. 2014), transport of contaminated sediments off the shelf (Lee et al. 2002), burial by clean sediments (LACSD 2014b), and *in situ* degradation (Eganhouse and Pontolillo 2008). These processes are expected to continue and

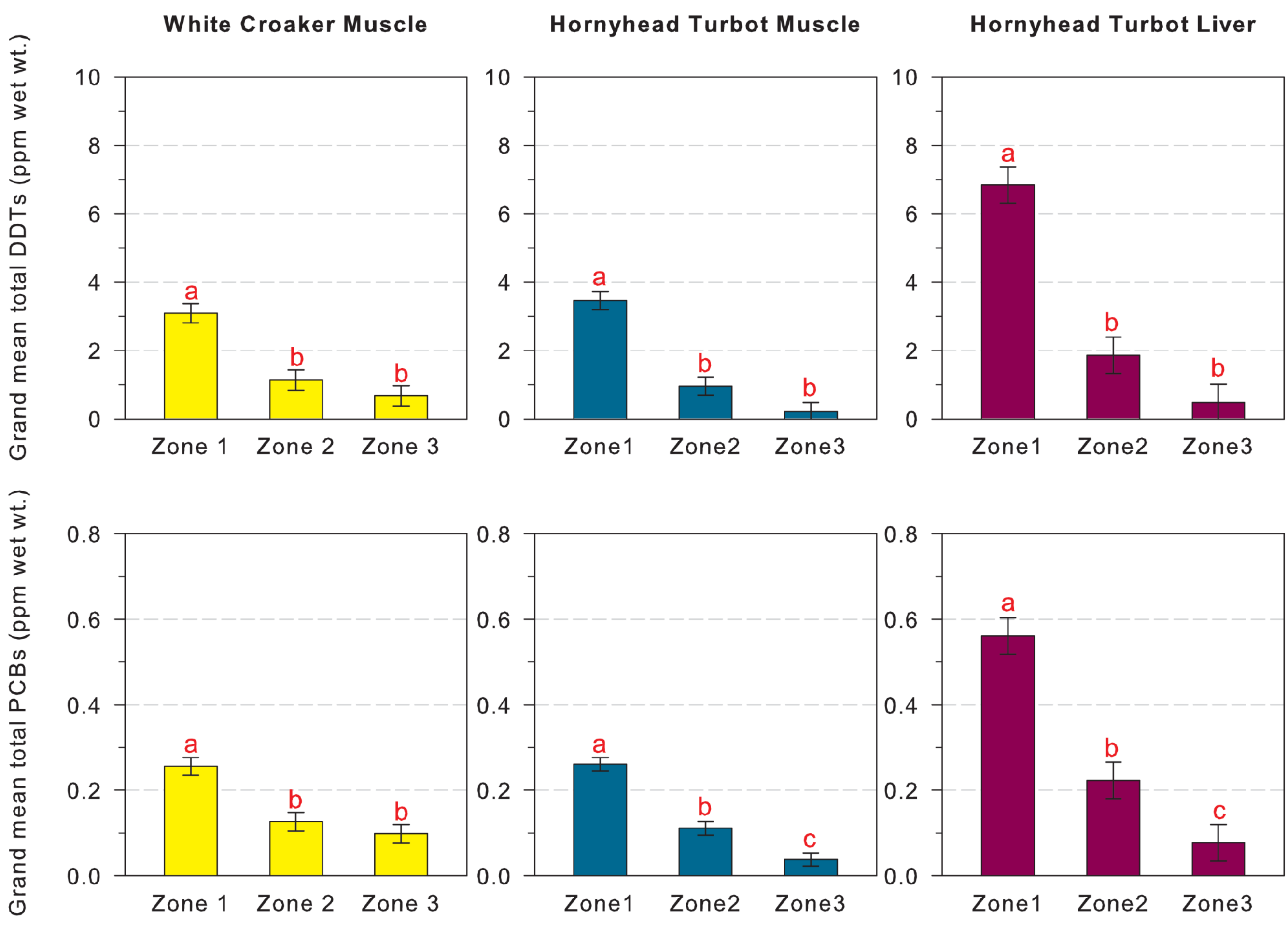

Figure 8.3 Spatial Trends Analysis of Fish Tissue Contamination

Two-way analysis of variance (ANOVA) of spatial trends in historical lipid normalized total DDTs and total PCBs in White Croaker muscle tissue (1990-present, except 2014) and Hornyhead Turbot muscle and liver tissue (2006-present) collected from Outfall Zone (Zone 1), Intermediate Zone (Zone 2) and Distant Zone (Zone 3) on the Palos Verdes shelf. Bars represent the grand mean of average concentrations from individual survey years for each zone. Error bars represent the model estimated standard error of the grand mean. Bars with different lowercase letters are statistically different while those that share a common letter are statistically similar (two-tailed; alpha = 0.05). Significant interaction was found between spatial and historical trends for both contaminants indicating the differences between zones vary depending on the decade.

further reduce fish exposure to DDTs and PCBs in the future.

Local Seafood Safety Survey

Applicable fish tissue contamination thresholds

Many factors are considered in evaluating human health risks associated with the consumption of locally caught seafood. Meal size, consumption frequency, preparation and cooking practices, length of exposure (acute or chronic), toxicological endpoint relevancy, acceptable risk level, and sensitivity of the consumer (adults, pregnant women, children, *etc*.) are some of the many key factors. Each variable also has uncertainties and/or variability that can greatly influence the estimation of risk associated with seafood consumption. As a result, agencies responsible for the protection of human health often differ in fish tissue contamination thresholds and consumption guidelines, based on their assumptions for these factors.

The primary agency responsible for establishing safe seafood consumption guidelines within the State of California is OEHHA. In 1991, OEHHA established 100 µg/kg wet weight as the maximum concentration of DDTs and PCBs allowed in fish tissues for unrestricted consumption (OEHHA 1991). The CDPH also issued an Advisory Limit of 0.5 mg/kg wet weight for mercury in fish tissue (Mearns et al. 1991).

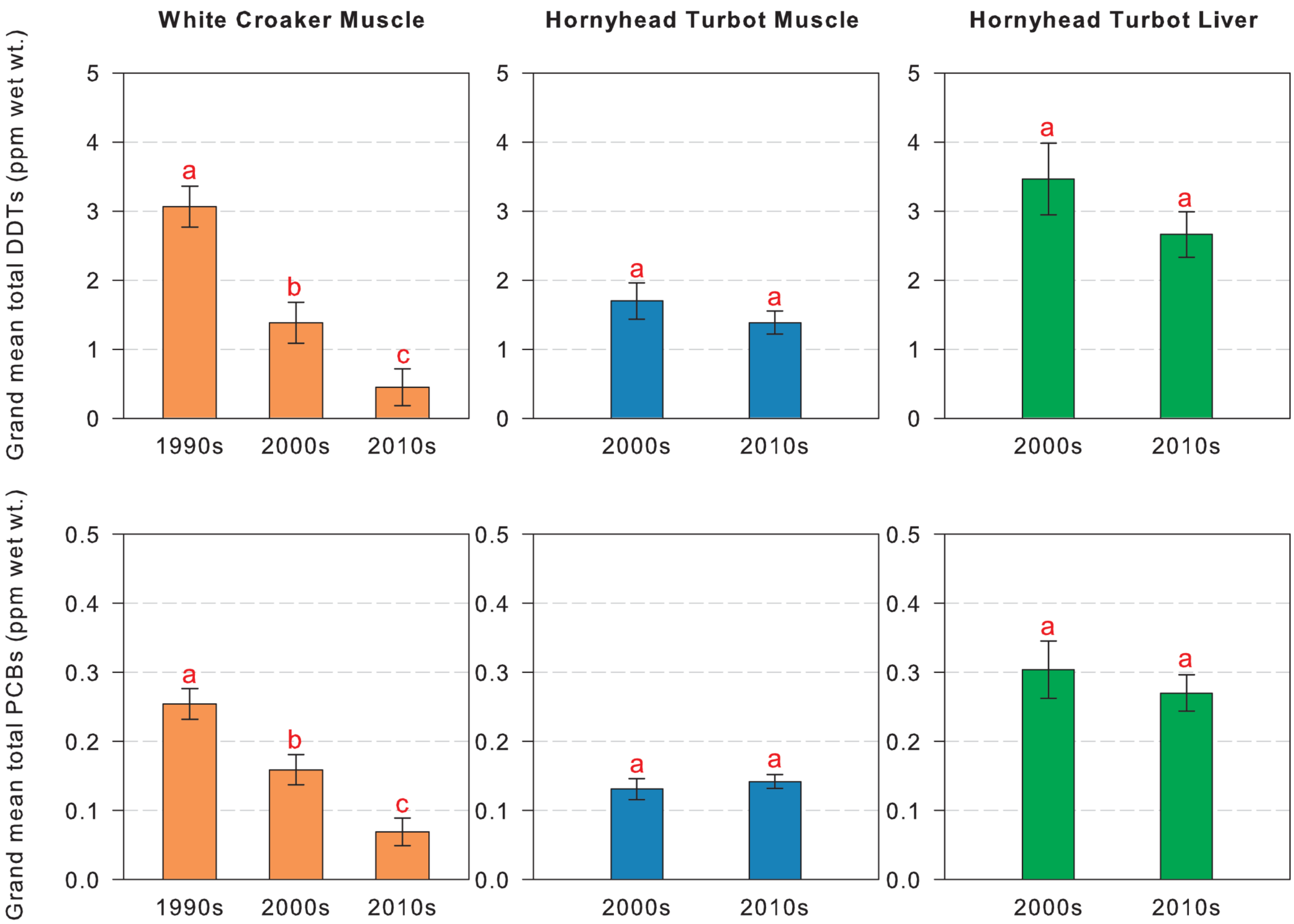

Figure 8.4 Historical trends Analysis of Fish Tissue Contamination

Two-way analysis of variance (ANOVA) of historical trends in lipid normalized total DDTs and total PCBs in White Croaker muscle tissue (1990-present, except 2014) and Hornyhead Turbot muscle and liver tissue (2006-present) collected from the three zones on the Palos Verdes shelf. Bars represent the grand mean of average concentrations from all zones in each decade. Error bars represent the model estimated standard error of the grand mean. Bars with different lowercase letters are statistically different while those that share a common letter are statistically similar (two-tailed; alpha = 0.05). Significant interaction between spatial and historical trends was found for both contaminants indicating the rate of change between decades is influenced by distance away from the outfall.

These guidelines were revised in 2008 to reflect current analytical capabilities, toxicological information, and consumption practices (OEHHA 2008). The final report included two benchmarks: Fish Contaminant Goals (FCGs) and Advisory Tissue Levels (ATLs).

FCGs are estimates of contaminant levels in fish that pose no significant health risk to individuals consuming sport fish at a standard consumption rate of 8 ounces/week (32 gram/day), prior to cooking, over a person's lifetime. FCGs serve as a starting point for OEHHA to assist other agencies who wish to develop fish tissue-based criteria for pollution mitigation or elimination. However, FCGs are based solely on public health without regard to economic considerations, technical feasibility, or the benefits of fish consumption.

The Advisory Tissue Levels (ATLs) were developed to balance the benefits of eating fish with the potential risk of contaminants consumed in fish tissue over a lifetime and are the basis for current consumption guidelines within the SCB. The most conservative ATLs allow the safe consumption of fish in 8-ounce servings three times a week. The three meals/week ATLs for DDTs and PCBs are 520 and 21 µg/kg wet weight, respectively (**Appendix 8.10**). The three meals/week ATLs for mercury are differentiated by gender and age due to the greater sensitivity of developing fetuses and children to the effects of mercury. The mercury ATL for adult males and women over 45 is 220 µg/kg wet weight and the mercury ATL for children (under 18) and women under 45 (childbearing age) is 70 µg/kg wet weight. Additionally, the NPDES permit revised in 2017 requires the Sanitation Districts to monitor selenium concentration in fish tissue. The three meals/week ATLs for selenium is 2,500 µg/kg wet weight.

The OEHHA guidance also provides ATLs that, when exceeded, identify fish that should not be eaten at all. The no consumption ATLs for DDTs and PCBs are 2,100 and 120 µg/kg wet weight, respectively. The mercury no consumption ATLs are 1,310 µg/kg wet weight for adult males and women over 45 and 440 µg/kg wet weight for children and women under 45. The ATLs of selenium for no consumption is 15,000 µg/kg wet weight. At this time, the State of California has not established any guidance values for arsenic in fish tissue (Appendix 8.10).

2018 Local Seafood Safety Survey

Comparisons of muscle tissue contamination levels in five locally caught sport fish species in relation to OEHHA ATLs (except arsenic) are provided in **Figure 8.5**. The results are presented for each zone as well as an average value for all three zones representing the entire Palos Verdes shelf. Due to fish and fisher movement patterns, it is likely that the Palos Verdes shelf would be evaluated as one water body when establishing any fish consumption guidelines.

The concentrations of DDTs in Barred Sand Bass, Vermilion Rockfish, Black Perch and Kelp Bass collected in all three zones and the Palos Verdes shelf average were below OEHHA's "No Consumption" ATL (2,100 µg/kg wet weight) and Three Meals/Week guideline (520 µg/kg wet weight, Figure 8.5A). White Croaker collected in all three zones and the Palos Verdes shelf average showed DDT concentrations higher than OEHHA's Three Meals/Week guideline, but lower than OEHHA's "No Consumption" ATL.

The concentrations of PCBs in White Croaker collected in all three zones exceed OEHHA's "No Consumption" ATL (120 µg/kg wet weight). Black Perch and Kelp Bass caught in all three zones were all under the reporting level (RL) of 10 µg/kg wet weight; The concentration of PCBs in Vermilion Rockfish was lower than the OEHHA's Three Meals/Week guideline (21 µg/kg wet weight) in Zone 1 and below detection in Zones 2 and 3. Barred Sand Bass exceeded the Three Meals/Week guideline but was below the "No Consumption" ATL for PCBs in Zones 1 and 2, and the Palos Verdes shelf average (Figure 8.5B).

The mercury concentrations in all five species collected from the Palos Verdes shelf were below the "No Consumption" mercury ATL for women under age 45 and children under age 18 (440 µg/kg wet weight). The mercury concentrations in Barred Sand Bass collected in all three zones, and Kelp Bass collected in Zones 2 and 3 and the Palos Verdes shelf exceeded the Three Meals/Week mercury ATL for adult men and women over age 45 (220 µg/kg wet weight). The mercury concentrations in Vermilion Rockfish caught in Zones 1 and 3 and Black Perch caught in Zones 1 and 2 were below the Three Meals/Week mercury ATL for women under age 45 and children under age 18 (70 µg/kg wet weight). The spatial pattern demonstrated that all fish collected in Zone 3 have higher mercury concentrations except Vermilion Rockfish (Figure 8.5C). Unlike DDTs and PCBs, the spatial pattern of mercury contamination does not indicate the discharge from JWPCP is the primary source of mercury contaminant. Rather, the gradient of contamination suggests that Santa Monica Bay, adjacent to Zone 3, may be the primary source of mercury contamination on the Palos Verdes shelf (Bay et al., 2015, Dodder et al., 2016).

The 2017 JWPCP NPDES permit revision appended the monitoring of selenium concentration in fish tissue. The selenium concentrations range from not detected (Black Perch, Zones 1 and 2) to 548 µg/kg wet weight (Vermilion Rockfish, Zone 1). The selenium concentrations of all caught species were below OEHHA's Three Meals/Week selenium ATL (2,500 µg/kg wet weight, Figure 8.5D).

The Palos Verdes shelf average concentrations of arsenic were highest in Vermilion Rockfish (Figure 8.5E). Mean arsenic concentrations for all five species ranged from 1,184 to 3,217 µg/kg wet weight while the highest arsenic concentrations were detected in Vermilion Rockfish in Zone 2 (3,910 µg/kg wet weight) and Zone 3 (3,580 µg/kg wet weight). Human health risk from local consumption of these species cannot be assessed because neither FCGs nor ATLs have been established by the State of California. However, the arsenic levels detected in these sport fish exceeded the range of means (390 -5,380 µg/kg wet weight) found in 14 sport fish species collected from Newport Bay, California (Allen et al. 2004).

Spatial trends for total DDTs and PCBs in White Croaker were consistent with results from the Local Bioaccumulation Trends Survey in that the highest concentrations were generally found in fish collected in the Outfall Zone (1) with lower concentrations observed further away from the outfall area (Zones 2 and 3). The same spatial pattern was not evident for mercury, selenium or arsenic. The highest concentrations of mercury were often found in the Distant Zone (3) and the lower concentrations were often associated with the Outfall Zone (1) and/or Intermediate Zone (2). These results suggest that the source of these contaminants to the Palos Verdes shelf was more diffuse and not primarily associated with historical or current JWPCP discharges.

CONCLUSIONS

Sediments contaminated by historic discharge of DDTs and PCBs to the Palos Verdes shelf through the JWPCP outfall at White Point remain the key source for bioaccumulation of these compounds in fish. White Croaker continues to carry significant body burdens of DDTs and PCBs, which are persistent in the Palos Verdes shelf sediments. The general spatial pattern shows that the highest tissue concentrations of DDTs and PCBs are adjacent to the outfall system and decrease with distance from the discharge zone. Statistically significant declines in White Croaker DDT and PCB tissue contamination with DDTs and PCBs have been observed along the PVS since the 1990s. Similarly, decreases in DDT and PCB in Hornyhead Turbot, particularly in the liver tissue, were observed between 2000 and 2010s but these declines were not statistically significant. The contaminant flux, sediment transport, burial, and biochemical transformation processes responsible for the observed declines are likely to lead to a continual decrease in DDT and PCB tissue concentrations.

The biennial Local Seafood Safety Survey found that White Croaker remains the most contaminated species for DDTs and PCBs. The tissue concentrations exceeded OEHHA's Three Meals/Week ATL for total DDTs (520 µg/kg wet weight) and "No Consumption" ATL for total PCBs (120 µg/kg wet weight). The other four species were below the Three Meals/Week ATL for both DDTs and PCBs (Figure 8.5). Concentrations of selenium were below the Three Meals/Week ATL for all five species collected off the Palos Verdes shelf. Mercury concentrations were below the No Consumption ATL for all five species, but sometimes exceeded the Three Meals/Week ATLs, depending on the species and location. Although no ATL has been developed by OEHHA for arsenic, elevated arsenic concentrations for Vermilion Rockfish collected in Zones 2 and 3 were observed in the 2018 Seafood Safety survey. Overall, the Local Seafood Safety Survey results are consistent with the JWPCP outfall as the likely source of contamination for DDTs and PCBs; however, it does not appear to be the source for mercury, selenium, or arsenic found in the local fish.

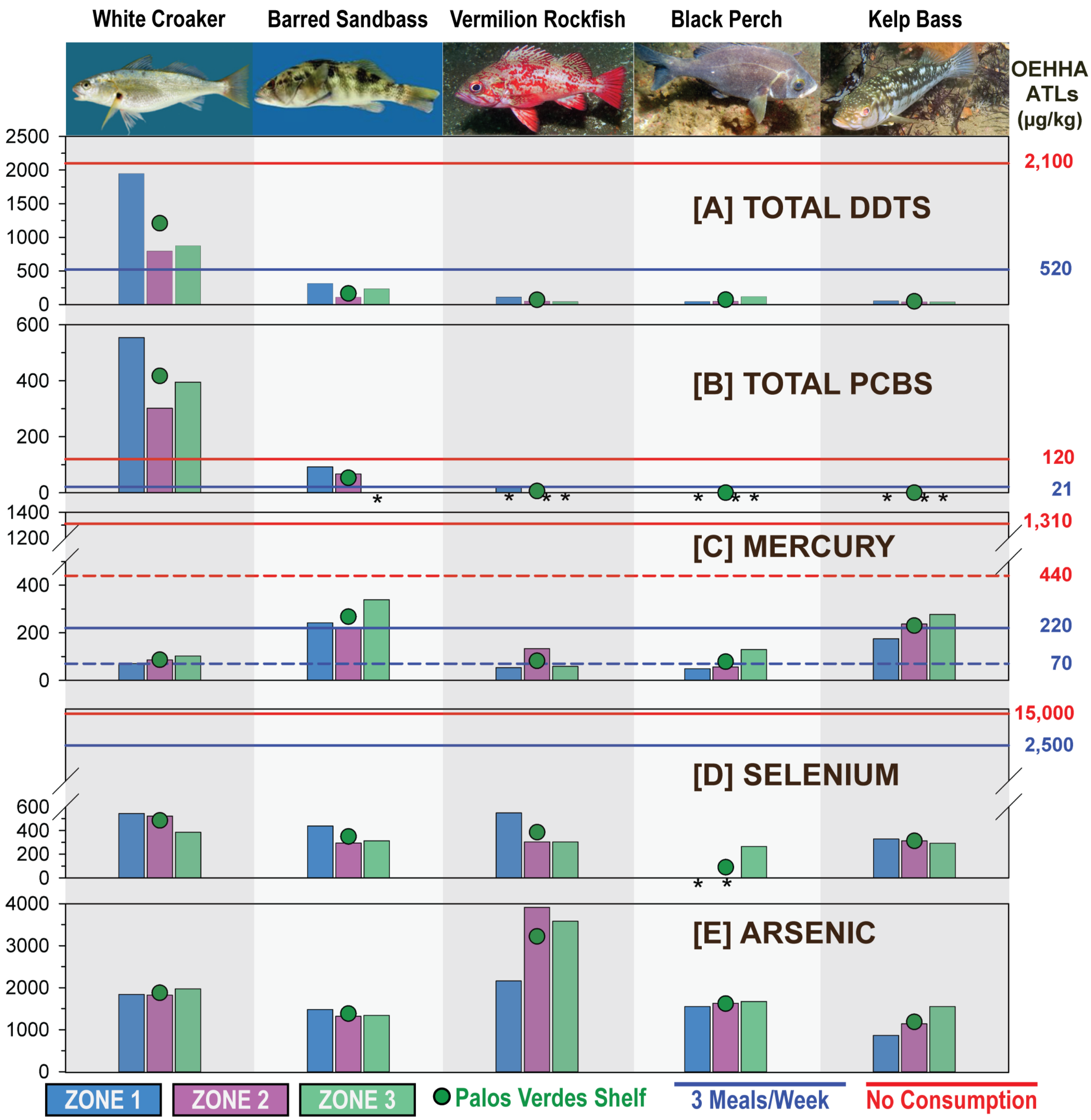

Figure 8.5 Assessment of Local Seafood Safety

Total DDTs [A], total PCBs [B], mercury [C], selenium [D], and arsenic [E] concentrations in muscle tissue of five species of sportfish collected in 2018 from three zones (Figure 9.1) on the Palos Verdes shelf. Contaminant concentrations for the Palos Verdes shelf (green circle) in each species were calculated as the mean concentration for the three sampling zones. Muscle tissue contaminant concentrations are compared with current California Department of Health Services Office of Environmental Health Hazard Assessment (OEHHA) Advisory Tissue Levels (ATLs) for three 8 ounce meals per week (blue lines) and no consumption (red lines). ATLs for mercury are differentiated by gender and/or age. The ATLs for women over 45 and all men are displayed as solid lines while the ATLs for children (under 18) and women under 45 are represented by the dashed lines. There are no current or proposed OEHHA ATLs for arsenic. Asterisk (*) denotes Total PCBs and Selenium values below the reporting limit (RL) of 10 µg/kg wet weight and 200 µg/kg wet weight, respectively.

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