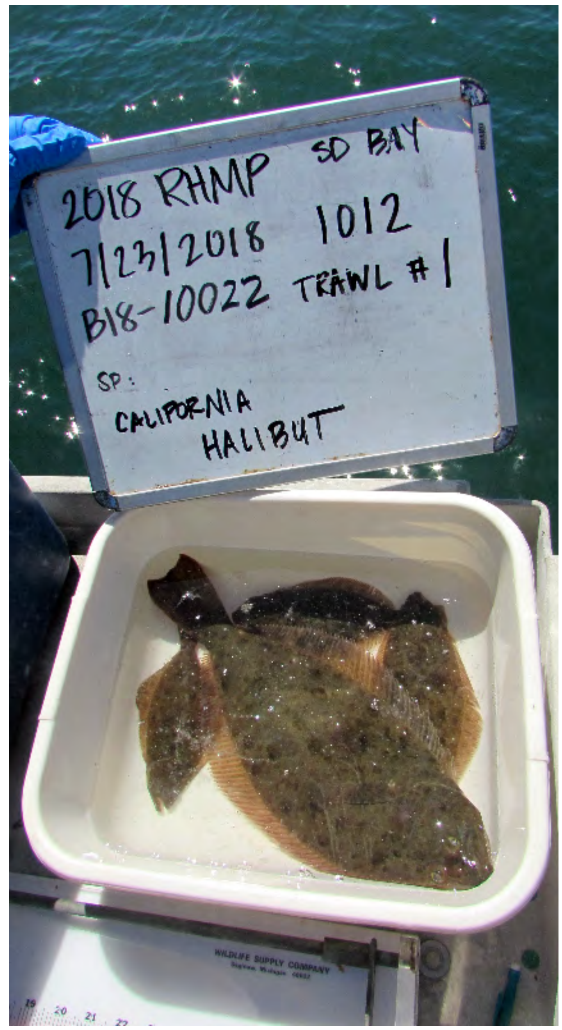
Contaminant Bioaccumulation in Edible Sport Fish Tissue



BIGHT '18

SURFACE WATER AMBIENT MONITORING PROGRAM

Southern California Bight
2018 Regional Monitoring Program
Volume V

SCCWRP Technical Report #1155

Southern California Bight 2018 Regional Monitoring Program Volume V: Contaminant Bioaccumulation in Edible Sport Fish Tissue

Produced by the
Southern California Bight 2018 Regional Monitoring Program
in partnership with the
Surface Water Ambient Monitoring Program

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FOREWORD

This study is the result of a productive collaboration between the California State Water Resources Control Board's Surface Water Ambient Monitoring Program (SWAMP) and the Southern California Bight 2018 Regional Marine Monitoring Program (Bight '18). This project is a part of a larger coordinated survey of the entire California coast. The SWAMP coastal survey is one of the largest sport fish surveys of its kind, sampling 65 coastal locations along the California Coast. The survey analyzes sport fish because they provide information on potential human exposure to contaminants and on the condition of the aquatic food web. The current survey is the second SWAMP coastal bioaccumulation in sport fish survey; the first was conducted in 2009-2010, wherein the Southern California Bight (SCB) was sampled in 2009. This report is focused on results from the 27 SCB locations sampled in 2018. Sampling in 2019, 2020, and 2021 will cover the remainder of the California coast. The monitoring plan and reports from the previous survey are available for download on the SWAMP Bioaccumulation Oversight Group (BOG) website: https://www.waterboards.ca.gov/water_issues/programs/swamp/coast_study.html.

Bight '18 is an integrated, collaborative effort to provide large-scale assessments of SCB. The Bight '18 survey is an extension of previous regional assessments conducted every five years dating back to 1994. This collaboration represents the combined efforts of nearly 100 organizations. Bight '18 is organized into five elements: 1) Sediment Quality (formerly Contaminant Impact Assessment/Coastal Ecology); 2) Microbiology; 3) Ocean Acidification; 4) Harmful Algal Blooms; and 5) Trash. This assessment report presents the results of the contaminant bioaccumulation in sport fish tissue portion of the survey, which is one component of the Sediment Quality element. Agencies providing support to the Contaminant Bioaccumulation in Edible Sport Fish Tissue study include: The San Diego Regional Harbor Monitoring Program, City of San Diego, Orange County Sanitation District, Orange County Public Works, Los Angeles County Sanitation Districts, City of Los Angeles Environmental Monitoring Division, and Physis Environmental Laboratory. Copies of this and other Bight '18 reports, as well as workplans and quality assurance plans, are available for download on SCCWRP's Regional Monitoring website: https://www.sccwrp.org/about/research-areas/regional-monitoring/southern-california-bight-regional-monitoring-program/.

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This report is a result of the dedication and hard work of many individuals who share a common goal of improving our understanding of the environmental quality of the Southern California Bight (SCB). The authors wish to thank the members of the Bight ‘18 Sediment Quality Planning Committee and the SWAMP Bioaccumulation Oversight Group (BOG) for their assistance with study design, sample analysis, data analysis, and report review. We also thank the Bight ‘18 Sediment Quality Planning Committee for their guidance and support of fish tissue chemistry measurements in regional monitoring and the Bight ‘18 Chemistry Committee for developing laboratory quality assurance and quality control practices and for their thoughtful review of the data. This study would not have been possible without the expertise in sample collection of the California Department of Fish and Wildlife. Support for fish tissue analysis was provided by the City of Los Angeles, City of San Diego, Orange County Public Works, Orange County Sanitation District, Physis Environmental Laboratory, San Diego Regional Harbor Monitoring Program, and Los Angeles County Sanitation Districts. Fish tissue chemistry measurements were conducted by the following laboratories: City of Los Angeles, Environmental Monitoring Division, City of San Diego, Los Angeles County Sanitation Districts, Orange County Sanitation District, Moss Landing Marine Laboratories, and Physis Environmental Laboratory.

ABSTRACT

Marine recreational fisheries in California are economically, socially, and culturally important; however, in urban ocean environments, consumption of contaminated seafood may present a human health risk. Recognizing that fish provide unique nutritional benefits while also serving as an exposure pathway for several chemicals of concern, the California Environmental Protection Agency Office of Environmental Health Hazard Assessment (OEHHA) developed Advisory Tissue Levels (ATLs) to be used in developing consumption recommendations to protect the overall health of fish consumers. ATLs provide the number of recommended fish servings that correspond to ranges of contaminant concentrations found in edible fish tissues. This study presents the results of a 2018 survey designed to characterize the extent and magnitude of bioaccumulation of contaminants in sport fish in the Southern California Bight (SCB) relative to ATL thresholds. Results were compared to those from a similar survey conducted in 2009. Of the contaminants measured in 2018, mercury most frequently exceeded ATL thresholds. Most zones exceeded the threshold for mercury concentrations in one or more target species for which people are advised to “consume not more than 2 servings per week.” Total Polychlorinated biphenyls (PCBs) were the only other contaminant for which fish tissues exceeded ATL thresholds, exceeding the least restrictive threshold (do not consume more than 7 servings per week) in a third of fishing zones. However, neither mercury nor total PCBs exceeded the most restrictive, “do not consume”, threshold. Total dichlorodiphenyltrichloroethanes (DDTs) and selenium concentrations were below all ATL thresholds in all fish sampled in this survey. While results in this study indicate that fish can generally be consumed a minimum of one serving per week, other local assessments of seafood safety during this same sampling period measured fish tissue levels that exceed the most restrictive “do not consume” threshold in some species. Therefore, the results from this study should not be used independently to assess local risk in any zone, but rather provide a regional assessment of sport fish contamination. To assess local angler risk, more species and composites of each species should be analyzed. Concentrations of contaminants in fish tissues have generally decreased since the 2009 survey. There has been a regional decrease in mercury, selenium, DDTs and PCBs in both Pacific Chub Mackerel and Kelp Bass, the two target species caught in the largest number of zones in both surveys. However, length-adjusted mercury values did not show a significant decline, emphasizing the importance of standardization in evaluating trends.

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Abbreviation	Definition
ANOVA	Analysis of Variance
ATL	Advisory Tissue Level
Bight ‘18	Southern California Bight 2018 Regional Marine Monitoring Program
BOG	Bioaccumulation Oversight Group
CV	Coefficient of variation
DDTs	Sum of measured dichlorodiphenyltrichloroethane congeners
g	gram
LACSD	Los Angeles County Sanitation Districts
MLML	Moss Landing Marine Laboratories
ng	nanogram
NPDES	National Pollutant Discharge Elimination System
OEHHA	California Office of Environmental Health Hazard Assessment
p	P-value, calculated probability
PCBs	Sum of measured polychlorinated biphenyls congeners
QA/QC	Quality Assurance and Quality Control
R	proportion of variance explained by regression analysis
R^2	coefficient of determination in regression analysis
SCB	The Southern California Bight
SE	standard error
SWAMP	Surface Water Ambient Monitoring Program
US EPA	United States Environmental Protection Agency
ww	wet weight

I. INTRODUCTION

Marine recreational fisheries in California are economically, socially, and culturally important. In 2015, more than 1.2 million anglers spent almost $2.5 billion on travel and durable goods during 5.8 million fishing trips in California (Schnaker et al. 2015). In the Southern California Bight (SCB), more than six million sport fish were landed by recreational anglers in 2018 alone and over half of these landings were retained by the angler (RecFIN 2020). Consumption of sport fish is also an important food source for the population, with nearly one-third of recreational and subsistence fishers surveyed in Los Angeles County reportedly consuming their catch (Pitchon and Norman 2012).

SCB coastal habitats are vulnerable to anthropogenic impacts, putting local fisheries at risk. More than 20 million people live within an hour's drive of the coast and coastal infrastructure includes 17 wastewater treatment facilities, the nation's two largest commercial ports, more than 20 pleasure craft harbors, and the nation's third-largest naval facility (Lyon and Stein 2009). Additionally, there are 17 major watersheds that discharge largely untreated surface runoff from urban and agricultural land uses to the SCB. As a result of these coastal human influences, the SCB has a long history of sediment contamination. These sediment quality impacts have been at the forefront of environmental management efforts for nearly five decades, and consequently, sediment quality has steadily improved in the SCB. However, some areas continue to have poor sediment quality, particularly those areas closest to anthropogenic sources (Schiff et al. 2019).

A combination of legacy contaminants and contaminants of emerging concern in the coastal environment represent a human health risk through consumption of contaminated seafood. Recreational fisheries primarily occur in State waters (within three nautical miles off the coast), areas most subject to anthropogenic discharges (Davis et al. 2012, Schiff et al. 2019). Contaminants can remain in coastal waters and sediments for decades and become biomagnified in aquatic food webs (Voutsas et al. 2002, Lavoie et al. 2013). Chemical contamination of fish has resulted in the issuance of fish consumption advisories in most states, including California. Although mercury contamination is a frequent basis for these advisories, polychlorinated biphenyls (PCBs) and chlorinated pesticides, such as chlordane and dichlorodiphenyltrichloroethanes (DDTs), are also often causative.

The 2008 Southern California Bight Regional Monitoring Program (Bight '08) was the last regional assessment of fish tissue bioaccumulation, with sampling conducted during the summer of 2009. This program found that sport fish tissue contamination was generally moderate but widespread (Davis et al. 2012). Sport fish in embayments had higher contaminant burdens than fish in the offshore zones, with tissues exceeding the mercury thresholds most frequently (i.e., consumption recommendations were less than 7 servings per week), followed by PCBs. This study determined that 84% of zones were moderate risk (22 zones) and 15% were high risk (4 zones) for mercury contamination. For PCBs, 80% were moderate risk (21 zones), and 11% were high risk (3 zones).

The goal of the 2018 Bight sport fish bioaccumulation survey was to characterize the current extent and magnitude of bioaccumulation of contaminants in sport fish in the SCB and document any changes since the 2009 survey. To meet this goal, we conducted a region-wide assessment of sport fish bioaccumulation according the following assessment conditions: 1) target waters where sport fishing occurs, 2) collect species commonly consumed by people, 3) analyze fish tissues that people eat, 4) measure constituents that represent a risk to human consumers, and 5) compare the results to those of previous investigations. This type of regional survey can provide context to on-going, site-specific monitoring near discharge locations by documenting fish contaminants over larger biogeographic scales. Furthermore, this survey is part of a larger, coordinated effort to survey bioaccumulation of contaminants in sport fish throughout the California coast. Once completed, the SCB can be placed into greater regional context. The statewide survey is being conducted in coordination with the California State Water Resources Control Board's Surface Water Ambient Monitoring Program (SWAMP) and the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP). Sampling was performed in 2019 in San Francisco Bay and will occur on the remainder of the coast in 2020 and 2021. A report on the full statewide survey will be available in 2023. It should be noted that sampling for these surveys is not comprehensive and therefore the data should not be used independently to assess human health risk at any single location. Local monitoring programs provide more intensive sampling over a larger range of fish species and should be included in assessments of risk at specific locations.

Contaminants Assessed

Trace Metals/Metalloids

Mercury, selenium, and arsenic (metals and metalloids often collectively referred to as metals) enter the coastal environment from both natural and anthropogenic sources, including industrial activities, notably, power plant emissions and mining (GESAMP 1986, Gribble et al. 2016). Metals enter aquatic systems via direct atmospheric deposition and wastewater and stormwater discharges. In the Bight '18 sediment chemistry monitoring program, mercury concentrations were higher in embayments compared to offshore, with the highest concentrations associated with marinas, whereas sediment selenium and arsenic concentrations were highest offshore (Du et al. 2020). In aquatic ecosystems, inorganic mercury is methylated in sediment and in the water column, and methylmercury, a potent neurotoxin, is biomagnified in the food web (Benoit et al. 2003). Selenium has caused reproductive failure in fish and deformities in bird species (Ogle et al. 1988, Hamilton 2004), and can pose a risk to humans. Arsenic is both an acute and chronic toxin and unlike mercury and selenium, the inorganic form is typically more toxic than the organic. Diet is the primary route of exposure for humans and exposure due to fish consumption and its resultant health effects are a global concern (Mergler et al. 2007).

Organic Contaminants

DDTs and PCBs are prevalent anthropogenic environmental contaminants. Although the production and use of these chemicals have been banned in the United States, considerable amounts of these persistent compounds are still commonly found in aquatic food webs (Loganathan and Kannan 1994, Parnell et al. 2008). These chemicals, especially PCBs, pose several health risks to human consumers of wild-caught fish (OEHHA 2008). Exposure to these organic contaminants has been associated with reproductive and immunologic dysfunction in marine mammals (Nakata et al. 1998). The lipophilicity and persistence of these compounds contribute to their bioaccumulation and biomagnification in sport fish.

DDTs are class of compounds that were commonly used as a pesticide for insect control in the United States, particularly in the 1940s and 1950s, until they were banned in 1972 by the United

States Environmental Protection Agency (USEPA). Furthermore, from the 1950s to the 1970s, approximately 1,000 metric tons of technical grade DDTs were discharged to the Palos Verdes Shelf in Los Angeles County, California, and the area was subsequently designated a Superfund site (CH2M Hill 2007). Although DDT was banned in 1972, it is still commonly measured in the central and northern Bight as a result of this source (Kivenson et al. 2019, Du et al. 2020).

PCBs are a class of stable, synthetic chlorinated hydrocarbons manufactured and used in the United States beginning in 1929, with production peaking in the 1960s. Due to their non-flammability, chemical stability, high boiling point, and insulating properties, PCBs were used in hundreds of industrial and commercial applications. The manufacture of PCBs ended in 1979 due to environmental and human health concerns; however, they persist as legacy contaminants in sediments and aquatic food webs (Parnell et al. 2008). In the Bight ‘18 sediment chemistry monitoring program, total PCBs concentration was highest in both embayments and offshore of the Palos Verdes Shelf and Santa Monica Bay (Du et al. 2020). Due to the stability of PCBs, marine food webs in all major ports in California are contaminated and tissues of fish living within these areas typically exhibit PCBs concentrations that exceed limits recommended for human consumption (Brown et al. 2006, Davis et al. 2012).

II. Methods

Sampling Design

The SCB has over 600 km of coastline from Point Conception (United States) to Punta Colonet (Mexico), which spans a diversity of habitats and fish populations and includes dense human population centers with a multitude of popular fishing locations. To conduct a regional assessment of fish bioaccumulation, we divided this expansive coastline into 27 spatial units (zones), targeting coastal waters where most sport fishing occurs (Figure 1, Table 1). Fishing zones recognize that fish are mobile, which can result in variable contaminant exposure as well as a range of locations in which any given fish might be caught. The offshore extent of fishing zones was confined to 200 m depth (approximate shelf break), but most frequently extended only as far as 60 m in depth since this is the limit of most recreational fishers. The longshore extent of fishing zones was selected using the following criteria:

- Complete coverage. For this to be a regional survey, the entire SCB coastline must be sampled.
- Fishing pressure. Zones are smaller and more numerous in areas with more fishing pressure. Popular fishing locations were identified from Jones (2004) and discussions with stakeholders.
- Expected homogeneity of contamination. Zones were delineated based on known gradients of contamination to ensure a relatively consistent fish contaminant exposure within a zone. Contamination gradients were defined using previous regional monitoring data (Schiff 2000).
- Stakeholder interest. Some intensification was included where stakeholders had specific interest and resources.

Fish sample collection was primarily conducted by the California Department of Fish and Wildlife under the auspices of the SWAMP. Sampling in San Diego County Bays was supplemented by the Regional Harbor Monitoring Program. Sample collection occurred between April 16 and November 6, 2018 using seines, trawls, hook and line, trap, and spear (BOG 2018, Ichikawa 2018).

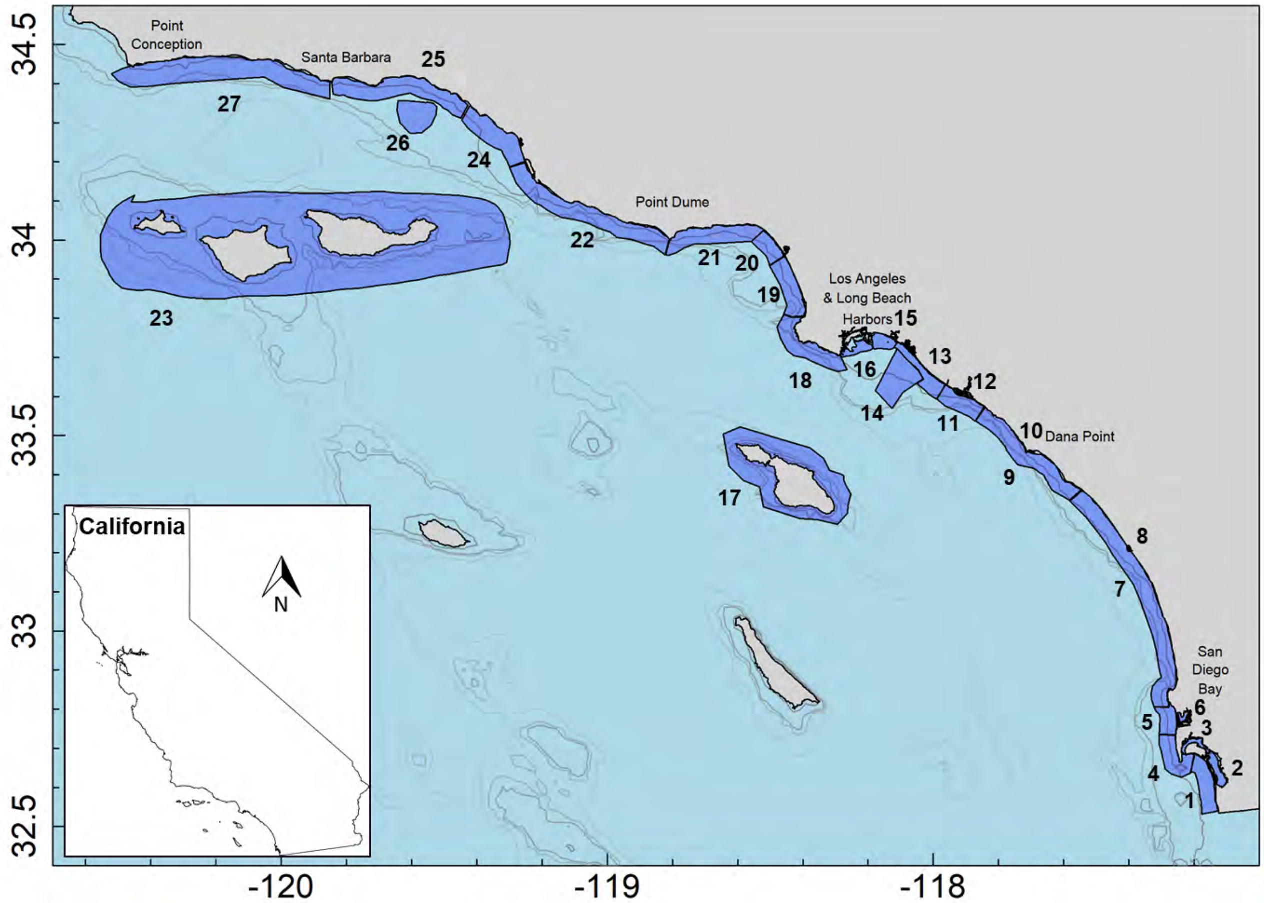

Figure 1. Map of southern California fishing zones (Ichikawa 2018).

Table 1. Fishing Zones

Station Code	Zone Name	Fishing Zone #	Stratum
91001TJNI	TJ to North Island	1	offshore
91202SDSB	SD South Bay	2	embayment
91203SDNB	SD North Bay	3	embayment
90804PLMA	Pt Loma	4	offshore
90605PLLJ	Pt Loma to La Jolla	5	offshore
90606MISS	Mission Bay	6	embayment
90407LJSO	La Jolla to San Onofre	7	offshore
90208OCNH	Oceanside Harbor	8	embayment
90109SOCC	San Onofre to Crystal Cove	9	offshore
90110DANA	Dana Point Harbor	10	embayment
80111CCSA	Crystal Cove to Santa Ana River	11	offshore
80112NWPT	Newport Bay	12	embayment
80113SASB	Santa Ana River to Seal Beach	13	offshore
80114ORCO	Orange County Oil Platforms	14	offshore
40515LNGB	Long Beach	15	embayment
41116SPDB	San Pedro Bay	16	embayment
40617CATI	Catalina Island	17	offshore
40418PVER	Palos Verdes	18	offshore
40419SSMB	South Santa Monica Bay	19	offshore
40420MSMB	Middle Santa Monica Bay	20	offshore
40421NSMB	North Santa Monica Bay	21	offshore
40422PTDU	Pt Dume to Oxnard	22	offshore
31623NCHI	Northern Channel Islands	23	offshore
40124VTRC	Ventura to Rincon	24	offshore
31525RCGA	Rincon to Goleta	25	offshore
31526SBCP	Santa Barbara Channel Oil Platform	26	offshore
31527GPTC	Goleta to Pt Conception	27	offshore

Target Species

The selection criteria for target fish species accounted for the high diversity of species, variation in habitat type and quality, variation in contamination exposure pathways, and varying ecological attributes of indicator species. The following criteria were used to select target species:

1. Popular for consumption. This was the primary factor in selecting fish species. Data on recreational fish catch data were collated from the Pacific Recreational Fisheries Information Network (RecFIN), a product of the Pacific States Marine Fisheries Commission (PSMFC), which integrates State and Federal marine recreational fishery sampling efforts (RecFIN 2020).

2. Widely distributed. Range of preferred species extended the length of the SCB.

3. Representative of different exposure pathways. Both benthic and pelagic feeders were included.

4. Continuity with previous monitoring efforts to facilitate comparability with existing monitoring programs.

5. Consistency with species collected in other parts of the state as part of the coordinated statewide coastal survey.

Fish species present across a wide distribution of zones were selected for assessment of regional extent and magnitude of contaminant bioaccumulation. Three species were selected as primary target species, while seven species were selected as secondary target species. Primary target species were fished until targeted number of specimens were caught, while secondary species were kept in case enough samples were collected Bight-wide to justify use in the regional assessment. The primary target species were White Croaker (*Genyonemus lineatus*), Kelp Bass (*Paralabrax clathratus*), and Pacific Chub Mackerel (*Scomber japonicus*). White Croaker is predominantly an epibenthic feeder, often associated with soft-bottom sediments. Kelp Bass is predominantly a water-column feeder, often associated with rocky substrate and kelp beds. Pacific Chub Mackerel is a water-column feeder with a geographically large range. The secondary species were California Halibut (*Paralichthys californicus*), Shiner Perch (*Cymatogaster aggregata*), Yellowfin Croaker (*Umbrina roncador*), Barred Sand Bass (*Paralabrax nebulifer*), Spotted Sand Bass (*Paralabrax maculatofasciatus*), Olive Rockfish (*Sebastes serranoides*), and California Scorpionfish (*Scorpaena guttata*). The California Halibut and Shiner Perch were selected because they are included in other zones in the statewide survey and in other regional monitoring efforts (e.g., the California State Water Resources Control Board's Sediment Quality Objective Program). The croaker, bass, and rockfish were selected because they serve as ecological replacements for primary species (i.e., same ecological niche or guild). The Scorpionfish and Pacific Chub Mackerel were selected because they are frequently assessed in other monitoring programs in the SCB, including National Pollutant Discharge Elimination System (NPDES) monitoring programs.

Sample Collection

Fish tissue was saved for analysis as either muscle tissue fillet with the skin off or whole fish without the head, tail, or internal organs. Muscle fillets are recommended by the USEPA (2000a) for large species, and whole fish without head or organs are recommended for smaller species. In this study, only the Shiner Perch was processed as a whole fish; all others were fillets. Upon collection, each fish was tagged with a unique identification number and measured for total length (longest length from tip of tail fin to tip of nose/mouth), fork length (for species with a clearly defined fork, the tip of the nose/mouth to the middle of the fork), and weight. During dissection, each fish was sexed and the weight of tissue recorded. Dissection and compositing of tissue samples was performed following USEPA guidance (USEPA 2000a). A total of three composite samples per species were targeted per fishing zone. A total of five specimens were targeted per composite sample. Specimens of legal size or larger were preferred but not required. If more than five specimens were collected, then the middle 75% of the length distribution was used for the composite. Specimens from this interquartile range were selected at random for inclusion in each composite. A table of the samples collected is provided in Appendix C.

Target Analytes and Analytical Methods

Fish tissue composites were evaluated for five common contaminants found in California sport fish, including three metals/metalloids: mercury, selenium, and arsenic; and two organic compound classes: total PCBs (sum of 43 polychlorinated biphenyl congeners) and total DDTs (sum of two dichlorodiphenyltrichloroethane isomers and five degradation products); percent lipids was also measured. All constituents were analyzed in wet tissue and are reported on a wet-weight (ww) basis.

This survey was a collaborative effort in which six laboratories (Moss Landing Marine Laboratory [MLML], City of Los Angles Environmental Monitoring Division, Los Angeles County Sanitation Districts [LACSD], Orange County Sanitation District, City of San Diego, and PHYSIS Environmental Laboratories) participated in the analysis of fish tissues for the above-mentioned contaminants. All laboratories were subject to a common set of rigorous quality assurance and quality control (QA/QC) guidelines to ensure comparability (see Appendix A: Quality Assurance and Quality Control). Analytical methods are described in detail below.

Metals/Metalloids

Total mercury, selenium, and arsenic were measured in all wet tissue composites. Laboratories could use different protocols if the methods were comparable and met QA/QC guidelines (Appendix A). Fish tissue samples for arsenic and selenium were digested in acid according to the standard methods (EPA7471B, EPA7473, EPA200.7, EPA245.7m, EPA3050B, EPA6020Bm). The resulting digestates were diluted to a specific volume with deionized water and subsequently analyzed by one or more of the following instrumental methods, depending on the laboratory: inductively coupled plasma mass spectrometry, inductively coupled plasma emission spectroscopy, flame atomic absorption, or graphite furnace atomic absorption. All laboratories analyzed mercury using cold vapor atomic absorption spectroscopy. In most cases, nearly all (> 95%) of the mercury present in fish fillets and in whole fish is methylmercury (Wiener et al. 2007, Greenfield and Jahn 2010). Therefore, USEPA (2000a) recommends that monitoring programs analyze total mercury as a proxy for methylmercury, thereby providing a conservative assessment most protective of human health. Mercury analyses were performed on individual fish for selected species by MLML to evaluate the relative increase in tissue mercury concentrations with fish size. Mercury concentrations are closely correlated with fish size in many species (Hammerschmidt and Fitzgerald 2006, Cai et al. 2007). Data on individual fish allows for consideration of fish size when evaluating spatial and temporal patterns, an approach that has been used in previous SWAMP sport fish surveys (Davis et al. 2012). Selenium and arsenic analyses were performed only on composite samples.

Organics

Total PCBs, a sum of 43 congeners, and total DDTs, a sum of two isomers and five degradation products, were analyzed in all fish tissue composites (Appendix B). The 43 PCBs congeners are a subset of the full 209 congeners, representing the most prevalent and toxic of these, consistent with those measured in previous surveys. Wet samples were solvent extracted using one of the following methods: accelerated solvent extraction, Soxhlet, or sonication. The extracts obtained were subjected to each laboratory’s own clean-up procedures and were analyzed by an appropriate gas chromatographic method. PCBs congeners and DDTs were analyzed using either dual-column gas chromatography with electron capture detector (GC-ECD) or gas chromatography with mass spectrometry (GC-MS) in the selected ion monitoring (SIM) mode. For sums, samples with concentrations below the limit of detection were considered zero concentration.

In general, levels of organic contaminants will vary in tissues in proportion to their lipid content. Lipid normalization minimizes the variability associated with differences in lipid content and allows for comparisons across sampling times, locations, and species (Randall et al. 1991). Thus, total lipids were analyzed in fish composites for this purpose using standard methods (EPA8270Cm). Organic contaminant concentrations were divided by the percentage of lipids for normalization and are reported in units of ng/g lipid.

Quality Assurance and Quality Control (QA/QC)

To ensure high data quality and comparability within and among laboratories, strict QA/QC guidelines were implemented during the study. A performance-based approach to QA/QC was adopted, allowing each participating laboratory the flexibility to utilize its own protocols, while meeting common data quality objectives (DQOs) for criteria pertaining to sensitivity, accuracy, and precision. In addition, prior to analysis of samples, an inter-laboratory comparison exercise, wherein each laboratory analyzed a certified reference material as well as a field reference material in triplicate, was conducted to ensure that all participating laboratories could provide data of high enough quality to address study objectives. All laboratories passed the inter-laboratory comparison and achieved goal targets for the DQOs. A detailed accounting of project quality assurance is provided in Appendix A.

Assessment Thresholds

Recognizing that fish consumption provides significant nutritional benefits while also serving as an exposure pathway for several chemicals of concern, California EPA's Office of Environmental Health Hazard Assessment (OEHHA) developed Advisory Tissue Levels (ATLs) to provide consumption recommendations that are designed to promote the overall health of the fish consumer. ATLs provide the number of recommended fish servings that correspond to a range of contaminant concentrations found in fish. ATLs are used to provide consumption advice to prevent consumers from being exposed to more than the average daily reference dose for non-carcinogens or to a risk level greater than $1x10^{-4}$ for carcinogens (not more than one additional cancer case in a population of 10,000 people consuming fish at the given consumption rate over a lifetime). ATLs are designed to encourage consumption of fish in quantities likely to provide significant health benefits, while discouraging consumption of fish that should not be eaten in the amount recommended for improving overall health because of contaminant concentrations (as eight ounces servings, prior to cooking, per week) (OEHHA 2008). Table 2 provides ATLs for the number of servings per week (adapted from OEHHA 2008, updated 2017).

Fish tissue concentrations for mercury, selenium, total PCBs, and total DDTs were compared to ATL thresholds to assess relative risk of contaminant bioaccumulation to fish consumers in the SCB. For mercury, the more restrictive thresholds are used (ATLs for women ages 18 to 49 and children ages 1 to 17). As an example, if a fish species was found to have tissue mercury concentrations of 550 ng/g ww, young women and children should not consume that species;

however, women over age 49 and men may consume that species, but not more than one 8-ounce serving per week.

Table 2. Fish Advisory Tissue Levels (ATLs) for selected contaminants based on carcinogenic or non-carcinogenic risk using an 8-ounce serving size per week (prior to cooking). Values are in ng/g (PPB), wet weight.

Contaminant	FCG[#]	ATLs for the Number of 8-ounce servings per week* (in ng/g)							
		7	6	5	4	3	2	1	Do not consume
Mercury (Women 18-49; Children 1-17)	220	≤ 31	31-36	36-44	44-55	55-70	70-150	150-440	> 440
Mercury (Women > 49; Men)		≤ 94	94-109	109-130	130-160	160-220	220-440	440-1,310	> 1,310
Selenium	7,400	≤ 1,000	1,000-1,200	1,200-1,400	1,400-1,800	1,800-2,500	2,500-4,900	4,900-15,000	> 15,000
PCBs	3.6	≤ 9	9-10	10-13	13-16	16-21	21-42	42-120	> 120
DDTs	21	≤ 220	220-260	260-310	310-390	390-520	520-1,000	1,000-2,100	> 2,100

*Thresholds for concern based on an assessment of human health risk by OEHHA (2008, updated 2017). All values given in ng/g (ppb) wet weight. One serving is defined as 8 ounces (227 g) prior to cooking.
[#]Fish Contaminant Goals (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 eight ounces per week (32 g/day), prior to cooking, over a lifetime and can provide a starting point for OEHHA to assist other agencies that wish to develop fish tissue-based criteria with a goal toward pollution mitigation or elimination.
[+]There are no ATLs for total arsenic.

Statistical Analysis

Data analyses were performed with R 4.0.2 (R Core Team 2020), using the tidyverse (Wickham et al. 2019), IDPmisc (Locher and Ruckstuhl 2012), and ggpubr packages (Kassambara 2018). Statistical analyses were conducted using the rstatix package (Kassambara 2020). Fish tissue concentration data were not normally distributed, so we log transformed the tissue concentrations (adding one to the result to account for non-detects, $\log_{10}$[concentration+1]) for statistical tests to evaluate differences among mean concentrations among species and zones, and among zones and years for Kelp Bass and Pacific Chub Mackerel, and interactions among these factors using two-way analysis of variance (ANOVA). We calculated Tukey HSD (Tukey Honest Significant Differences) of pair-wise differences among zones. We calculated Pearson’s correlations on log-transformed mercury concentration and length data to determine significance of this relationship. We also used a principal components analysis on untransformed data using the FactoMineR and factoextra packages (Lê et al. 2008) to explore relationships among parameters and fishing zones for Kelp Bass and Pacific Chub Mackerel.

Undetectable concentrations were assigned a concentration of 0 ng/g ww for analysis. Similarly, DDT isomers and degradation products and PCB congeners were assigned a concentration of 0 ng/g ww for the summation; therefore, a total DDTs or PCBs concentration of “0” indicates that no isomers/congeners were detected.

The measurement of mercury in individual samples of predator species (Kelp Bass, Barred Sand Bass, and Spotted Sand Bass) provided a foundation for statistical procedures to adjust for the relationship with fish length. Concentrations for each fish were adjusted to a length of 360 mm– this length was in the middle of the overall size distribution caught for these species and also within the legal size range (minimum of 356 mm). Estimates of length-adjusted means were based on simple linear regressions of the data for each zone. This approach provides an independently-derived estimate of the zone mean that can be compared to any other zone mean of interest: other zone means from the same sampling period; means from the same zone in past sampling; or any other zone mean of interest (Davis et al. 2012).

III. RESULTS

2018 Survey

The "do not consume" threshold was not exceeded for any contaminant in any of the composite samples of target species sampled during this survey. However, fish tissue concentrations within and among zones were variable for each of the different contaminants. Consequently, there are differences in the recommended number of servings of each fish species based on contaminant (Figure 2) and where it was caught (Figure 3). The following sections will describe the results for each contaminant.

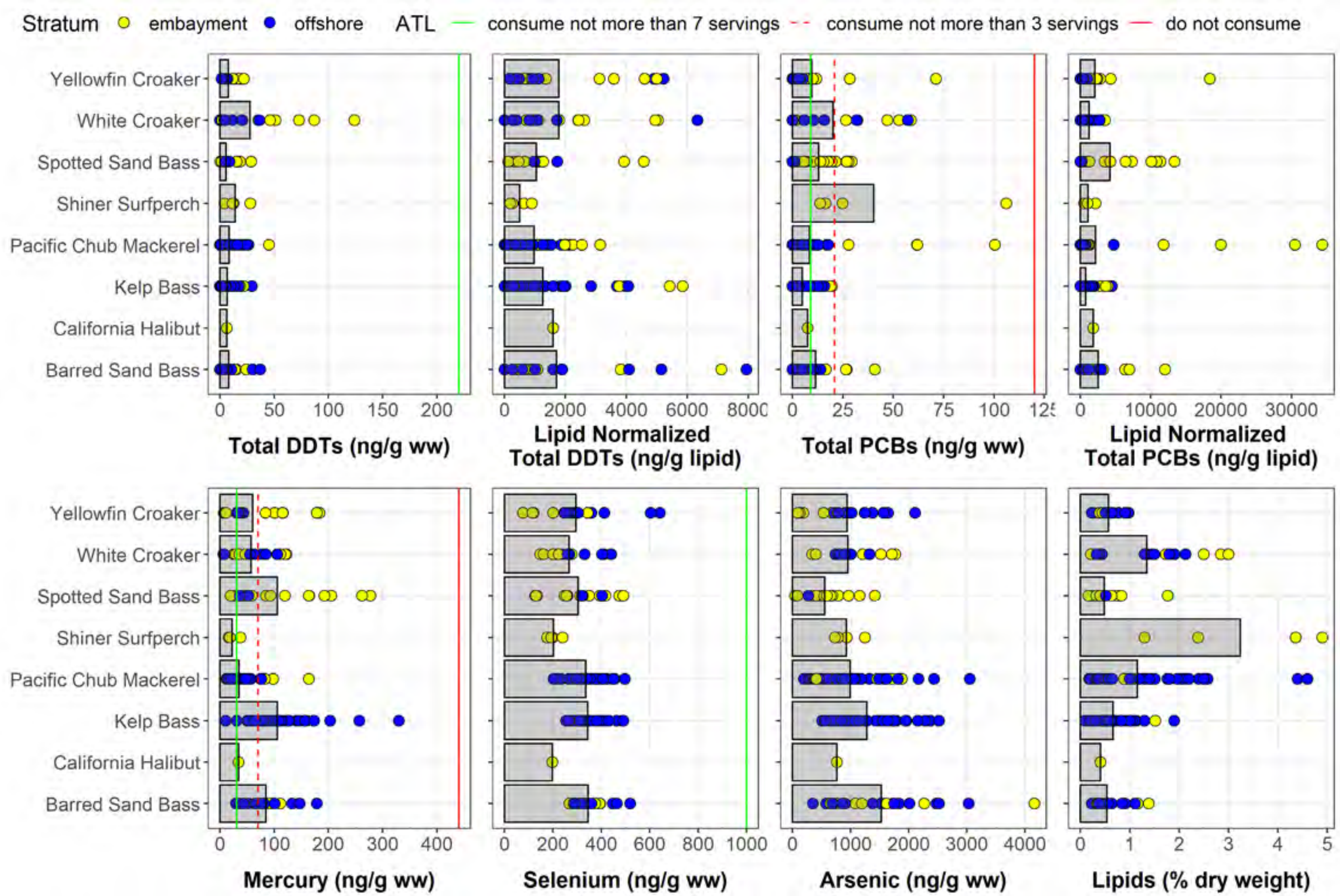

Figure 2. Fish tissue concentrations for total DDTs, lipid-normalized total DDTs, total PCBs, lipid-normalized total PCBs, mercury, selenium, arsenic, and lipids by species relative to select OEHHA ATLs for the sensitive population (women ages 18-49 and children under 17). Green line represents the least restrictive threshold (recommended consumption not to exceed 7 servings per week). The dotted red line represents a middle threshold (recommended consumption of not more than 3 servings per week). The solid red line is the most restrictive threshold "do not consume". Gray boxes represent the mean concentration for each species.

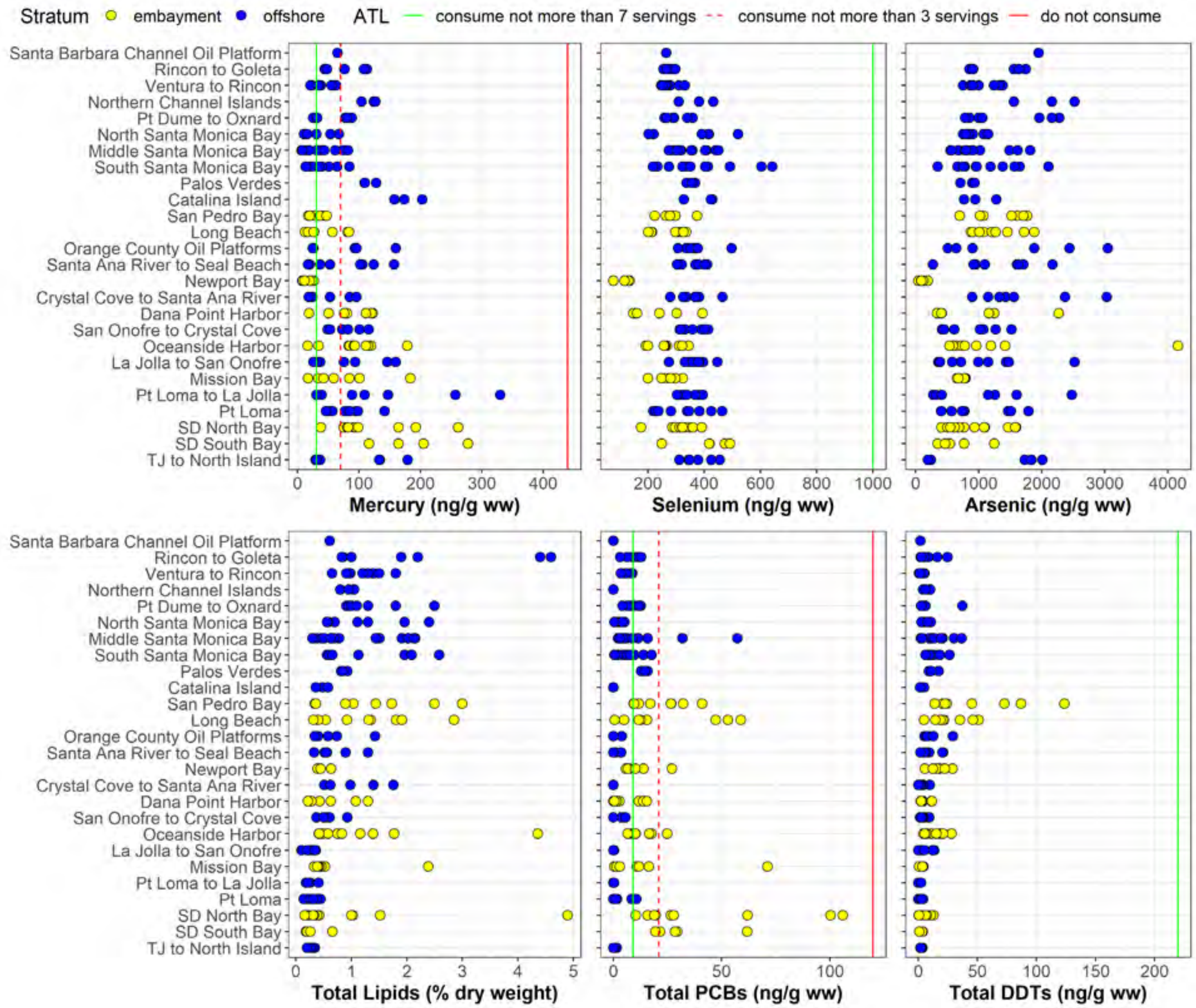

Figure 3. Tissue concentrations of measured parameters for all target species by fishing zone relative to select OEHHA ATLs for the sensitive population (women ages 18- 49 and children under 17). Green line represents the least restrictive threshold (recommended consumption not to exceed 7 servings per week). The dotted red line represents a middle threshold (recommended consumption of not more than 3 servings per week). The solid red line is the most restrictive threshold “do not consume”.

Trace Metals/Metalloids

Mercury

Of the contaminants analyzed in target species, mercury had the greatest number of composites that exceeded ATL thresholds. No fish composites had mercury concentrations that exceeded the "do not consume" OEHHA ATL fish consumption threshold of 440 ng/g ww for the sensitive population (women ages 18- 49 and children under 17, Figures 3 and 4), although three individual Kelp Bass exceeded this threshold (Figure 5). There was detectable mercury in all fish tissues sampled, with composite tissue concentrations ranging from 6.7 to 330 ng/g ww, and individuals ranging from 10 to 900 ng/g ww. Seventy-one percent of all fish composites were above the least restrictive threshold of consumption (not to exceed seven servings per week for the sensitive population [≤ 31 ng/g ww]), and species-specific mean concentrations were higher than this threshold for all species except for Shiner Perch (note that Shiner Perch had the smallest sample size: four composites from four zones). Nearly half of the tissue composites (46%) were considered safe to consume three or more servings per week (≤ 70 ng/g ww).

There were significant differences in fish tissue mercury concentrations among species (ANOVA, $p = 2 \times 10^{-15}$) (Figure 4). For tissue composites collected in the same zone, Kelp Bass had higher mercury concentrations compared to Pacific Chub Mackerel for all but one zone (93% of zones, Figure 4). Of the species caught region wide, Pacific Chub Mackerel (caught in 19 zones) had the lowest mean tissue mercury concentrations (Figure D1). Only California Halibut and Shiner Surfperch, caught in just 1 and 4 zones respectively, had lower means (Figure 2). There was also some variability among composites of the same species within the same zone. Standard deviations ranged from small (< 1 ng/g ww, for several species) to large (113 ng/g ww for Kelp Bass in Point Loma to La Jolla) (Figure 4). Coefficients of variation (CV) for mercury ranged from 0.1 – 67.4%. They were relatively low for a third of the species/zone groups (n = 20 with CV < 10%) and were highly variable for two species in two zones (CV > 60%, Barred Sand Bass in La Jolla to San Onofre and Kelp Bass in North Santa Monica Bay) (Appendix D). White Croaker had the lowest CV and Barred Sand Bass had the highest.

There were generally no clear spatial gradients in fish tissue mercury concentrations observed in composite samples. For the two species with balanced sample sizes along the coast, Kelp Bass and Pacific Chub Mackerel, there were no clear along-shore gradients. For species with balanced sample sizes between embayment and offshore zones, Pacific Chub Mackerel, Barred Sand Bass, and White Croaker, fish tissue mercury concentrations were not statistically different between samples caught in embayment and offshore zones (two-way ANOVA, Figures 2 and 4). However, there were significant differences within a species among fishing zones (two-way ANOVA, $p = 1.8 \times 10^{-5}$) (Figures 3 and 4). In addition, for the two species most commonly caught in embayments, the Spotted Sand Bass and Yellowfin Croaker, embayment zones had higher tissue mercury concentrations ($p = 0.03$) compared to offshore zones; however, sample size for these two species in the offshore zones was limited. Spotted Sand Bass had high concentrations in both San Diego Bay zones, the second and third-highest mean concentrations in the study (Kelp Bass in Point Loma to La Jolla, just outside of San Diego Bay, had the highest mean mercury within a zone). Northern San Diego Bay stands out as a zone that had high mercury concentrations for multiple fish species, and it was the only zone to exceed the ATL threshold which advises consumption not to exceed 3 servings per week for all four of the most commonly caught fish species (Kelp Bass, Pacific Chub Mackerel, Barred Sand Bass, and

Spotted Sand Bass). South San Diego Bay also exceeded ATL thresholds for both species sampled there (Pacific Chub Mackerel and Spotted Sand Bass). Catalina Island and the Northern Channel Islands zones both had relatively high mercury concentrations in Kelp Bass, despite being located away from the coast.

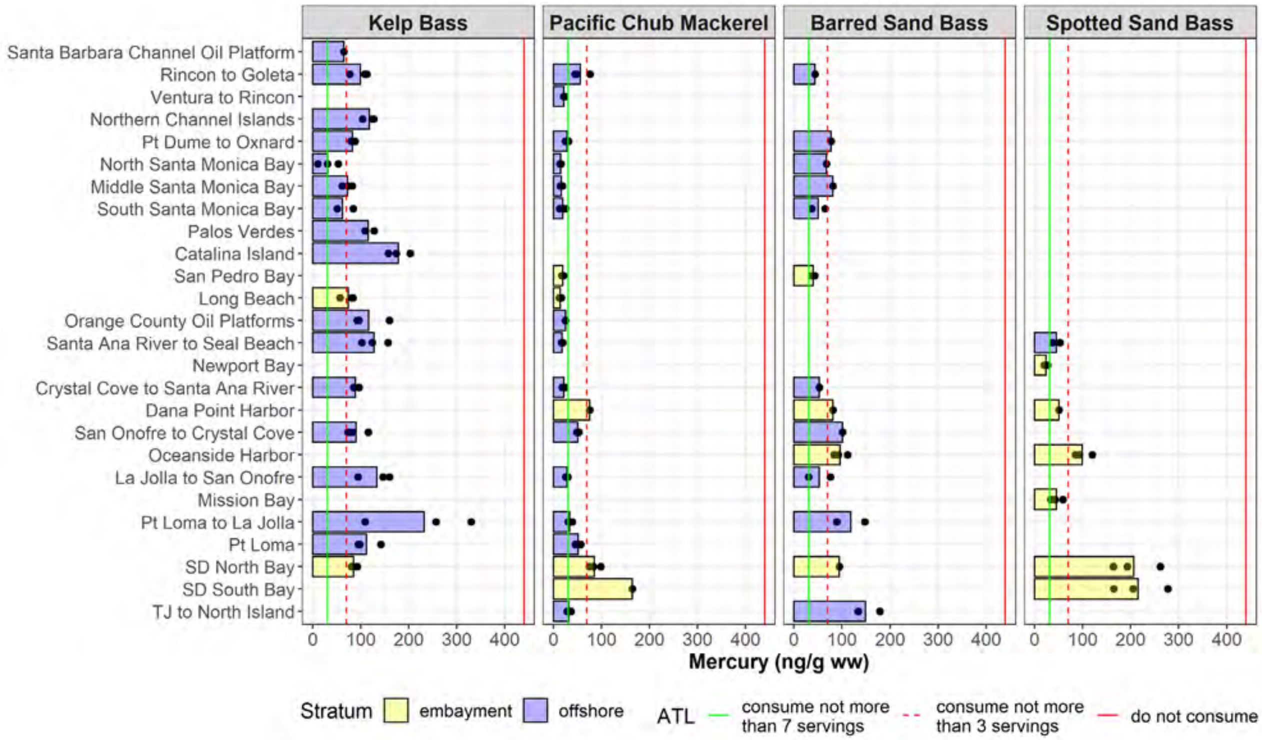

Figure 4. Mercury concentrations in composite samples, by location, in the four most commonly caught target fish species. Bars represent the mean of the composite samples collected. Black dots represent each composite concentration. Bar color indicates whether the zone is an embayment (yellow) or offshore (blue). Vertical lines represent ATL thresholds for the sensitive population.

Mercury concentrations were correlated with fish total length, in fish composites (using mean length) and individuals for all species (Pearson's correlation, $r = 0.525$, $p = 2.2 \times 10^{-16}$, Figure 5). The Bight survey samples represent composites of the most common fish sizes caught during the survey period. However, the mean length of each fish species caught within a zone was variable among zones, for example, for Kelp Bass mean length ranged from 238.5 mm (North Santa Monica Bay) to 332.4 mm (Catalina Island).

SWAMP's statewide fish monitoring program includes assessment of mercury in individual fish of selected predator species that are high mercury accumulators (e.g., Kelp Bass, Barred Sand Bass, and Spotted Sand Bass), which allows for a calculation of mean concentrations adjusted for length (Davis et al. 2012). Length adjustments were made for these species based on linear regressions of mercury versus total length for individual fish of each species in each zone. The Kelp Bass dataset was the most extensive and provided the best basis for evaluating spatial and temporal patterns in length-adjusted mercury concentrations (Table 2). In many cases (a little more than half), the linear regressions for Kelp Bass were not significant and length-adjusted means could not be calculated. The lack of significance in many of these regressions was possibly due to a combination of the following factors, which came into play to varying degrees in different zones: the small number of fish collected, high variance in mercury tissue concentration among the fish caught (sometimes in the form of outliers), a small slope in the linear regression of length to mercury concentration that was difficult to detect, a limited size range of fish that were obtained, and a weaker relationship between length and age for longer-lived species. Barred Sand Bass were also collected in many zones, but a significant regression for the length to mercury concentration relationship was obtained for only one zone; therefore, a length-adjusted analysis was not conducted for this species. Spotted Sand Bass were only collected in three zones, so a length-adjusted analysis was also not conducted for this species.

The assessment of patterns in individual fish mercury concentrations based on analysis of covariance of results for Kelp Bass indicated that overall spatial and temporal variation in the Bight was low. For Kelp Bass, length-adjusted means could be calculated for 8 of the 17 zones where Kelp Bass were collected. Relative to species with a similar trophic position in other habitats in California (e.g., Largemouth Bass in lakes and reservoirs), Kelp Bass had a narrow range of length-adjusted mean concentrations across the Bight, from a low of 120 ng/g ww in Crystal Cove to Santa Ana River to a high of 230 ng/g ww at Orange County Oil Platforms. Non-overlapping 95% confidence intervals of these arithmetic mean concentrations indicate that the means at the upper end of this range were statistically significantly different from the means at the lower end. However, a difference of only about 100 ng/g ww across these zones is not toxicologically meaningful – corresponding to a shift from the upper end of OEHHA's ATL concentration range for two servings per week (> 70-150 ng/g) to the lower end of the ATL range for three servings per week (> 150-440 ng/g). The three zones that can be compared to 2009 results showed no significant change between 2009 and 2018 based on the overlapping 95% confidence intervals.

Table 3. Length-adjusted means and 95% confidence intervals of the mean for mercury (ng/g ww) in Kelp Bass in the 2009 and 2018 surveys. Bold values show zones sampled in both the 2009 and 2018 surveys.

	2009		**2018**	
Fishing Zone	**Mean (ng/g ww)**	**95% CI**	**Mean (ng/g ww)**	**95% CI**
Rincon to Goleta			133	117-149
Northern Channel Islands	**227**	**187-267**	**192**	**175-209**
Pt Dume to Oxnard			142	132-152
North Santa Monica Bay	175	150-200		
Middle Santa Monica Bay	231	200-262		
South Santa Monica Bay			150	129-171
Palos Verdes	**183**	**162-204**	**184**	**152-216**
Catalina Island	209	172-246		
Orange County Oil Platforms			226	198-254
Crystal Cove to Santa Ana River	**133**	**122-144**	**121**	**112-130**
La Jolla to San Onofre	201	172-230		
Pt Loma			127	114-140
Count	7		8	
Mean (all zones)	194		159	

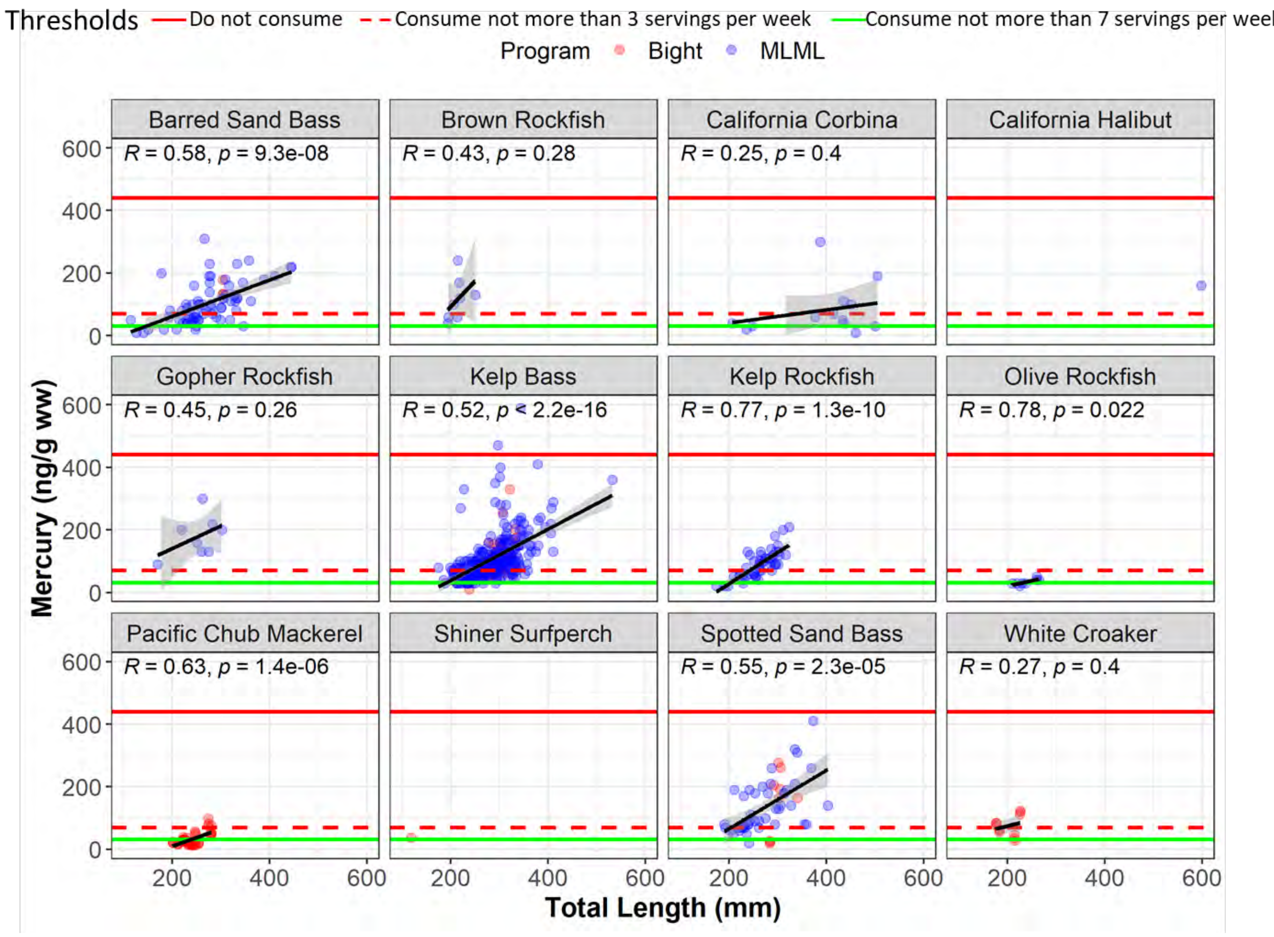

Figure 5. Fish tissue mercury concentrations as a function of average total fish length for fish composites (Bight Samples, red) and individuals (MLML Samples, blue). R = Pearson coefficients.

Selenium

All fish tissue composites were below the most conservative ATL threshold (≤ 1000 ng/g ww). Selenium was detectable in all sampled tissue, with concentrations ranging from 77 ng/g ww to 642 ng/g ww (Figures 2 and 3). Mean concentrations within a zone ranged from 105 ng/g ww to 553 ng/g ww (Figure 6).

As with mercury, there were differences in fish tissue selenium concentrations among species (ANOVA, $p = 2.0 \times 10^{-16}$, Figure 6). Of the target species, Barred Sand Bass, Kelp Bass, and Pacific Chub Mackerel had the highest selenium concentrations (Figure D1). Unlike mercury, the species differences were not consistent among zones (Tukey's HSD). There was also some variability in selenium tissue concentrations within a zone among replicate composites of the same species, with standard deviations ranging from 2.6 ng/g ww to 123 ng/g ww. Overall, the CV for selenium for species within a zone was lower than for mercury, with all zones having CV < 40% and over 60% of the zones having CV < 10% (Appendix B). Both selenium and mercury had 60 zone-species sets (out of 79) with a number of composites of 2 or more. Selenium CV ranges were 1 – 37% and 0.1 – 67% for mercury (Figure D2). Yellowfin Croaker had the highest

CV and White Croaker had the lowest. There were no patterns of any fish species having less variability across zones or any zone having consistently less variability for fish species.

There were no clear spatial patterns in selenium concentrations in fish tissue composites. While there were significant differences within a species between fishing zones based on two-way (species by fishing zone) ANOVA ($p = 2 \times 10^{-16}$), there were no clear along-shore spatial gradients among zones (Figure 3 and 6), there were no obvious “hot spots” with high selenium values, and no significant difference between fish caught in embayment zones versus those caught offshore for any target species (Figure 2 and 6).

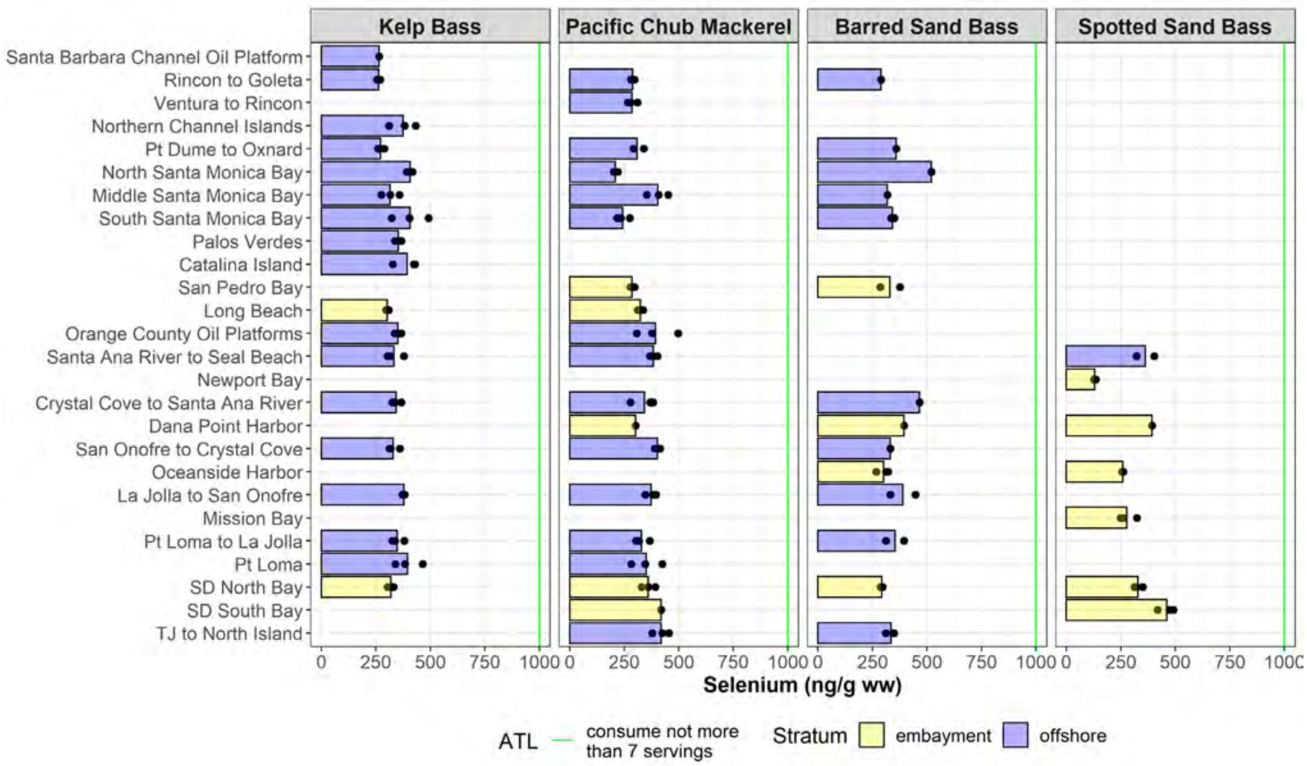

Figure 6. Composite selenium concentrations in the four most commonly caught target fish species. Bars represent the mean of the composite samples collected. Black dots represent each composite concentration. Bar color indicates whether the zone is an embayment (yellow) or offshore (blue). Vertical lines represent ATL thresholds.

Arsenic

Total arsenic was detectable in all samples, with concentrations ranging from 45 ng/g ww to 4,162 ng/g ww (Figures 2 and 3). There are no OEHHA human health thresholds for total arsenic concentrations in fish tissues; therefore, a comparable assessment of human health risks from arsenic contamination to the other contaminants described in this report is not possible. However, we were able to document differences in fish tissue concentrations among species and zones.

There were significant differences in arsenic concentrations among fish species (ANOVA, $p = 2.0 \times 10^{-16}$) (Figure 7), but species were not consistently higher or lower among zones (Tukey’s

HSD). Of the target species, Barred Sand Bass and Kelp Bass had the highest concentrations of arsenic, consistent with findings that arsenic concentrations are typically highest in demersal species (Figure D1, Taylor et al. 2017). Arsenic concentrations within the same zone were variable among composites of the same species, with standard deviations in arsenic concentrations among composites ranging from 2.1 ng/g ww to 1,887 ng/g ww. Coefficients of variation (CV) were low for a third of the species/zone groups (n = 19 with CV < 10) and were highly variable for two species in four zones (CV > 60, Barred Sand Bass in South Santa Monica Bay, Oceanside Harbor, and La Jolla to San Onofre and Pacific Chub Mackerel in North San Diego Bay) (Appendix D). Barred Sand Bass had the highest CV and Spotted Sand Bass the lowest. The range of CV were similar to mercury, with the exception of Barred Sand Bass, which generally had higher CV (Figure D2). There was no significant difference in the amount of variability among composites across zones or between species.

There were no clear spatial patterns in arsenic concentrations in fish tissue composites. While there were significant differences within a species among fishing zones based on two-way, species by fishing zone, ANOVA ($p = 2.0 \times 10^{-16}$), there were no consistent along-shore spatial gradients among zones (Figure 3 and 7), there were no obvious “hot spots” associated with high arsenic values, and no significant difference between fish caught in embayment zones versus those caught offshore for any target species (Figure 2 and 7).

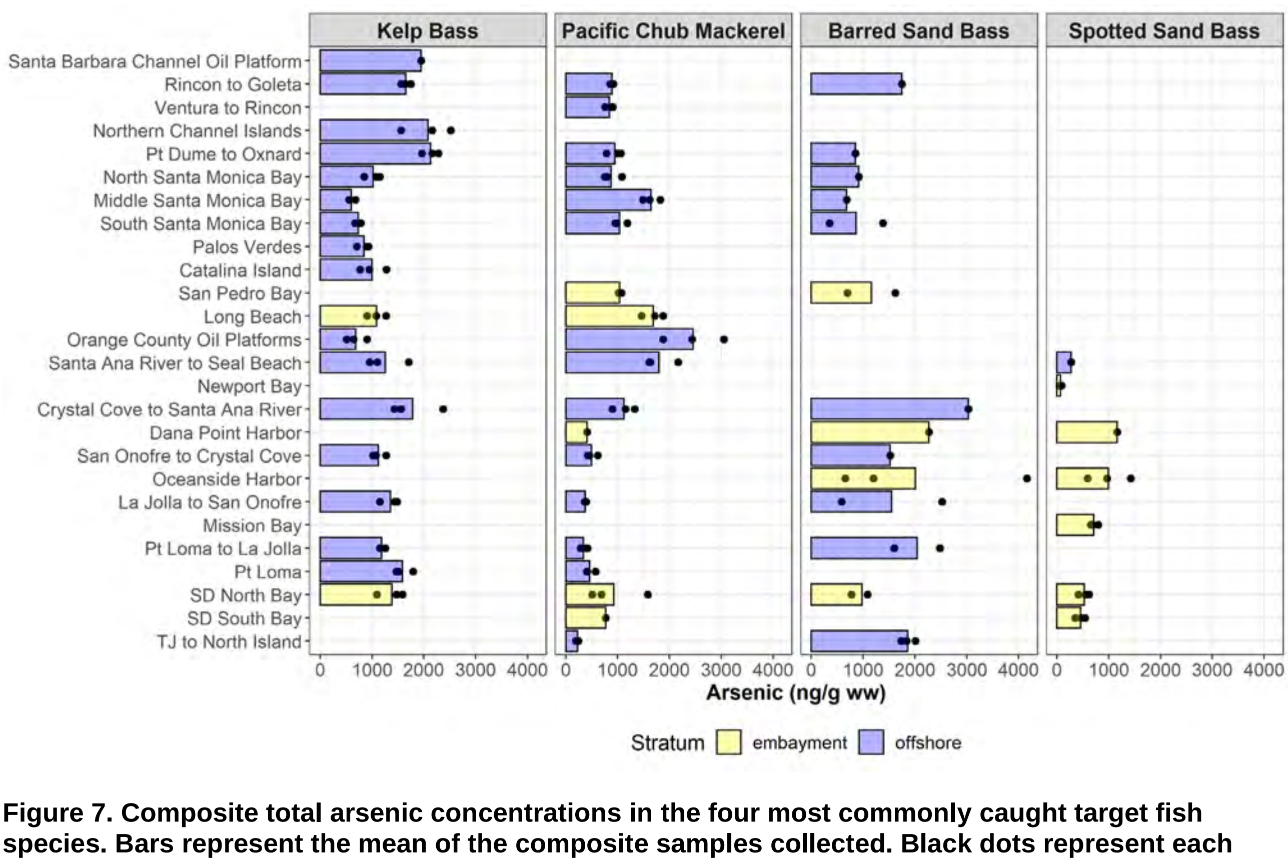

Figure 7. Composite total arsenic concentrations in the four most commonly caught target fish species. Bars represent the mean of the composite samples collected. Black dots represent each composite concentration. Bar color indicates whether the zone is an embayment (yellow) or offshore (blue). There are no ATL thresholds for total arsenic.

Organic Contaminants

Total DDTs

All fish tissue composites were considered safe to eat for up to seven servings per week based on the ATL thresholds for total DDTs (≤ 220 ng/g ww). Total DDTs was detectable in 95% of composites, undetectable in 10 composites, and ranged from 0.36 to 123 ng/g ww in composites in which it was detected (Figures 2 and 8).

There were significant differences in total DDTs among fish species (ANOVA, $< 2 \times 10^{-16}$) (Figure 8, top panel). Of the target species, White Croaker had the highest concentrations of total DDTs (Figure D1). There was also within-zone variability for all species, with standard deviations in total DDTs concentrations among composites ranging from 0.1 ng/g ww to 26 ng/g ww. Coefficients of variation (CV) were high compared to metals and metalloids, with nearly 30% of the species/zone groups (n = 17) with CV > 60% and only 12% (n = 6 of 59) of species/zone groupings had low variability (CV < 10%; Appendix D). White Croaker had the highest CV, with all other species having generally similar CV. No zone was significantly more variable than other zones.

There were no consistent spatial patterns in fish tissue total DDTs concentrations. There were significant differences within a species among zones (two-way ANOVA, $< 2 \times 10^{-16}$), but no along-shore gradients (Figures 3 and 8), and no significant difference between fish caught in embayment zones versus those caught offshore for any target species (two-way ANOVA, Figures 2 and 8).

Organic contaminant concentrations in tissues are often associated with lipid content; therefore, lipid-normalization of total DDTs concentration provides a better means of evaluating spatial and temporal patterns of contamination. Normalization would partially account for some differences in fish species tissue concentrations related to fecundity, age, sex, etc., allowing for a more direct estimate of chemical exposure (Figure 8, lower panel). With lipid-normalization, there were significant differences among fish species (ANOVA, $p < 2 \times 10^{-16}$), and significant differences within a species among fishing zones (two-way ANOVA, $p < 2 \times 10^{-16}$). The lipid-normalized data indicate elevated concentrations of DDTs in fish tissues, particularly Kelp Bass and Pacific Chub Mackerel, in the central Bight region (Point Dume to Seal Beach), the region associated with the Palos Verdes Superfund site. Lipid-normalized total DDTs concentrations in Barred Sand Bass were some of the highest values in the Bight and were also highly variable among zones, with mean values ranging from non-detectable to 37 ng/g lipid.

Figure 8. Composite total DDTs concentrations in the four most commonly caught target fish species. Bars represent the mean of the composite samples collected. Black dots represent each composite concentration. Bar color indicates whether the zone is an embayment (yellow) or offshore (blue). Vertical lines represent ATL thresholds. There are no ATL thresholds for lipid-normalized tissue concentrations.

Total PCBs

Total PCBs had the second greatest number of composites that exceeded ATL thresholds after mercury, although none of the composites had total PCBs concentrations that exceeded the “do not consume” threshold of 120 ng/g ww (Figure 3). Total PCBs were detectable in 73% of fish tissue composites, with tissue concentrations ranging from 0.27 ng/g ww to 106 ng/g ww. Thirty-six percent of composites had total PCBs concentrations below the lowest OEHHA threshold ($\leq$ 9 ng/g ww). Eighty-six percent of tissue composites had concentrations below 21 ng/g ww (the low end of the range for the two serving per week ATL).

There were significant differences in total PCBs concentrations among fish species (ANOVA, $p = 4.1 \times 10^{-10}$) (Figure 9, top panel), though some of this variability may be due to the fact that different species had significantly different lipid concentrations (Figure D1). Of the target species, Pacific Chub Mackerel and White Croaker had the highest concentrations of total PCBs, with mean values greater than 50 ng/g ww (North and South San Diego Bay for Mackerel and Long Beach for Croaker) and also the highest lipid concentrations (Figure 2, Figure D1). Shiner Surfperch had the highest mean concentration in one composite, but also the highest lipid concentrations (Figure D1). There was variability in species composites within a zone, with standard deviations in total PCBs concentrations ranging from 0 ng/g ww (for samples where PCBs congeners were undetected, reporting limit 1 ng/g ww) to 36 ng/g ww. Coefficients of variation (CV) were highest for total PCBs among all contaminants, with 30% of the species/zone groups ($n = 19$ with $CV > 60\%$) and only 10% ($n = 5$) had low variability ($CV < 10\%$) for species collected within a zone (Appendix D, Figure D2). No species was significantly more variable than other species and no zone was significantly more variable than other zones.

There were some spatial patterns in PCBs concentrations, and there were significant differences within a species among fishing zones (two-way ANOVA, $p = 9 \times 10^{-13}$). In particular, fish caught in embayments were significantly higher than fish caught offshore in this survey (two-way ANOVA, $p = 7.7 \times 10^{-16}$). Fish caught in San Diego Bay had some of the highest concentrations recorded (Figure 9), though there was significant variability within that zone ranging from 18 ng/g ww for Kelp Bass to 63 ng/g ww for Pacific Chub Mackerel. However, there were no clear along-shore gradients among zones (Figure 9).

As with DDTs, lipid normalization partially accounted for some differences in fish species tissue concentrations, allowing for a more direct estimate of chemical exposure (Figure 9, lower panel). As noted above, fish species with highest total PCBs also generally had the highest lipid content (Figure D1). With lipid-normalization, there were significant differences among fish species (ANOVA, $p < 2 \times 10^{-16}$), and within a species significant differences among fishing zones (two-way ANOVA, $p = 5 \times 10^{-9}$). Lipid-normalization increased the difference between embayment and offshore zones, particularly indicating elevated concentrations of total PCBs in fish in San Diego Bay for Pacific Chub Mackerel and Spotted Sand Bass. Lipid-normalized PCBs in Pacific Chub Mackerel in San Diego Bay was more than twice that of the next-highest fish species (20,8000 and 34,400 ng/g lipid in North and South San Diego Bay, respectively).

Figure 9. Composite total PCBs concentrations in the four most commonly caught target fish species. Bars represent the mean of the composite samples collected. Black dots represent each composite concentration. Bar color indicates whether the zone is an embayment (yellow) or offshore (blue). Vertical lines represent ATL thresholds. There are no ATL thresholds for lipid-normalized tissue concentrations.

Comparison to 2009 Survey

Metals/Metalloids

Kelp Bass and Pacific Chub Mackerel composite samples had significantly lower mercury and selenium concentrations in the 2018 survey compared to 2009 (Figure 10, Table 5). These two species were selected for this analysis because they had broad geographic distributions in both surveys. For Kelp Bass, concentrations were lower in 2018 compared to 2009 in 86% of zones for mercury and 50% of zones for selenium (Figure 10). For Pacific Chub Mackerel, 88% of zones had lower mercury and selenium concentrations in 2018 compared to 2009. For those zones that had higher concentrations in 2018, most of these zones were not consistent between Kelp Bass and Pacific Chub Mackerel, with one exception (San Onofre to Crystal Cove for selenium, both Kelp Bass and Pacific Chub Mackerel had higher concentrations in 2018 compared to 2009).

Length-adjusted mean mercury concentrations in Kelp Bass were not significantly different between the two surveys in the three zones (Table 3). Length-adjusted means for Kelp Bass in 2009 were obtained from a different subset of zones but were nevertheless generally similar to the means obtained in 2018. The 2009 means ranged from a low of 130 ng/g ww in Crystal Cove to Santa Ana River (the same zone with the lowest mean in 2018) to a high of 230 ng/g ww at Northern Channel Islands and Middle Santa Monica Bay. As in 2018, there were statistically significant differences among these means, but they did not represent a substantial difference toxicologically – corresponding to a shift from the upper end of OEHHA's ATL concentration range for two servings per week (> 70-150 ng/g) to the lower end of the ATL range for three servings per week (> 150-440 ng/g). Length-adjusted means were obtained in both surveys for three zones: Northern Channel Islands, Palos Verdes, and Crystal Cove to Santa Ana River. The 2018 means for each of these zones were not significantly different from the means observed in 2009. The means for Palos Verdes and Crystal Cove to Santa Ana River were nearly identical in the two surveys.

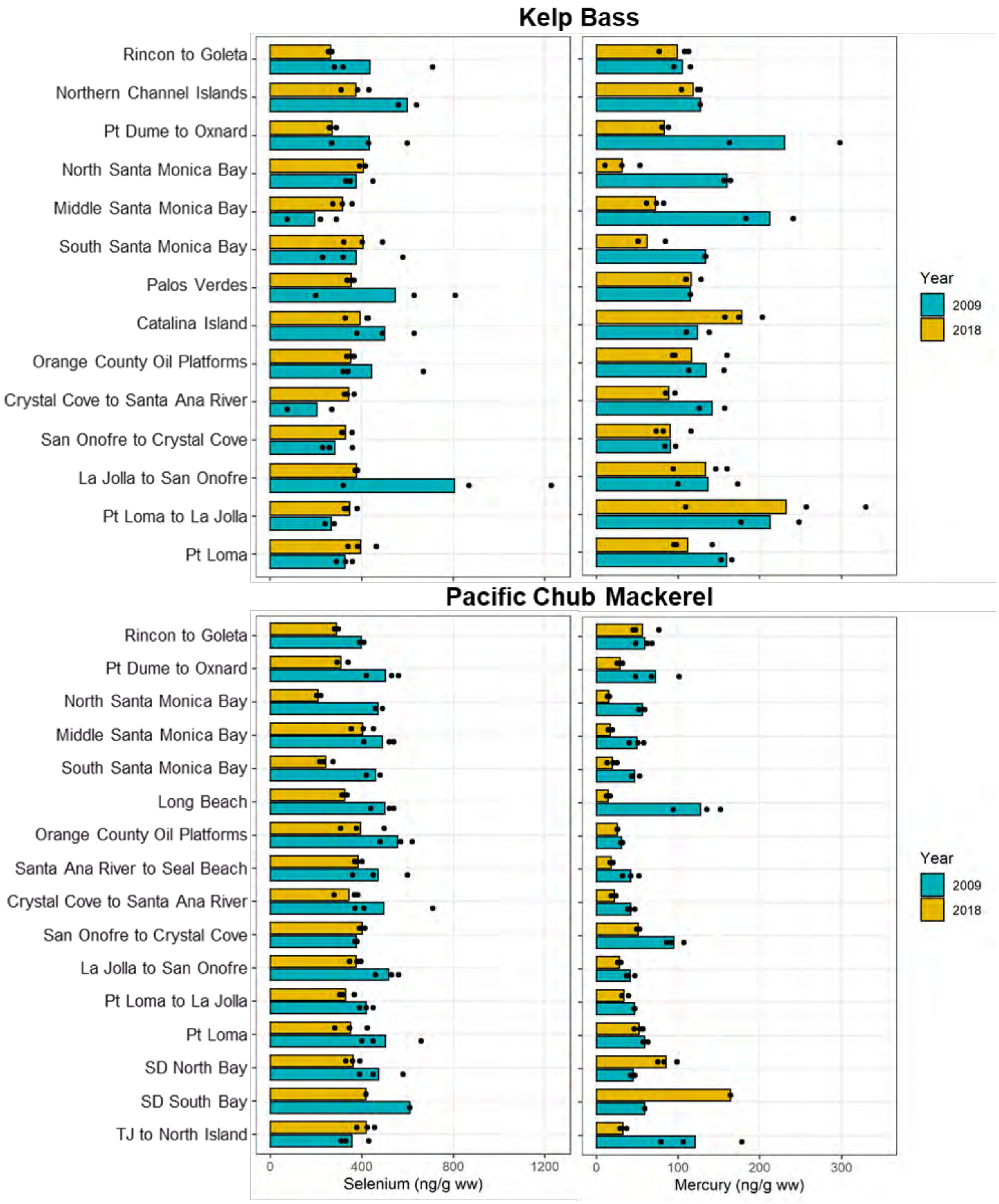

Figure 10. Difference in fish tissue concentrations of selenium (left) and mercury (right), for Kelp Bass (top) and Pacific Chub Mackerel (bottom), during the Bight '08 survey (blue) and Bight '18 survey (gold).

Organic Contaminants

Kelp Bass and Pacific Chub Mackerel tissues had significantly lower concentrations of organic contaminants in 2018 compared to 2009 (Figure 11, Table 4). Mean concentrations for both lipid-normalized total DDTs and total PCBs were significantly lower during 2018 relative to 2009. For Kelp Bass, 100% of zones had lower lipid-normalized total DDTs and total PCBs concentrations in 2018 compared to 2009 (Figure 11). For Pacific Chub Mackerel, 100% of zones had lower lipid-normalized total DDTs and 88% of zones had lower lipid-normalized total PCBs in 2018 compared to 2009. Only North and South San Diego Bay had higher lipid-normalized total PCBs in Pacific Chub Mackerel in 2018. While there were significant differences in lipid content in both species during the two surveys (two-way ANOVA of lipid content by zone, $p = 6.00 \times 10^{-5}$ and 2.38×10^{-15} for Kelp Bass and Pacific Chub Mackerel, respectively), there was no consistent pattern spatially or temporally (Figure 12).

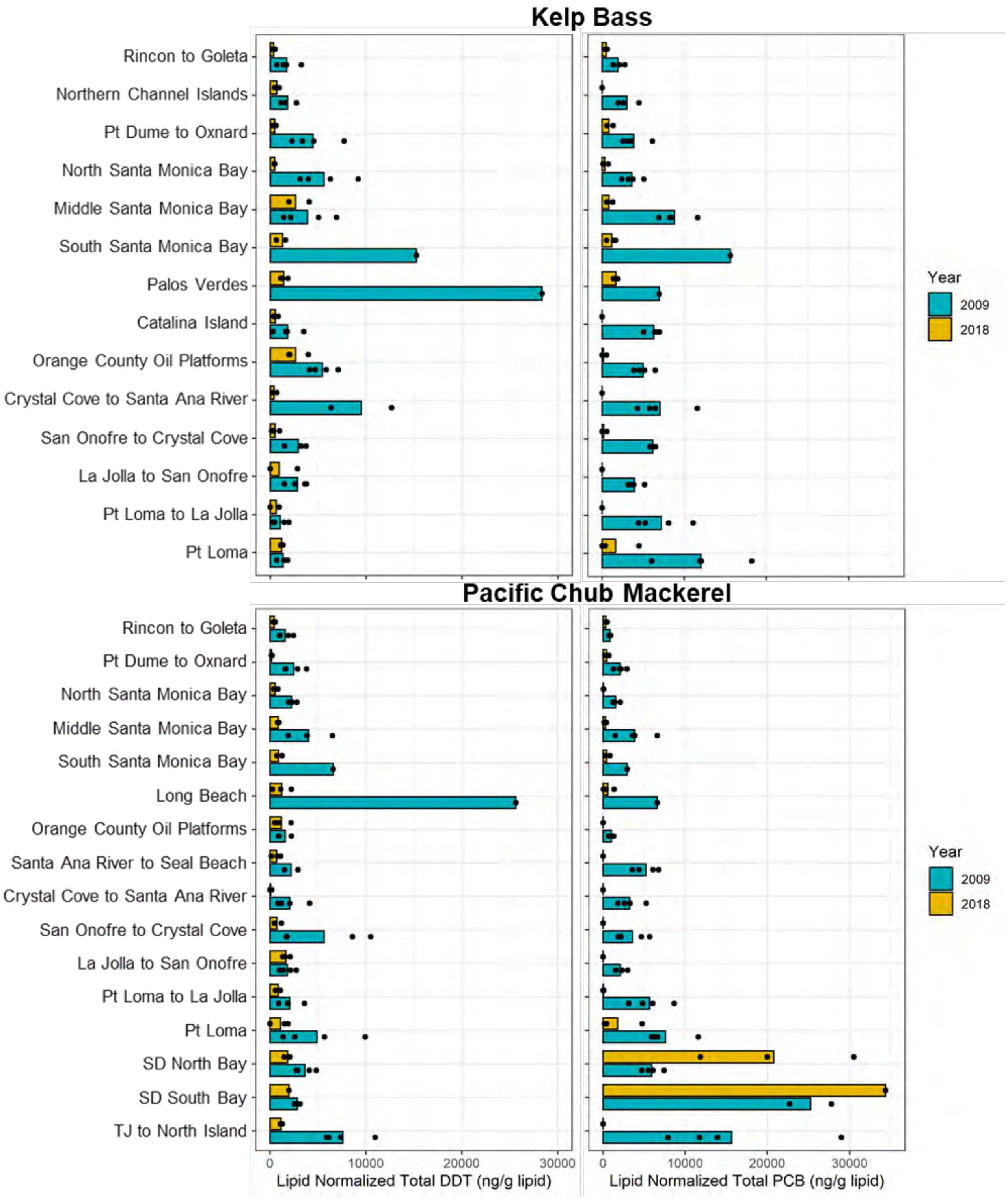

Figure 11. Difference in fish tissue concentrations of lipid-normalized total DDTs (left) and lipid-normalized PCBs (right), for Kelp Bass (top) and Pacific Chub Mackerel (bottom), during the Bight ‘08 survey (blue) and Bight '18 survey (gold).

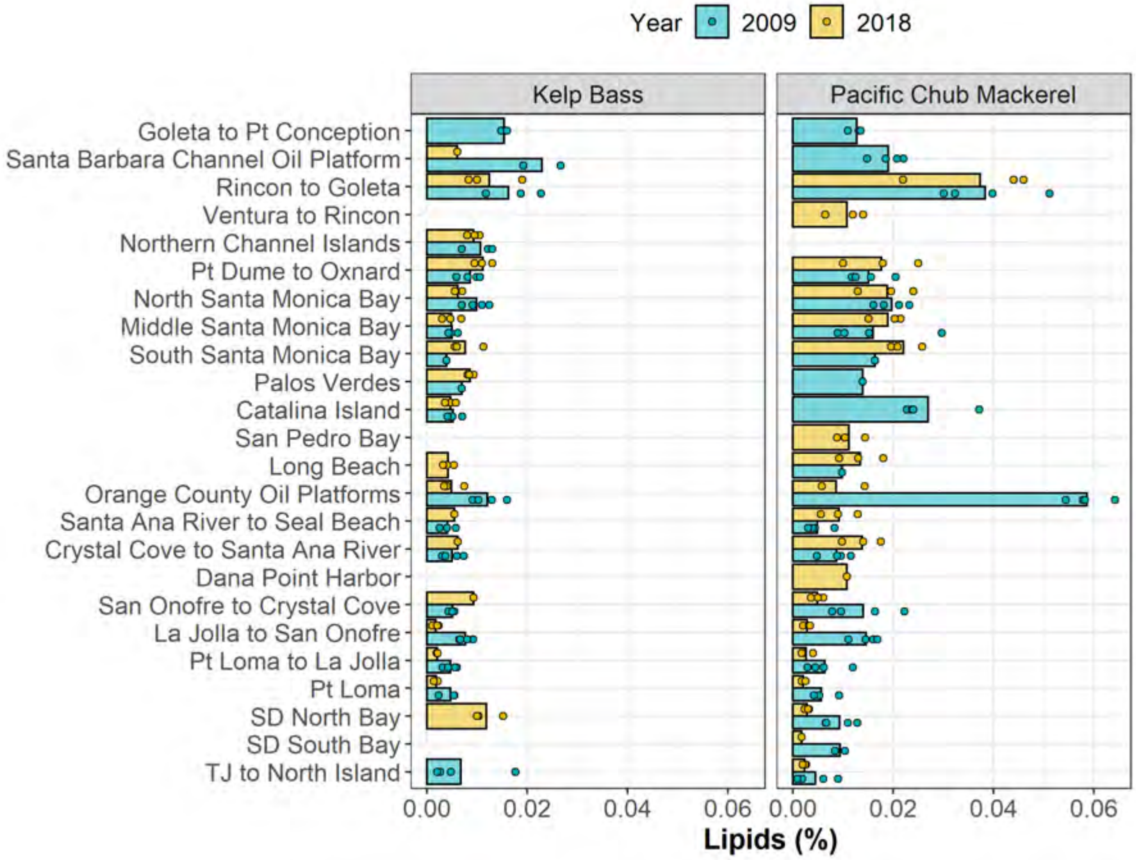

Figure 12. Difference in lipid content between 2009 and 2018 surveys. Bars represent mean concentrations; dots are values for each composite.

Table 4. Contaminant means and standard deviations and p-values for two-way ANOVA for Kelp Bass and Pacific Chub Mackerel for 2009 and 2018 on log-normalized data. Units for metals/metalloids are ng/g ww. Units for organics are ng/g lipid.

Species	Parameter	Mean		Standard Deviation		Two-way ANOVA p-values (log-transformed data)		
		2009	2018	2009	2018	Year	Fishing Zone	Year & Zone
Kelp Bass	Mercury	140	106	45	53	6. x10^{-5}	0.00012	0.0012
Pacific Chub Mackerel	Mercury	61	35	33	27	2.5 x10^{-13}	2.8 x10^{-13}	4.8 x10^{-14}
Kelp Bass	Selenium	445	345	310	54	0.068	0.013	0.039
Pacific Chub Mackerel	Selenium	477	337	109	67	7.8 x10^{-13}	0.0088	0.011
Kelp Bass	Total DDTs	3930	1260	3930	1360	2.6 x10^{-15}	1.7 x10^{-13}	< 2 x10^{-16}
Pacific Chub Mackerel	Total DDTs	3460	970	3390	750	3.9 x10^{-13}	1.1 x10^{-8}	1.5 x10^{-6}
Kelp Bass	Total PCBs	6900	750	5020	1080	< 2 x10^{-16}	2.6 x10^{-8}	8.1 x10^{-6}
Pacific Chub Mackerel	Total PCBs	4800	2160	5590	6850	2.1 x10^{-6}	< 2 x10^{-16}	1.4 x10^{-10}

IV. Discussion

Sport fish in the SCB are generally considered safe for consumption of at least one serving per week. The OEHHA ATL thresholds were designed with the recognition that human consumption of fish provides significant health benefits. Moreover, subsistence fishing is an important food source for communities in southern California (Pitchon and Norman 2012). Results from this survey indicate that sport fishing in the SCB can generally continue to serve this important role. None of the fish tissue composites measured in this study exceeded the most restrictive threshold ("do not consume") for any contaminant. However, of the contaminants assessed, mercury and total PCBs concentrations in fish tissues exceeded some ATL thresholds for some fish species throughout the Bight, suggesting a limited number of servings of these species per week can be safely consumed (Figure 13). Notably, there are several species for which there are statewide advisories recommending women ages 18-49 and children under 17 not consume, but none of these species are among the target species investigated in this study (e.g., sharks and several species of rockfish, OEHHA 2016). Several zones had mean concentrations that exceeded some consumption thresholds for more than one contaminant. For example, both mercury and total PCBs thresholds were exceeded in five zones for Kelp Bass, six for Pacific Chub Mackerel, eight for Barred Sand Bass, and five for Spotted Sand Bass (Figure 13), although the thresholds exceeded were not usually the same (e.g., thresholds exceeded for mercury were generally more restrictive than for PCBs, with the exception of San Diego Bay).

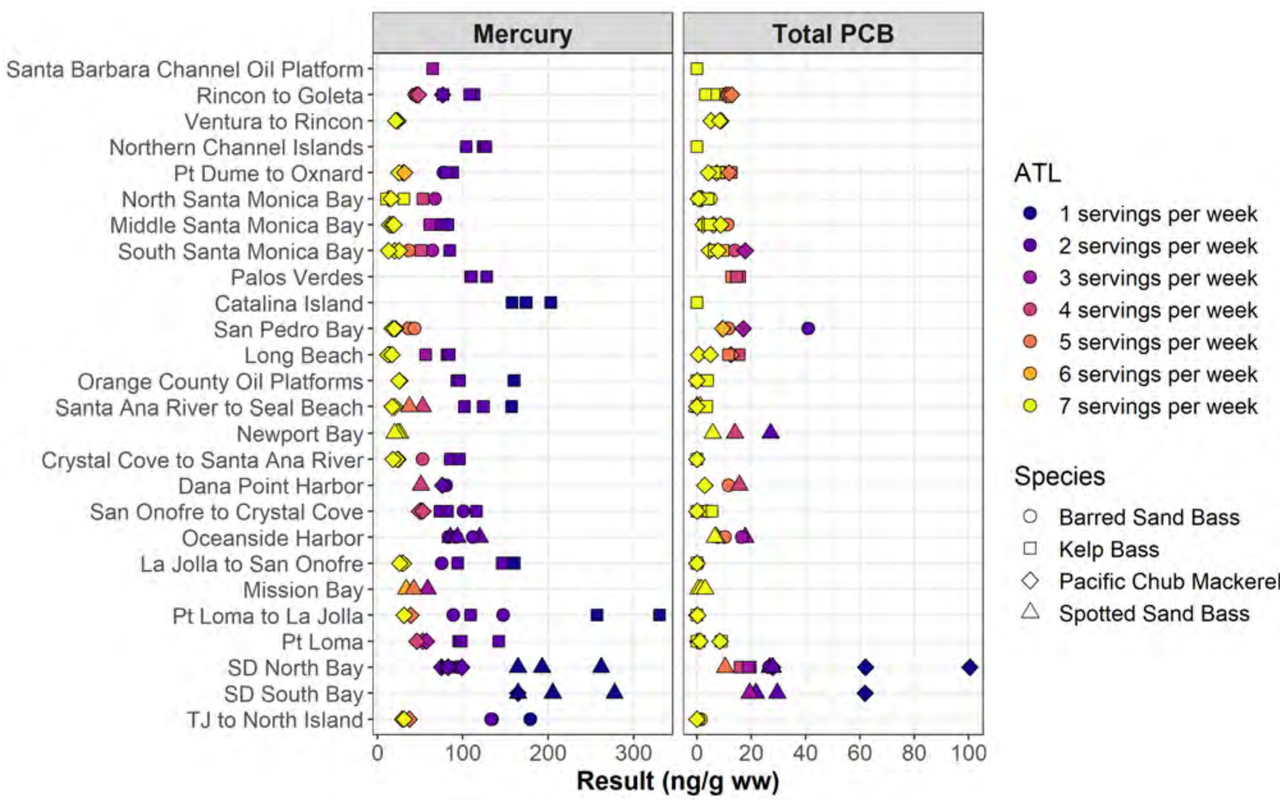

Figure 13. Fish mercury and total PCBs concentrations for the four most commonly caught species by fishing zone. Colors indicate the advisory tissue level category based on the concentrations of each contaminant and shapes indicate the species.

Human health risk due to arsenic contamination of SCB sport fish is uncertain. As noted above, there are no OEHHA thresholds for arsenic. However, the USEPA provides monthly fish consumption limits for inorganic arsenic concentrations in fish tissues in their Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories Report (Table 5), which provides a range of risk-based consumption thresholds based on both carcinogenic and noncarcinogenic health endpoints (USEPA 2000b). We analyzed total arsenic in this study, so to screen for potential human health impacts from inorganic arsenic contamination we had to estimate the inorganic arsenic concentration from the total. Data from the worldwide literature indicate the percent of inorganic arsenic in marine and estuarine finfish does not generally exceed 10% of the total concentration but may range up to 30% (Lorenzana et al. 2009, Taylor et al. 2017). The consensus is that 85 to 90% of the arsenic in the edible parts of marine fish is organic arsenic (e.g., arsenobetaine, arsenochloline, dimethylarsinic acid) consistent with other estimates that 10% is inorganic arsenic (USEPA 2003). Given these ranges, we conducted a screening evaluation of expected health risk from inorganic arsenic using the U.S. EPA thresholds, assuming 10% of total arsenic was inorganic (Figure 14). Applying this assumption to the dataset, no zone exceeded the do not consume threshold for noncarcinogenic health endpoints and 41% of composites (80 out of 193) were recommended for unrestricted consumption. However, 30% of composites (57 out of 193) exceeded the do not consume threshold for cancer endpoints and all zones and species exhibited some degree of recommended restriction for this endpoint. Given these results, there may be a human health risk from arsenic contamination of fish tissues for cancer-related health endpoints. Further investigation is required to determine if the 10% assumption is correct for Southern California Bight species.

Table 5. Monthly fish consumption limits for inorganic arsenic concentrations in fish tissues based on carcinogenic and noncarcinogenic health endpoints assuming an 8 oz (0.227 kg) serving size. Values are in ng/g (PPB), wet weight. (modified from USEPA 2000b)

Risk Based Consumption Limit Servings per month	Fish Tissue Concentrations for noncancer health endpoints	Fish Tissue Concentrations for cancer health endpoints
Unrestricted (> 16)	< 88	< 2
8 servings	230 – 350	5.2 – 7.8
3 servings	700 – 940	16 – 21
Do not consume	> 5600	> 130

* Based on adult body weight of 70 kg.

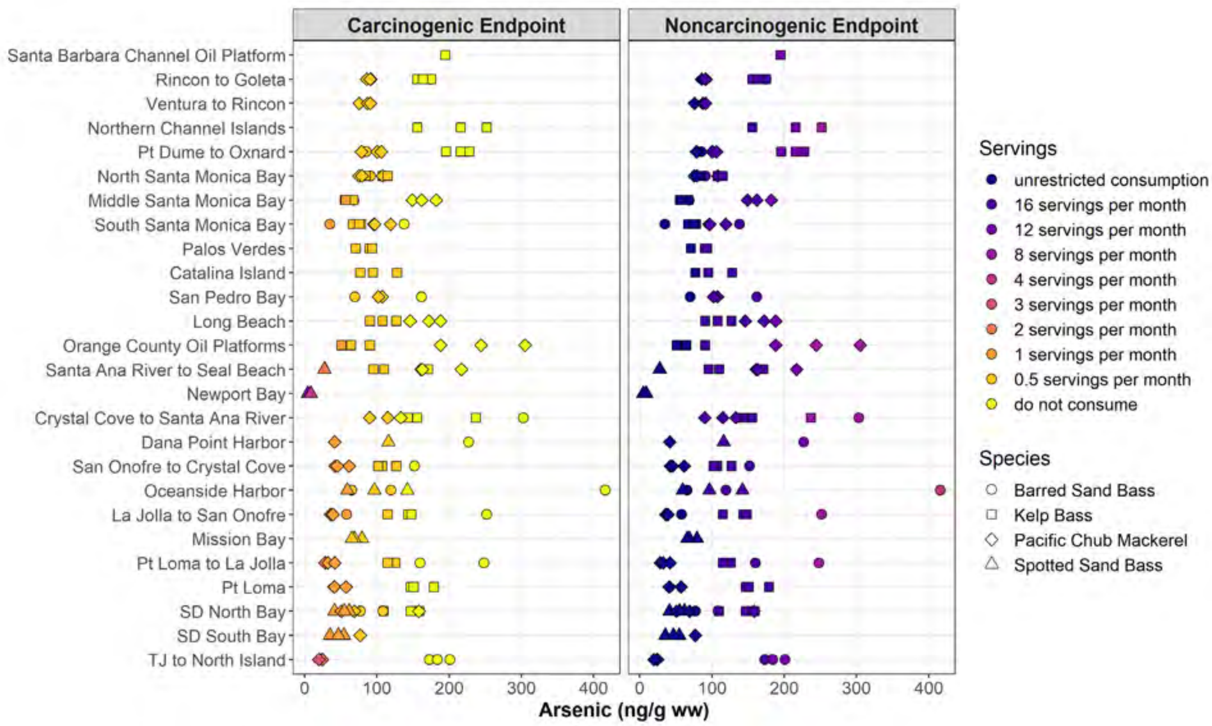

Figure 14. Estimated fish tissue arsenic concentrations for the four most commonly caught species by fishing zone assuming inorganic arsenic is 10% of the total arsenic concentration. Colors indicate the consumption advisory category based on the concentrations of inorganic arsenic and USEPA monthly fish consumption limits and shapes indicate the species.

Contaminants in fish tissues may be associated with sediment sources of those contaminants. Some zones were associated with specific chemical contaminants or combinations thereof (Figure 15, principal components analysis [PCA] of contaminant concentrations in Kelp Bass and Pacific Chub Mackerel). Furthermore, patterns in fish tissue contamination were often correlated with sediment sources of those contaminants as determined by the regional assessment of sediment chemistry conducted at the same time as the 2018 sport fish survey (Du et al. 2020). The PCA results indicate that total DDTs in fish tissues are positively associated with Santa Monica Bay and Palos Verdes, consistent with the location of a Superfund site and subsequent sediment contamination patterns associated with prevailing currents (Du et al. 2020). Total PCBs concentrations in fish tissues were associated with San Diego Bay and Long Beach, zones that also had high sediment concentrations of these contaminants. Fish tissue arsenic was highest in the northern Bight region, where sediment arsenic concentrations were highest. Interestingly, combinations of chemical contaminants associated with specific zones were not necessarily consistent between the two fish species and not always associated with sediment contamination within that zone. Such differences could be due to the mobility patterns of fish species, which can be several dozens of kilometers and may obscure spatial patterns among zones, as well as differences in prey and habitat selection (Parnell et al. 2008).

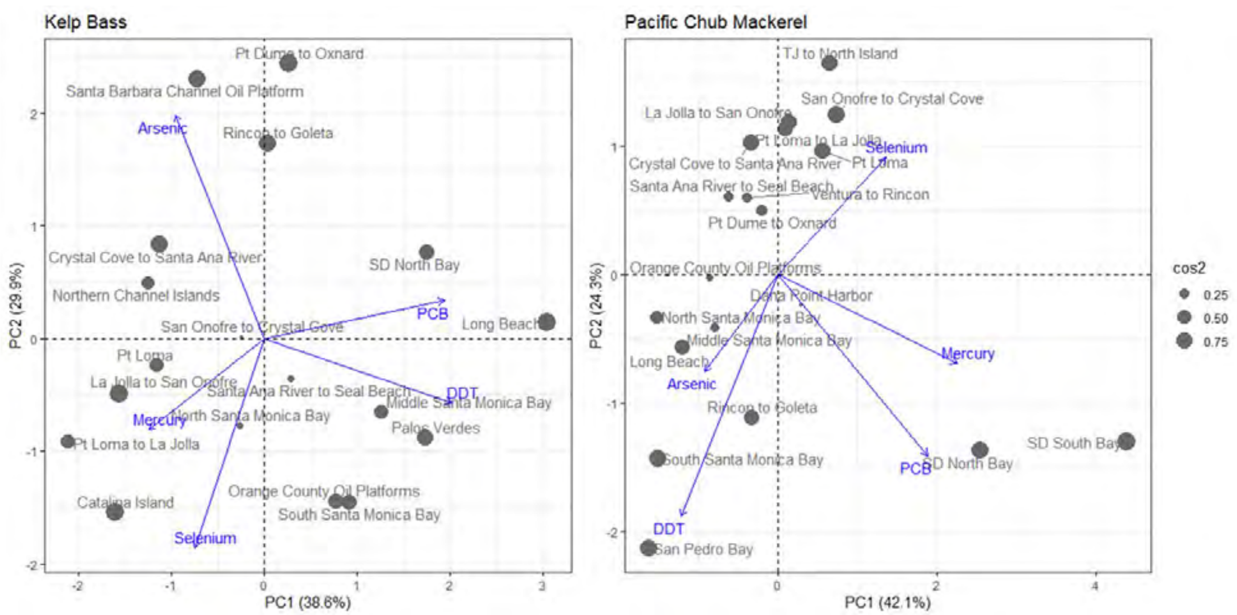

Figure 15. Principal components analysis biplot showing the position of each fish tissue composite Kelp Bass (left) and Pacific Chub Mackerel (right) in terms of the first two principal components (points) and how each of the contaminants map (blue arrows). The proportion of the total variance explained by each of the first two principal components is given on each axis. The cos2 (square cosine), or the importance of a principal component for the observation, is given by the size of the point. Positive correlated variables point to the same side of the plot. Negative correlated variables point to opposite sides of the graph.

This survey represents a synoptic assessment of fish tissue bioaccumulation of contaminants; however, potential human health risk related to fish consumption in specific regions may be greater or lower than described here. This survey represents fish caught on a specific day with a consistent level of effort applied to each zone. However, more intensive, targeted fishing efforts in specific zones have indicated that fish tissue concentrations in some species, including species not targeted for this study, may be greater than those described in this report. For example, the Palos Verdes (PV) Seafood Safety Survey conducted by the Los Angeles County Sanitation Districts (LACSD 2019, 2020), conducted during the same year as this survey, intensively fished the PV Shelf (Figure 16), a known hotspot for legacy DDTs as described above and in Du et al. (2020). The Bight Program/SWAMP survey caught enough fish for three composites of Kelp Bass in Zone 18 (Palos Verdes) compared to the LACSD survey, which had three composites of each of five species. For Kelp Bass, there was good coherence between concentrations recorded in both studies; however, the LACSD survey sampled a greater number of fish and some of these had different tissue concentrations relative to the Kelp Bass measured in the Bight survey. This was most notable in White Croaker, which exceeded the “do not consume” threshold for total PCBs and had high concentrations of total DDTs (Figure 17). This discrepancy highlights possible sampling bias from under-sampling fish species in some zones. However, the purpose of the Bight study was to characterize the regional extent and magnitude of regional fish contamination, not to provide detailed assessment of risk in specific zones. While information from the Bight/SWAMP survey can contribute to development of local fish consumption advisories, a more intensive sampling approach that includes more than one or two species, such as the LACSD seafood safety survey, is more appropriate to accurately characterize local risk.

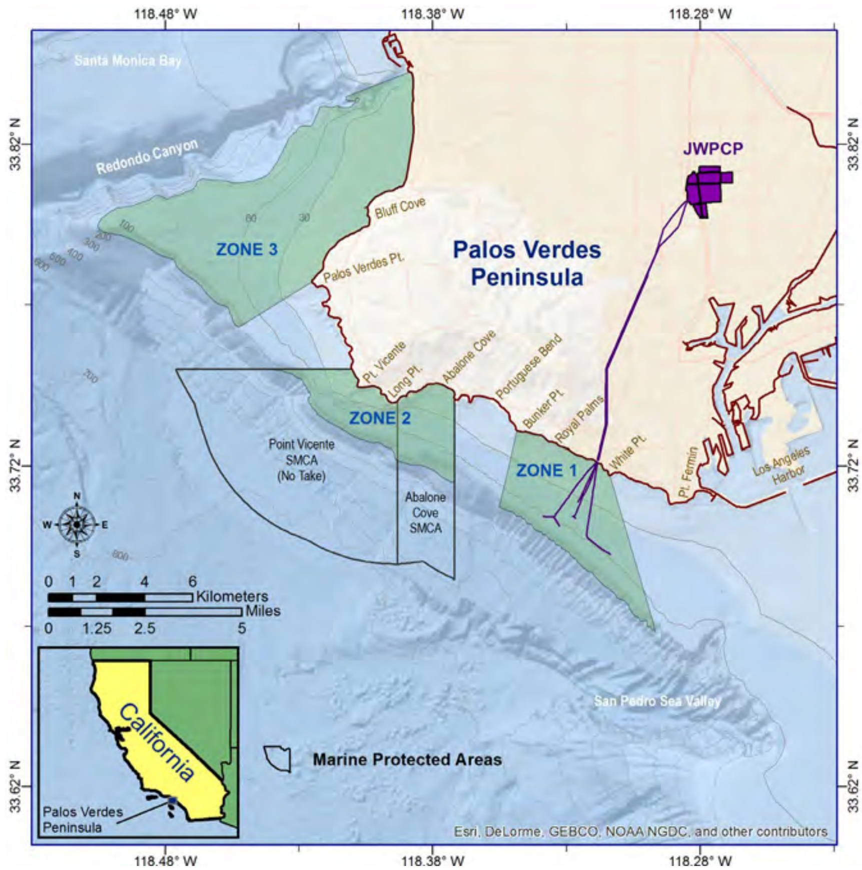

Figure 16. Fishing zones for Palos Verdes 2018 Local Seafood Safety Survey, conducted by Los Angeles County Sanitation Districts (LACSD 2019). This zone encompasses the entirety of Zone 18 in the Bight survey.

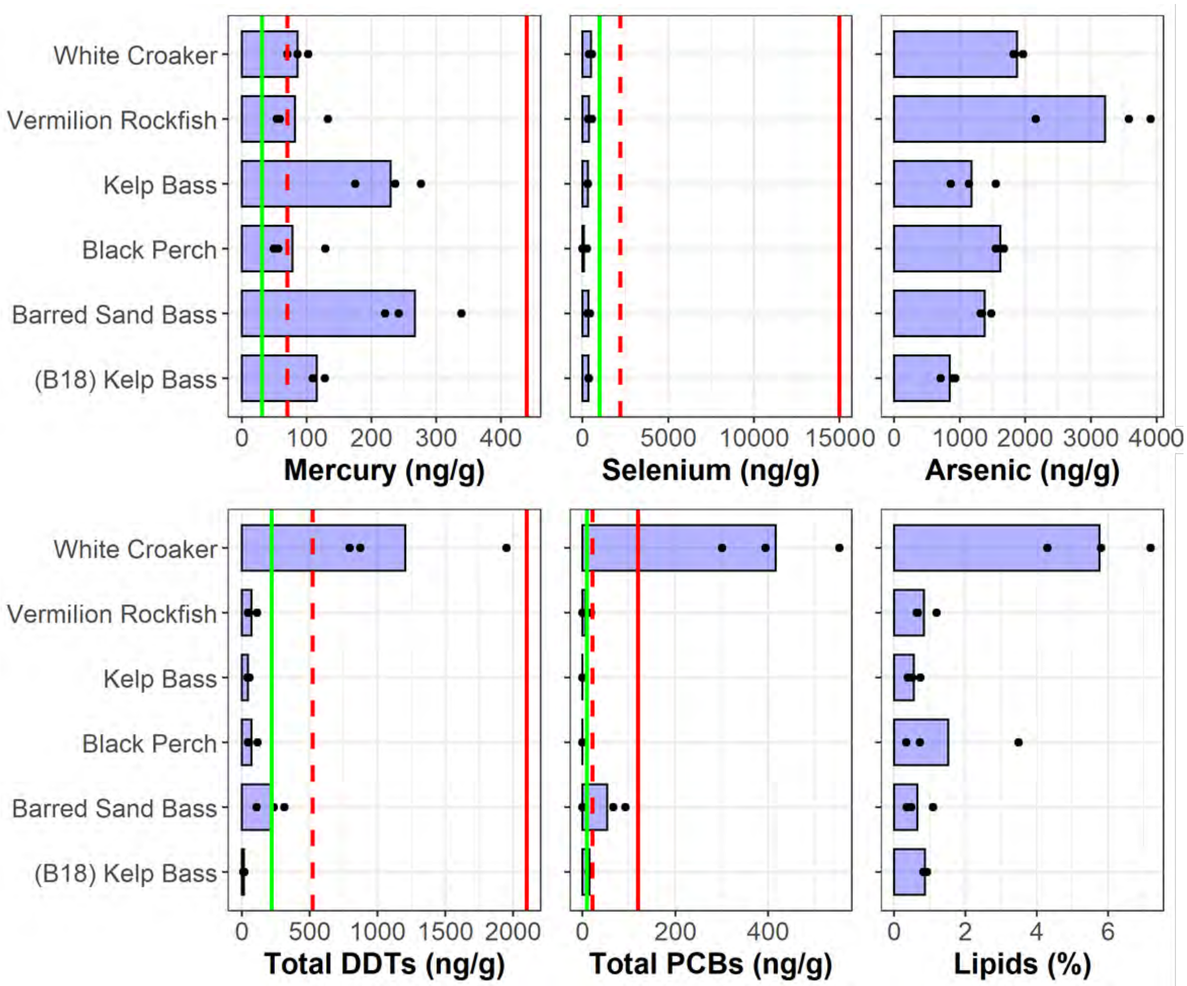

Figure 17. Comparison between Kelp Bass tissues collected on the PV shelf (Zone 18) and analyzed as a part of the Bight Bioaccumulation study and the five species caught during the Los Angeles County Sanitation Districts (LACSD) Seafood Safety Survey (LACSD 2019, 2020).

Contaminant concentrations in fish were generally lower in 2018 compared to 2009, but uncertainties remain. Fish tissue concentrations for both metals/metalloids and organic contaminants were lower in 2018 than in 2009. While mercury and PCBs are still a concern for fish consumption, the lower concentrations potentially signal a lessening of human health risk through time. For example, for Kelp Bass and Pacific Chub Mackerel, the two species that had the greatest regional coverage, mercury concentrations decreased from 140 to 106 ng/g ww and 61 to 35 ng/g ww, respectively, since the 2009 survey. Lipid-normalized PCBs concentrations decreased from 6900 to 750 ng/g lipid and 4800 to 2160 ng/g lipid for Kelp Bass and Pacific Chub Mackerel, respectively. This is consistent with sediment chemistry data, which have also shown a decrease in mercury and PCBs concentrations since the 2009 survey (Du et al. 2020). However, it should be noted that these metals results do not include an adjustment for length or age. Some contaminants, such as mercury are known to increase with age and size in some fish (Phillips et al. 1997), a pattern we saw in some fish species in this survey (Figure 5). Accounting for age and thus lifetime exposure can be an important factor when comparing bioaccumulation among individuals. Thus, normalizing tissue concentration by fish length makes comparisons among sites and between times more robust if length-age relationships are significant. Indeed, when normalized for length, Kelp Bass did not have a significant decrease in tissue mercury concentrations between 2009 and 2018 in the three zones where comparable data were available. As such, future mercury monitoring should include length-normalization, preferably accompanied by aging the fish, for spatial and temporal trends analysis.

V. CONCLUSIONS

This survey provides a regional assessment of fish tissue bioaccumulation of specific contaminants. The major conclusions from this effort are as follows:

- **Chemical contaminant concentrations in the target sport species fish throughout the SCB were below OEHHA advisory thresholds advising no human consumption of sport fish.** No contaminants exceeded the "do not consume" threshold, suggesting consuming one serving per week does not pose significant health risk for any of the target species in any of the zones sampled in this survey. Neither DDTs nor selenium concentrations exceeded any ATL threshold. However, mercury and PCBs exceeded some ATL thresholds in some fishing zones as described below.

- **Mercury concentrations most frequently exceeded ATL thresholds; therefore, mercury contamination is of greatest concern to human health through sport fish consumption.** Most zones exceeded the advisory threshold recommended consumption of not more than 2 servings per week threshold (70 ng/g ww) for the sensitive population (children and women ages 18-49) in one or more target species, more than any other contaminant measured in the survey.

- **PCBs contamination is also a concern for human health through sport fish consumption with tissues exceeding advisory thresholds in a third of fishing zones.** PCBs were the only other contaminant for which fish exceeded consumption advisory thresholds, but at a lesser extent and lower magnitude compared to mercury.

- **Concentrations of contaminants in fish tissues were generally lower in 2018 compared to 2009.** Contaminants in both Pacific Chub Mackerel and Kelp Bass, the two target species caught in the largest number of zones in both surveys, were lower in 2018 than in 2009. Mean mercury concentrations decreased from 140 to 106 ng/g ww in Kelp Bass and from 61 to 35 ng/g ww in Chub Mackerel from, respectively, 2009 to 2018. Mean mercury concentrations decreased or remained the same for both species in all zones except for two for both species (North and South San Diego Bay for Pacific Chub Mackerel and Point Loma to La Jolla and Catalina Island for Kelp Bass). A more rigorous investigation involving length-adjusted means in Kelp Bass showed no significant difference between the two time periods, reinforcing the value of length or age standardization for temporal and spatial assessments. Mean lipid-normalized total PCBs concentrations decreased from 6900 to 750 ng/g lipids in Kelp Bass and from 4800 to 2160 ng/g lipids in Pacific Chub Mackerel. Mean PCBs decreased in all zones for Kelp Bass and in all zones except two (North and South San Diego Bay) for Pacific Chub Mackerel.

VI. RECOMMENDATIONS

Several recommendations have been suggested by the planning committee for future surveys:

1) **Collaborations established to characterize SCB seafood concentrations have been productive and should be continued.** This study would not have been possible without the expertise and resources from SWAMP. Furthermore, as with the 2009 survey, the SCB can be placed into greater regional context with the continuation of sampling throughout the State. The Bight Program provides additional samples, species, replication, and analytes not achievable by SWAMP alone. The integration of the two programs creates a larger regional dataset and provides consensus with a larger number of managers to create consistent statewide messaging. Large regional surveys such as these are a valuable resource for understanding bioaccumulation and human health risk. Moreover, the Bight Program and participating agencies should increase interactions with OEHHA to support the fish advisory process with monitoring data.

2) **Further investigation of embayment sources of contamination and pathways should be considered.** Fish tissue concentrations for total PCBs were highest in embayments and zones with high PCBs concentrations also had high mercury concentrations. Elevated tissue contaminants are consistent with high sediment concentrations in these areas as reported in the Bight ’18 Sediment Chemistry Report. In addition, embayment zones were the only zones to exhibit higher PCBs concentrations in fish tissues in 2018 compared to 2009. Embayments are popular for recreational and subsistence fishing; therefore, further investigation into the sources and pathways for fish contamination and subsequent risk to human health should be considered for these zones. For embayments undergoing remediation, continued fish monitoring can help determine the effectiveness of these efforts.

3) **Study design and protocols should be refined in future surveys to increase utility for bioaccumulation assessments.** Because fish tissue mercury concentrations are known to increase with age/length, future surveys should apply length normalization, and age normalization if possible, for mercury concentrations in predator species to allow for a more robust assessment of spatial and temporal patterns. In addition, there is no OEHHA human health threshold for total arsenic so no statements can be made to assess human health risk based on tissue concentrations. However, when we applied the 10% of total arsenic for

screening, we found some exceedances of thresholds for the USEPA inorganic arsenic carcinogenic health endpoint. Therefore, further investigation may be warranted and the Bight Program should either consider new ways to utilize the data (i.e., comparison to ongoing monitoring programs) or resolve the question of relative proportion of inorganic to total arsenic in SCB fish so that a more accurate assessment of risk can be made. Finally, because there were some inconsistencies with reporting limits from different agencies, the reporting limit DQOs for tissue contaminants should be re-evaluated to better align minimum target reporting limits (RLs) with quantifiable detection capabilities.

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Appendix A: Quality Assurance and Quality Control (QA/QC)

The primary goal of the quality assurance and quality control (QA/QC) effort was to ensure that the fish tissue chemistry data generated among the many study participants were comparable and complete. Therefore, a performance-based approach to QA/QC was adopted, allowing each participating laboratory the flexibility to utilize its own protocols, while meeting common data quality objectives (DQOs) for criteria pertaining to sensitivity, accuracy, and precision. This is the same approach used in previous regional surveys (Gossett et al. 2003) and was carried out in accordance with the Bight '18 Quality Assurance Manual. This section details the quality assurance analysis for samples collected in Bight '18. Quality assurance and quality control for tissues analyzed in the 2009 study are included in the final report for that study "Contaminants in Fish from the California Coast, 2009-2010: Summary Report on a Two-Year Screening Survey" (Davis et al. 2012) and is available online: https://www.waterboards.ca.gov/water_issues/programs/swamp/docs/coast_study/bog2012may/coast2012report.pdf.

There are no differences between QA/QC data quality objectives (reporting limits, detection limits, etc.) or practices (inter-laboratory comparison, data acceptance criteria) between the 2009 and 2018 survey.

Reporting Limits

To achieve study goals, minimum target reporting limits (RL) for each analyte were set forth in the Bight '18 Quality Assurance Manual based on ATLs that were developed by OEHHA. Overall, participant specific minimum RLs were lower than or comparable to the targets; therefore, the analyses were performed with adequate sensitivity. Exceptions are as follows: the 84% success in meeting the required RLs for DDTs and PCBs, respectively, were due to two laboratories' RLs exceeding the target RLs; however, if MDLs were below the target RLs when non-detect values were reported, it indicates there was no measurement bias.

Table A1. Achieved reporting levels in fish tissue. Percent success is based on the number of samples meeting the required reporting level.

Parameter	Required Reporting Level	Reporting Level Range Achieved	Percent Success
Arsenic (µg/g ww)	0.3	0.007-0.3	100%
Mercury (µg/g ww)	0.02	0.00002-0.02	100%
Selenium (µg/g ww)	0.4	0.0099-0.4	100%
DDTs (ng/g ww)	1	0.5-3	84%
PCBs (ng/g ww)	1	0.4-4	84%

In order to evaluate whether the RL issue for DDTs and PCBs would be an issue, we conducted a sensitivity analysis where we assumed all non-detects for each DDTs or PCBs parameter have a value equal to the reported MDL. For total DDTs, we added 10 ng/g to each DDTs analyte for this analysis. Applying this to the data, it would not change the assessment for total DDTs because none of the effected composites would cross the lowest consumption threshold (550 ng/g). For total PCBs, we added 21 ng/g to each PCBs congener for this analysis. As a result, 21 composites would change from no threshold exceedance to the threshold exceedance for no more than 2 servings per week (21 ng/g PCBs), so it would have an effect on the assessment outcome.

However, the chemistry technical committee recommended that these non-detects should be treated as “0” regardless of the reported RL because the lab in question routinely hit their lowest calibration standard of 0.5 ng/g, suggesting they had the sensitivity to detect low concentrations, despite the reported RL. The issue stems from the mismatch in how RLs are reported for different agencies and the technical committee recommends review of target RLs and how they are calculated in future surveys to avoid the discrepancy in the future.

Inter-Laboratory Comparison Exercises

Prior to analysis of field samples, reference fish tissue samples were selected, prepared, and analyzed by all participating labs to assess the inter-laboratory comparability of analytical results. Metals and organic measurements were each evaluated using two types of reference materials: a certified reference material (CRM) with assigned certified or reference values, and reference materials generated from fish tissue with regionally relevant matrices and ranges of expected target analyte concentrations. The reference materials were measured in triplicate, and at least two of the replicates must be within the target criteria to achieve passing results (Table A2). Laboratories were required to pass the inter-laboratory comparison before analyzing field samples. A summary of inter-laboratory comparison results is in Table A3.

Table A2. Fish tissue chemistry intercalibration results summary. Percentages refer to the number of parameter analyses that passed the acceptance criteria.

Reference Material	Parameter	Criteria	LACSD	OCSD	CLA	CSD	Physis	Summary
SRM 1946	Individual PCBs Congeners	Within 50% of target value for 70% of the analytes	81%	81%	89%	93%	96%	All passed (≥ 78%)
SRM 1946	Individual OC Pesticides	Within 50% of target value for 70% of the analytes	89%	100%	89%	89%	100%	All passed (≥ 89%)
Organics Field Reference	Total PCBs	50% of the mean value	100%	100%	100%	100%	100%	All passed (100%)
Organics Field Reference	Total OC Pesticides	50% of the mean value	100%	100%	100%	100%	100%	All passed (100%)
DORM-4	Individual Metals	30% of the mean value for 2 of 3 analytes	100%	100%	100%	100%	100%	All passed (100%)
Metals Field Reference	Individual Metals	30% of the mean value for 2 of 3 analytes	100%	100%	100%	67%	100%	All passed (≥ 67%)

Reference Materials

Organics CRM

Standard Reference Material (SRM) 1946 tests method accuracy. Laboratories are required to obtain concentrations within 50% of the certified or reference value for 70% of the compounds within each class. Information on this material can be found on the National Institute of Standards and Technology website: https://www-s.nist.gov/srmors/view_detail.cfm?srm=1946.

Trace Metals CRM

Dorm-4 tests method accuracy. Laboratories are required to obtain concentrations within 30% of the certified value for 2 of 3 analytes, including selenium, arsenic and mercury. Information on this material can be found on the National Research Council of Canada's (NRC) Metrology Research Centre website: https://www.nrc-cnrc.gc.ca/eng/solutions/advisory/crm/list_product.html.

Field Reference Material

The field reference material provided by the Los Angeles County Sanitation Districts County from Palos Verdes Shelf was used to test both inter- and intra-laboratory precision when analyzing a sample with high levels of DDTs and potential interferences was not present in SRM 1946 and DORM-4. Laboratories are required to obtain a total class concentration within 50% of the grand mean value for PCBs and DDTs. Laboratories are also required to obtain a concentration within 30% of the grand mean value for 2 of 3 trace metals.

Table A3. Tissue chemistry intercalibration results summary

Lab	Participating Bight Lab	Parameter		
		Metals	PCBs	DDTs
CLA	Yes	Pass	Pass	Pass
LACSD	Yes	Pass	Pass	Pass
OCSD	Yes	Pass	Pass	Pass
CSD	Yes	Pass	Pass	Pass
Physis	Yes	Pass	Pass	Pass

Performance-Based Quality Control Goals and Success

Quality Control (QC) goals are described in detail in the Bight ‘18 Quality Assurance Manual (Bight ‘18 Sediment Quality Committee, 2018), and summarized along with the results in Table A4. The completeness, defined as the proportion of the expected data that was collected in the measurement process was 100%. The frequency success of running QC samples was 100%. Note that exception occurred for PCBs and DDTs due to usage of alternative SRMs. The accuracy and precision success of the QC samples was 100%.

Table A4. Summary of performance-based QC criteria and project success in fish tissue analysis within those criteria.

Quality Control Parameter	Metals		PCBs & DDTs	
	DQO	Success	DQO	Success
Completeness	100%	100%	100%	100%
Method Blank Frequency Success Accuracy Success	 1/batch < MDL or < 5% of result	 100% 100%	 1/batch < 10 times MDL	 100% 100%
Blank Spike Frequency Success Accuracy Success	 1/batch 25% of true value	 100% 100%	 Not Required	 NA
Reference Material Frequency Success Accuracy Success	 1/batch Within ± 30% of certified value for all 3 analytes	 100% 100%	 1/batch ± 50% of certified value for ≥ 70% of selected analytes	 100% 100%
Matrix Spike Frequency Success Accuracy Success	 1/batch 25% of true value for all 3 analytes	 100% 100%	 1/batch 50-150% recovery of spiked mass for > 70% of analytes	 100% 100%
Sample or MS Duplicate Frequency Success Accuracy Success	 1 / batch RPD < 25%	 100% 100%	 1/batch RPD < 50% for > 70% of analyte	 100% 100%

Holding Times

Holding time results are shown in Table A5. The 100% holding time success for trace metals and organic contaminants was achieved.

Table A5. Achieved sample holding times. Percent success is based on the number of samples meeting the required holding time.

Parameter	Required Holding Time	Holding Time Range (days)	Percent Success
Trace Metals	1 year	< 210	100%
DDTs	1 year	< 210	100%
PCBs	1 year	< 210	100%

APPENDIX B. CHEMICAL CONSTITUENTS

All chemical constituents were measured on wet tissues and are reported on a wet weight basis.

Trace Metals/Metaloids

Total Arsenic
Total Mercury
Total Selenium

DDTs Isomers and Degradation Products

4,4'-DDTs
2,4'-DDTs
4,4'-DDD
2,4'-DDD
4,4'-DDE
2,4'-DDE
4,4'-DDMU

PCBs Congeners

PCBs 8
PCBs 18
PCBs 28
PCBs 37
PCBs 44
PCBs 49
PCBs 52
PCBs 66
PCBs 70
PCBs 74
PCBs 77
PCBs 81
PCBs 87
PCBs 99
PCBs 101
PCBs 105
PCBs 110
PCBs 114
PCBs 118
PCBs 119
PCBs 123
PCBs 126
PCBs 128
PCBs 138
PCBs 149
PCBs 151
PCBs 153
PCBs 156
PCBs 157
PCBs 158
PCBs 167
PCBs 168
PCBs 169
PCBs 170
PCBs 177
PCBs 180
PCBs 183
PCBs 187
PCBs 189
PCBs 194
PCBs 195
PCBs 201
PCBs 206

APPENDIX C. FISH TISSUE SAMPLES COLLECTED

Table C1. Summary of fish in composited samples. NA indicates data was not recorded or there were insufficient fish in a composite to calculate the parameters (e.g., 1 fish per composite so no standard deviation or coefficient of variation was recorded).

Zone	Zone Name	Species	Total Length (mm)			Weight (g)			Percent Female
			Mean	Standard Deviation	Coefficient of Variation	Mean	Standard Deviation	Coefficient of Variation	
1	TJ to North Island	Barred Sand Bass	303.9	0.3	0.1	344.0	34.6	10.1	33%
3	SD North Bay	Barred Sand Bass	279.5	0.7	0.3	288.4	8.0	2.8	75%
5	Pt Loma to La Jolla	Barred Sand Bass	252.2	2.6	1.0	220.8	5.9	2.7	67%
7	La Jolla to San Onofre	Barred Sand Bass	178.4	41.9	23.5	83.6	55.7	66.6	81%
8	Oceanside Harbor	Barred Sand Bass	269.6	2.1	0.8	258.0	65.6	25.4	44%
9	San Onofre to Crystal Cove	Barred Sand Bass	258.6	NA	NA	237.0	NA	NA	60%
10	Dana Point Harbor	Barred Sand Bass	237.4	NA	NA	154.0	NA	NA	70%
11	Crystal Cove to Santa Ana River	Barred Sand Bass	237.8	NA	NA	198.8	NA	NA	75%
16	San Pedro Bay	Barred Sand Bass	262.8	2.1	0.8	258.5	4.9	1.9	50%
19	South Santa Monica Bay	Barred Sand Bass	257.0	0.0	0.0	265.2	45.0	17.0	67%
20	Middle Santa Monica Bay	Barred Sand Bass	320.3	NA	NA	575.0	NA	NA	33%
21	North Santa Monica Bay	Barred Sand Bass	241.0	NA	NA	205.0	NA	NA	100%
22	Pt Dume to Oxnard	Barred Sand Bass	327.8	NA	NA	451.3	NA	NA	0%
25	Rincon to Goleta	Barred Sand Bass	203.7	NA	NA	156.7	NA	NA	33%
8	Oceanside Harbor	California Halibut	183.0	NA	NA	61.7	NA	NA	50%
3	SD North Bay	Kelp Bass	303.9	1.2	0.4	446.7	12.3	2.8	75%
4	Pt Loma	Kelp Bass	302.9	9.2	3.0	375.3	39.7	10.6	56%
5	Pt Loma to La Jolla	Kelp Bass	311.9	8.5	2.7	422.1	40.8	9.7	75%
7	La Jolla to San Onofre	Kelp Bass	302.4	4.3	1.4	362.4	37.7	10.4	58%
9	San Onofre to Crystal Cove	Kelp Bass	287.5	0.2	0.1	318.0	9.3	2.9	53%

Zon e	Zone Name	Species	Total Length (mm) Mean	Standard Deviation	Coefficient of Variation	Weight (g) Mean	Standard Deviation	Coefficient of Variation	Percent Female
11	Crystal Cove to Santa Ana River	Kelp Bass	283.2	15.5	5.5	344.2	120.6	35.0	67%
13	Santa Ana River to Seal Beach	Kelp Bass	282.4	12.1	4.3	304.3	31.7	10.4	53%
14	Orange County Oil Platforms	Kelp Bass	277.7	0.1	0.0	270.0	18.7	6.9	60%
15	Long Beach	Kelp Bass	303.3	0.9	0.3	341.1	12.9	3.8	56%
17	Catalina Island	Kelp Bass	332.4	0.2	0.1	448.0	19.3	4.3	80%
18	Palos Verdes	Kelp Bass	317.9	1.0	0.3	453.0	2.0	0.4	33%
19	South Santa Monica Bay	Kelp Bass	279.6	0.4	0.1	318.0	17.5	5.5	67%
20	Middle Santa Monica Bay	Kelp Bass	310.2	0.3	0.1	418.3	7.0	1.7	53%
21	North Santa Monica Bay	Kelp Bass	238.5	0.8	0.3	212.0	3.6	1.7	67%
22	Pt Dume to Oxnard	Kelp Bass	277.6	0.6	0.2	316.7	10.3	3.2	53%
23	Northern Channel Islands	Kelp Bass	315.9	0.1	0.0	406.7	25.4	6.3	73%
25	Rincon to Goleta	Kelp Bass	325.3	0.8	0.3	439.3	10.3	2.3	80%
26	Santa Barbara Channel Oil Platform	Kelp Bass	297.2	NA	NA	364.0	NA	NA	60%
1	TJ to North Island	Pacific Chub Mackerel	228.1	1.3	0.6	99.3	2.3	2.3	39%
2	SD South Bay	Pacific Chub Mackerel	NA	NA	NA	184.0	NA	NA	80%
3	SD North Bay	Pacific Chub Mackerel	274.0	0.4	0.1	184.3	2.5	1.4	40%
4	Pt Loma	Pacific Chub Mackerel	247.1	0.6	0.2	135.3	4.0	3.0	56%
5	Pt Loma to La Jolla	Pacific Chub Mackerel	222.7	0.2	0.1	95.3	5.2	5.5	47%
7	La Jolla to San Onofre	Pacific Chub Mackerel	221.5	0.1	0.1	86.8	2.3	2.7	73%
9	San Onofre to Crystal Cove	Pacific Chub Mackerel	279.7	0.5	0.2	206.0	4.0	1.9	53%
10	Dana Point Harbor	Pacific Chub Mackerel	280.0	NA	NA	225.0	NA	NA	60%
11	Crystal Cove to Santa Ana River	Pacific Chub Mackerel	234.1	0.2	0.1	110.5	3.9	3.6	40%
13	Santa Ana River to Seal Beach	Pacific Chub Mackerel	211.9	0.1	0.1	80.2	2.6	3.2	57%

Zone	Zone Name	Species	Total Length (mm)			Weight (g)			Percent Female
			Mean	Standard Deviation	Coefficient of Variation	Mean	Standard Deviation	Coefficient of Variation	
14	Orange County Oil Platforms	Pacific Chub Mackerel	220.1	0.6	0.3	94.9	2.0	2.2	53%
15	Long Beach	Pacific Chub Mackerel	239.3	0.1	0.0	124.8	4.3	3.4	77%
16	San Pedro Bay	Pacific Chub Mackerel	255.9	3.7	1.4	159.1	8.4	5.3	47%
19	South Santa Monica Bay	Pacific Chub Mackerel	246.1	0.1	0.0	159.3	16.4	10.3	57%
20	Middle Santa Monica Bay	Pacific Chub Mackerel	232.5	0.1	0.0	114.1	1.8	1.6	27%
21	North Santa Monica Bay	Pacific Chub Mackerel	243.3	0.5	0.2	130.1	5.4	4.2	93%
22	Pt Dume to Oxnard	Pacific Chub Mackerel	226.3	0.3	0.1	105.5	1.2	1.1	40%
24	Ventura to Rincon	Pacific Chub Mackerel	201.5	0.2	0.1	65.1	1.6	2.5	63%
25	Rincon to Goleta	Pacific Chub Mackerel	279.9	0.1	0.0	190.7	8.0	4.2	60%
3	SD North Bay	Shiner Surfperch	118.1	NA	NA	27.9	NA	NA	30%
6	Mission Bay	Shiner Surfperch	84.1	NA	NA	10.2	NA	NA	50%
8	Oceanside Harbor	Shiner Surfperch	82.5	NA	NA	14.0	NA	NA	35%
10	Dana Point Harbor	Shiner Surfperch	104.7	NA	NA	16.4	NA	NA	45%
2	SD South Bay	Spotted Sand Bass	311.1	26.3	8.4	445.8	144.0	32.3	11%
3	SD North Bay	Spotted Sand Bass	304.4	1.3	0.4	391.6	8.6	2.2	22%
6	Mission Bay	Spotted Sand Bass	264.7	39.1	14.8	317.7	125.9	39.6	33%
8	Oceanside Harbor	Spotted Sand Bass	274.2	0.4	0.1	341.3	7.3	2.2	50%
10	Dana Point Harbor	Spotted Sand Bass	232.5	NA	NA	176.3	NA	NA	38%
12	Newport Bay	Spotted Sand Bass	283.6	0.5	0.2	352.1	10.6	3.0	56%
13	Santa Ana River to Seal Beach	Spotted Sand Bass	261.3	8.5	3.2	259.2	34.2	13.2	50%
4	Pt Loma	White Croaker	176.5	0.1	0.1	59.0	2.1	3.6	93%
10	Dana Point Harbor	White Croaker	225.7	0.7	0.3	112.2	5.1	4.5	89%
13	Santa Ana River to Seal Beach	White Croaker	201.4	NA	NA	90.2	NA	NA	80%
15	Long Beach	White Croaker	195.9	0.1	0.1	102.9	2.9	2.8	93%
16	San Pedro Bay	White Croaker	214.1	0.3	0.1	123.4	8.1	6.6	33%

Zone	Zone Name	Species	Total Length (mm) Mean	Standard Deviation	Coefficient of Variation	Weight (g) Mean	Standard Deviation	Coefficient of Variation	Percent Female
20	Middle Santa Monica Bay	White Croaker	148.4	1.1	0.8	43.4	0.6	1.4	71%
24	Ventura to Rincon	White Croaker	183.1	0.1	0.1	80.0	2.5	3.1	87%
2	SD South Bay	Yellowfin Croaker	282.6	NA	NA	307.2	NA	NA	60%
6	Mission Bay	Yellowfin Croaker	291.4	0.9	0.3	330.9	5.6	1.7	53%
7	La Jolla to San Onofre	Yellowfin Croaker	233.5	0.2	0.1	163.5	8.7	5.3	33%
8	Oceanside Harbor	Yellowfin Croaker	354.0	1.4	0.4	610.0	47.1	7.7	50%
12	Newport Bay	Yellowfin Croaker	228.1	1.3	0.6	158.3	3.5	2.2	44%
19	South Santa Monica Bay	Yellowfin Croaker	202.5	1.0	0.5	102.5	5.8	5.7	57%
20	Middle Santa Monica Bay	Yellowfin Croaker	224.1	0.4	0.2	146.9	4.4	3.0	40%
24	Ventura to Rincon	Yellowfin Croaker	229.0	1.3	0.6	178.2	6.3	3.6	33%

Table C2. Summary of fish in individual samples used in mercury analysis. NA indicates data was not recorded or there were insufficient fish in a composite to calculate the parameters (e.g., 1 fish per composite so no standard deviation or coefficient of variation was recorded).

Zone	Zone Name	Species	Total Length (mm)			Weight (g)			Percent Female
			Mean	Standard Deviation	Coefficient of Variation	Mean	Standard Deviation	Coefficient of Variation	
1	TJ to North Island	Barred Sand Bass	307.1	39.4	12.8	360.0	147.8	41.1	29%
1	TJ to North Island	California Halibut	750.0	NA	NA	5310.0	NA	NA	100%
2	SD South Bay	California Halibut	623.0	NA	NA	2650.0	NA	NA	100%
2	SD South Bay	Spotted Sand Bass	273.3	59.2	21.7	324.6	222.5	68.6	25%
3	SD North Bay	Barred Sand Bass	279.5	47.5	17.0	288.4	128.4	44.5	75%
3	SD North Bay	California Halibut	525.0	NA	NA	1260.0	NA	NA	100%
3	SD North Bay	Kelp Bass	284.0	39.5	13.9	371.5	169.7	45.7	56%
3	SD North Bay	Spotted Sand Bass	267.4	47.1	17.6	288.2	136.6	47.4	53%
4	Pt Loma	Barred Sand Bass	349.2	60.2	17.2	521.3	265.3	50.9	67%
4	Pt Loma	Kelp Bass	250.4	53.2	21.2	229.0	162.5	71.0	45%
5	Pt Loma to La Jolla	Barred Sand Bass	252.2	20.3	8.0	220.8	55.1	24.9	67%
5	Pt Loma to La Jolla	Kelp Bass	305.9	74.5	24.3	451.5	417.0	92.4	65%
5	Pt Loma to La Jolla	Olive Rockfish	238.3	21.0	8.8	222.5	36.8	16.6	50%
6	Mission Bay	Spotted Sand Bass	253.6	42.2	16.6	287.1	139.9	48.7	26%
7	La Jolla to San Onofre	Barred Sand Bass	178.4	38.0	21.3	83.6	48.8	58.4	81%
7	La Jolla to San Onofre	California Halibut	250.4	99.1	39.6	208.6	299.1	143.4	71%
7	La Jolla to San Onofre	Kelp Bass	290.0	42.8	14.8	328.1	153.9	46.9	64%
7	La Jolla to San Onofre	Spotted Sand Bass	230.6	36.2	15.7	202.4	93.1	46.0	100%
8	Oceanside Harbor	Barred Sand Bass	263.1	37.5	14.2	245.8	107.5	43.7	50%
8	Oceanside Harbor	Spotted Sand Bass	274.2	30.4	11.1	341.3	114.7	33.6	50%
9	San Onofre to Crystal Cove	Barred Sand Bass	258.6	32.0	12.4	237.0	94.1	39.7	60%
9	San Onofre to Crystal Cove	Kelp Bass	278.7	36.9	13.2	293.7	104.9	35.7	53%

Zone	Zone Name	Species	Total Length (mm) Mean	Total Length (mm) Standard Deviation	Total Length (mm) Coefficient of Variation	Weight (g) Mean	Weight (g) Standard Deviation	Weight (g) Coefficient of Variation	Percent Female
10	Dana Point Harbor	Barred Sand Bass	237.4	35.3	14.9	154.0	60.8	39.5	70%
10	Dana Point Harbor	Spotted Sand Bass	232.5	43.3	18.6	176.3	97.7	55.5	38%
11	Crystal Cove to Santa Ana River	Barred Sand Bass	237.8	14.6	6.2	198.8	26.9	13.5	75%
11	Crystal Cove to Santa Ana River	Kelp Bass	281.4	62.7	22.3	333.5	273.8	82.1	65%
12	Newport Bay	Spotted Sand Bass	283.5	58.0	20.5	351.4	218.9	62.3	55%
13	Santa Ana River to Seal Beach	Kelp Bass	269.9	37.3	13.8	271.1	129.6	47.8	58%
13	Santa Ana River to Seal Beach	Spotted Sand Bass	254.0	41.1	16.2	240.7	126.1	52.4	57%
14	Orange County Oil Platforms	Kelp Bass	274.9	43.7	15.9	294.4	244.9	83.2	60%
15	Long Beach	California Halibut	598.0	NA	NA	2040.0	NA	NA	100%
15	Long Beach	Kelp Bass	295.9	33.9	11.5	321.8	110.7	34.4	50%
16	San Pedro Bay	Barred Sand Bass	262.8	50.9	19.4	258.5	133.7	51.7	50%
17	Catalina Island	Kelp Bass	324.3	28.4	8.8	419.7	114.4	27.3	72%
18	Palos Verdes	Kelp Bass	308.8	53.4	17.3	422.6	230.0	54.4	29%
19	South Santa Monica Bay	Barred Sand Bass	257.0	47.2	18.3	265.2	168.0	63.3	67%
19	South Santa Monica Bay	Kelp Bass	263.7	42.8	16.2	274.6	127.6	46.5	63%
20	Middle Santa Monica Bay	Barred Sand Bass	320.3	108.7	33.9	575.0	525.3	91.4	33%
20	Middle Santa Monica Bay	Kelp Bass	298.7	30.7	10.3	382.6	114.6	29.9	58%
21	North Santa Monica Bay	Barred Sand Bass	241.0	15.6	6.5	205.0	49.5	24.1	100%
21	North Santa Monica Bay	California Halibut	748.0	NA	NA	4945.0	NA	NA	100%
21	North Santa Monica Bay	Kelp Bass	238.5	22.9	9.6	212.0	61.3	28.9	67%
22	Pt Dume to Oxnard	Barred Sand Bass	327.8	26.0	7.9	451.3	92.1	20.4	0%
22	Pt Dume to Oxnard	Kelp Bass	272.0	52.0	19.1	303.1	165.4	54.6	56%
23	Northern Channel Islands	Kelp Bass	315.9	37.7	11.9	406.7	143.1	35.2	73%

Zone	Zone Name	Species	Total Length (mm)			Weight (g)			Percent Female
			Mean	Standard Deviation	Coefficient of Variation	Mean	Standard Deviation	Coefficient of Variation	
25	Rincon to Goleta	Barred Sand Bass	203.7	76.8	37.7	156.7	46.5	29.7	33%
25	Rincon to Goleta	Kelp Bass	304.5	50.6	16.6	371.5	184.4	49.6	75%
26	Santa Barbara Channel Oil Platform	Kelp Bass	297.2	33.3	11.2	364.0	117.0	32.1	60%

APPENDIX D. DATA SUMMARY

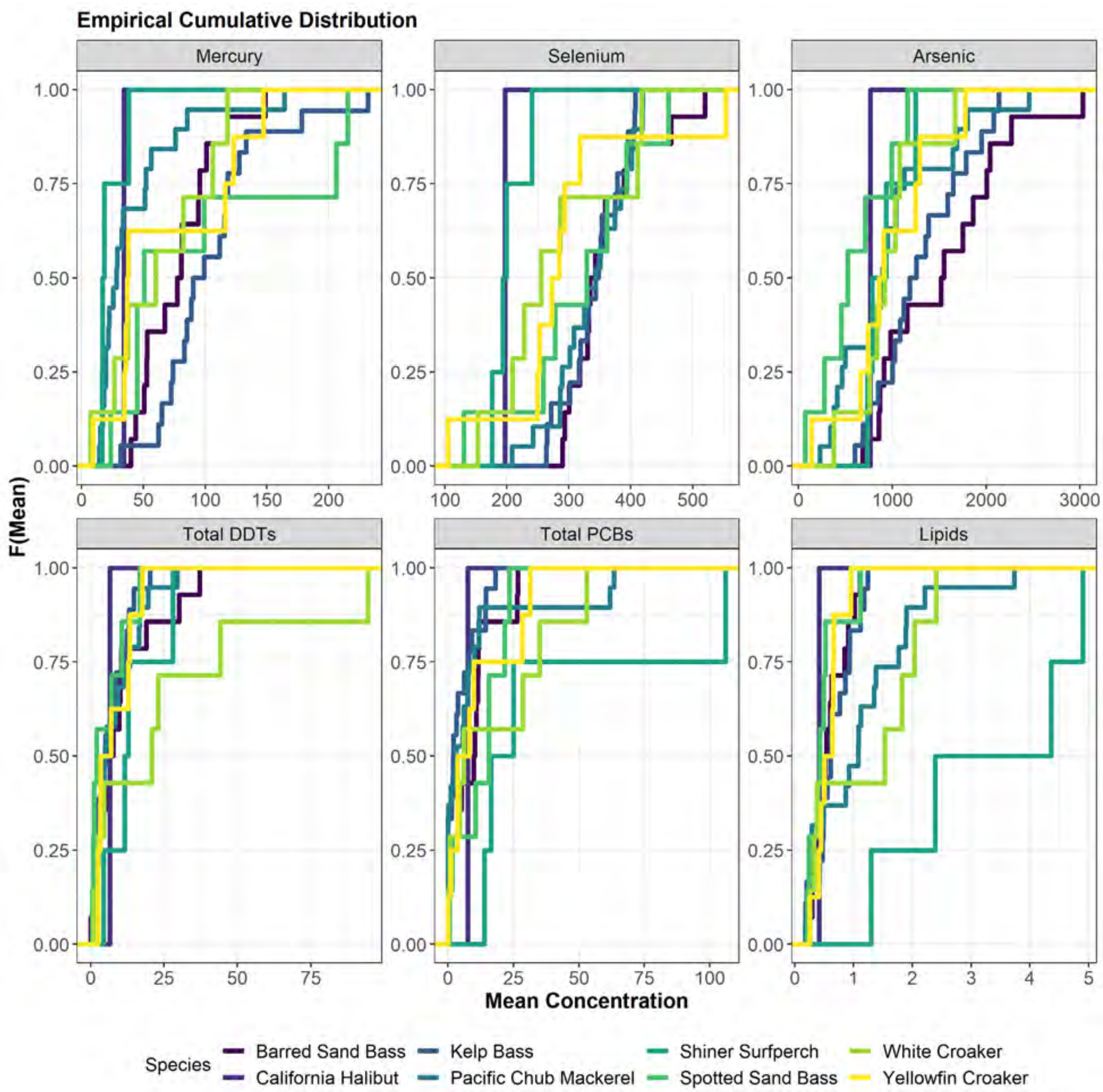

Figure D1. Cumulative Distribution Function of mean contaminant concentrations by zones for all fish species.

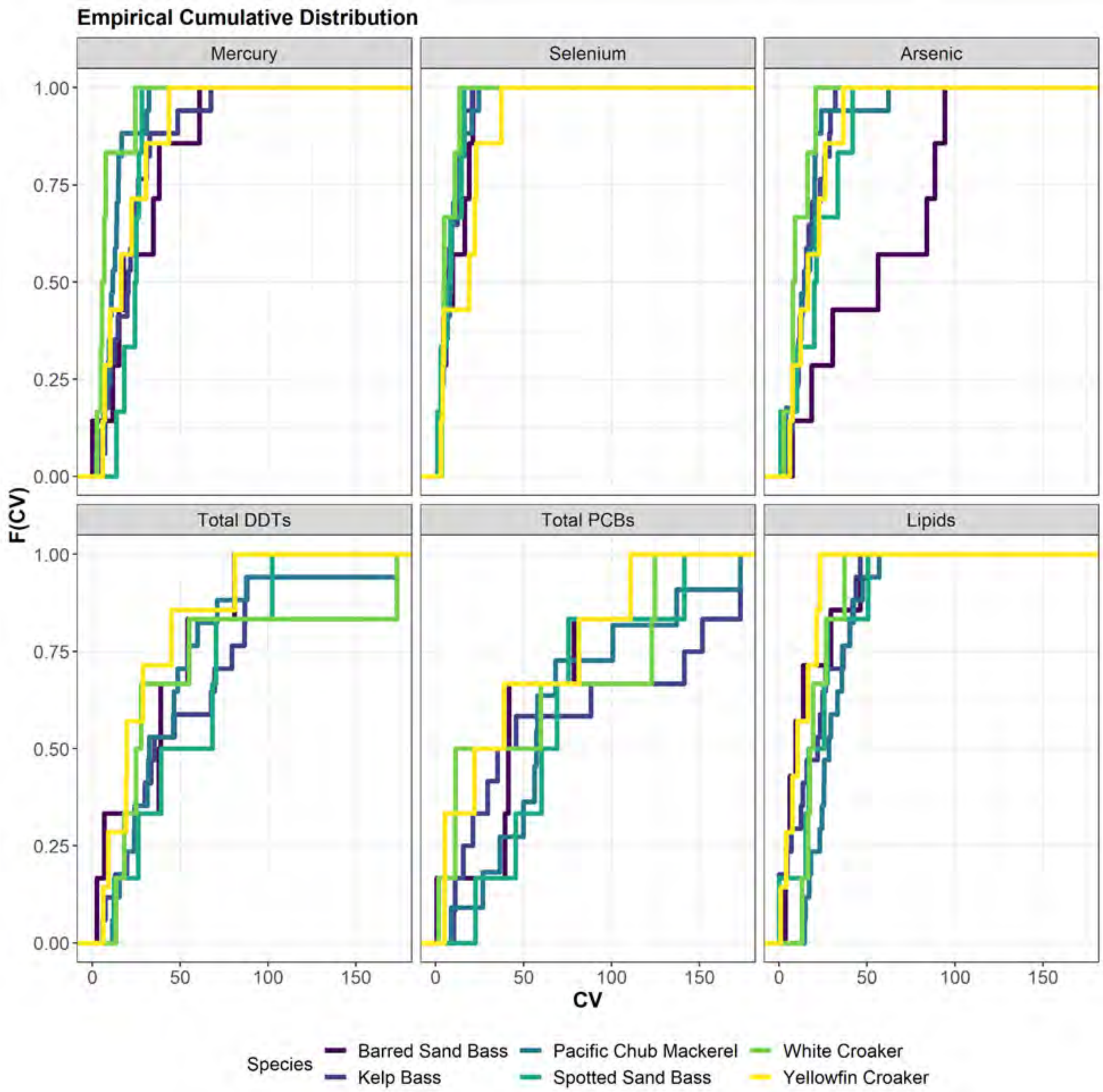

Figure D2. Cumulative Distribution Function of Coefficients of Variation of contaminant concentrations by zones for all fish species.

Summary of Contaminant Concentrations in Fish Tissues by Species in the SCB.

Analyte	Species	n	Mean (ng/g ww)	Minimum (ng/g ww)	Maximum (ng/g ww)	Standard Deviation	Coefficient of Variation
Mercury	Barred Sand Bass	24	85.2	30.0	179.0	37.1	43.6
Mercury	California Halibut	1	34.3	34.3	34.3	NA	NA
Mercury	Kelp Bass	52	106.2	10.6	330.0	52.9	49.8
Mercury	Pacific Chub Mackerel	53	35.2	12.0	164.3	26.9	76.5
Mercury	Shiner Surfperch	4	22.5	16.5	38.0	10.4	46.2
Mercury	Spotted Sand Bass	18	106.1	20.0	277.2	84.4	79.6
Mercury	White Croaker	19	57.9	6.7	122.5	38.9	67.1
Mercury	Yellowfin Croaker	20	60.3	7.4	183.8	52.3	86.7
Selenium	Barred Sand Bass	24	345.6	267.9	520.0	61.5	17.8
Selenium	California Halibut	1	197.2	197.2	197.2	NA	NA
Selenium	Kelp Bass	52	344.6	255.0	492.0	53.7	15.6
Selenium	Pacific Chub Mackerel	53	336.6	202.0	498.0	67.0	19.9
Selenium	Shiner Surfperch	4	202.4	176.4	240.5	27.2	13.4
Selenium	Spotted Sand Bass	18	304.9	127.0	491.3	108.2	35.5
Selenium	White Croaker	19	266.3	148.2	441.0	91.2	34.2
Selenium	Yellowfin Croaker	20	294.7	77.2	642.0	138.4	47.0
Arsenic	Barred Sand Bass	24	1532.6	351.5	4161.8	895.5	58.4
Arsenic	California Halibut	1	765.9	765.9	765.9	NA	NA
Arsenic	Kelp Bass	52	1279.3	512.0	2520.0	498.3	39.0
Arsenic	Pacific Chub Mackerel	53	995.3	196.0	3050.0	611.8	61.5
Arsenic	Shiner Surfperch	4	926.0	732.6	1248.9	231.7	25.0
Arsenic	Spotted Sand Bass	18	554.6	44.9	1420.2	367.6	66.3
Arsenic	White Croaker	19	955.8	341.7	1770.0	404.9	42.4
Arsenic	Yellowfin Croaker	20	942.6	94.2	2110.0	516.5	54.8
Total PCBs	Barred Sand Bass	26	11.5	0.0	41.0	11.3	98.3
Total PCBs	California Halibut	1	7.6	7.6	7.6	NA	NA
Total PCBs	Kelp Bass	51	4.9	0.0	19.6	6.0	122.6
Total PCBs	Pacific Chub Mackerel	53	8.5	0.0	100.4	17.9	211.3
Total PCBs	Shiner Surfperch	4	40.3	13.8	106.0	44.0	109.3
Total PCBs	Spotted Sand Bass	18	13.1	0.0	29.5	10.5	80.0
Total PCBs	White Croaker	19	20.2	0.0	58.9	21.1	104.7
Total PCBs	Yellowfin Croaker	20	9.6	0.0	71.3	15.9	166.2
Total DDTs	Barred Sand Bass	26	8.3	0.0	37.2	9.5	114.1
Total DDTs	California Halibut	1	6.6	6.6	6.6	NA	NA
Total DDTs	Kelp Bass	51	6.9	0.0	29.4	6.4	92.7
Total DDTs	Pacific Chub Mackerel	53	8.4	0.0	45.3	8.7	103.5
Total DDTs	Shiner Surfperch	4	14.2	4.4	28.0	9.9	69.8
Total DDTs	Spotted Sand Bass	18	5.9	0.4	29.0	7.9	134.3

Analyte	Species	n	Mean (ng/g ww)	Minimum (ng/g ww)	Maximum (ng/g ww)	Standard Deviation	Coefficient of Variation
Total DDTs	White Croaker	19	27.9	0.0	123.8	34.8	124.9
Total DDTs	Yellowfin Croaker	20	7.7	1.5	22.3	6.6	85.2
Lipids	Barred Sand Bass	24	0.5	0.2	1.4	0.3	58.2
Lipids	California Halibut	1	0.4	0.4	0.4	NA	NA
Lipids	Kelp Bass	51	0.7	0.1	1.9	0.4	56.1
Lipids	Pacific Chub Mackerel	53	1.2	0.2	4.6	1.0	85.3
Lipids	Shiner Surfperch	4	3.2	1.3	4.9	1.7	52.0
Lipids	Spotted Sand Bass	18	0.5	0.2	1.8	0.4	75.4
Lipids	White Croaker	19	1.4	0.2	3.0	0.9	68.4
Lipids	Yellowfin Croaker	20	0.6	0.2	1.0	0.2	37.6

Summary of Mercury Tissue Concentrations by Species and Zone.

Units are ng/g ww.

Species	Fishing Zone	N	Mean Mercury	Standard Deviation	Coefficient of Variation
Barred Sand Bass	Crystal Cove to Santa Ana River	1	53.0	NA	NA
Barred Sand Bass	Dana Point Harbor	1	80.7	NA	NA
Barred Sand Bass	La Jolla to San Onofre	2	52.8	32.2	61.0
Barred Sand Bass	Middle Santa Monica Bay	1	81.3	NA	NA
Barred Sand Bass	North Santa Monica Bay	1	67.2	NA	NA
Barred Sand Bass	Oceanside Harbor	3	95.7	14.6	15.2
Barred Sand Bass	Pt Dume to Oxnard	1	77.5	NA	NA
Barred Sand Bass	Pt Loma to La Jolla	2	118.0	41.0	34.8
Barred Sand Bass	Rincon to Goleta	1	43.9	NA	NA
Barred Sand Bass	San Onofre to Crystal Cove	1	101.0	NA	NA
Barred Sand Bass	San Pedro Bay	2	40.0	4.6	11.6
Barred Sand Bass	SD North Bay	3	94.5	0.0	0.1
Barred Sand Bass	South Santa Monica Bay	2	50.7	19.3	38.2
Barred Sand Bass	TJ to North Island	3	148.7	26.3	17.7
Kelp Bass	Catalina Island	3	178.2	23.0	12.9
Kelp Bass	Crystal Cove to Santa Ana River	3	88.7	6.4	7.2
Kelp Bass	La Jolla to San Onofre	3	133.3	34.8	26.1
Kelp Bass	Long Beach	3	73.9	15.1	20.4
Kelp Bass	Middle Santa Monica Bay	3	72.4	10.5	14.6
Kelp Bass	North Santa Monica Bay	3	31.6	21.3	67.4
Kelp Bass	Northern Channel Islands	3	118.3	12.5	10.6
Kelp Bass	Orange County Oil Platforms	3	116.3	37.8	32.5
Kelp Bass	Palos Verdes	3	115.7	10.7	9.2
Kelp Bass	Pt Dume to Oxnard	3	83.0	4.4	5.3
Kelp Bass	Pt Loma	3	111.7	26.3	23.6

Species	Fishing Zone	N	Mean Mercury	Standard Deviation	Coefficient of Variation
Kelp Bass	Pt Loma to La Jolla	3	232.0	112.6	48.5
Kelp Bass	Rincon to Goleta	3	99.3	19.6	19.8
Kelp Bass	San Onofre to Crystal Cove	3	90.3	22.7	25.1
Kelp Bass	Santa Ana River to Seal Beach	3	127.7	27.7	21.7
Kelp Bass	Santa Barbara Channel Oil Platform	1	65.0	NA	NA
Kelp Bass	SD North Bay	3	85.3	6.1	7.2
Kelp Bass	South Santa Monica Bay	3	62.2	19.3	31.0
Pacific Chub Mackerel	Crystal Cove to Santa Ana River	3	21.7	3.2	14.8
Pacific Chub Mackerel	Dana Point Harbor	1	75.9	NA	NA
Pacific Chub Mackerel	La Jolla to San Onofre	3	28.3	2.1	7.3
Pacific Chub Mackerel	Long Beach	3	14.4	2.4	16.7
Pacific Chub Mackerel	Middle Santa Monica Bay	3	16.8	2.5	14.9
Pacific Chub Mackerel	North Santa Monica Bay	3	15.1	1.4	9.2
Pacific Chub Mackerel	Orange County Oil Platforms	3	25.7	0.6	2.2
Pacific Chub Mackerel	Pt Dume to Oxnard	3	29.0	3.4	11.6
Pacific Chub Mackerel	Pt Loma	3	52.0	5.6	10.7
Pacific Chub Mackerel	Pt Loma to La Jolla	3	33.7	4.6	13.7
Pacific Chub Mackerel	Rincon to Goleta	3	56.2	17.4	30.9
Pacific Chub Mackerel	San Onofre to Crystal Cove	3	51.3	2.1	4.1
Pacific Chub Mackerel	San Pedro Bay	3	19.5	2.0	10.1
Pacific Chub Mackerel	Santa Ana River to Seal Beach	3	18.0	1.7	9.6
Pacific Chub Mackerel	SD North Bay	3	85.4	12.0	14.0
Pacific Chub Mackerel	SD South Bay	1	164.3	NA	NA
Pacific Chub Mackerel	South Santa Monica Bay	3	19.5	6.3	32.2
Pacific Chub Mackerel	TJ to North Island	3	32.3	4.2	12.9
Pacific Chub Mackerel	Ventura to Rincon	3	22.2	1.4	6.5
Spotted Sand Bass	Dana Point Harbor	1	50.6	NA	NA
Spotted Sand Bass	Mission Bay	3	45.0	12.7	28.2
Spotted Sand Bass	Newport Bay	3	23.4	3.2	13.7
Spotted Sand Bass	Oceanside Harbor	3	99.3	18.0	18.1
Spotted Sand Bass	Santa Ana River to Seal Beach	2	45.0	11.3	25.1
Spotted Sand Bass	SD North Bay	3	206.2	50.1	24.3
Spotted Sand Bass	SD South Bay	3	215.6	57.1	26.5
White Croaker	Dana Point Harbor	3	118.1	5.9	5.0
White Croaker	Long Beach	3	26.4	0.7	2.7
White Croaker	Middle Santa Monica Bay	3	7.4	0.6	7.6
White Croaker	Pt Loma	3	82.3	4.6	5.6
White Croaker	San Pedro Bay	3	37.4	9.2	24.5
White Croaker	Santa Ana River to Seal Beach	1	106.0	NA	NA
White Croaker	Ventura to Rincon	3	59.8	4.0	6.7
Yellowfin Croaker	La Jolla to San Onofre	2	34.5	3.5	10.2
Yellowfin Croaker	Middle Santa Monica Bay	3	37.8	6.3	16.6

Species	Fishing Zone	N	Mean Mercury	Standard Deviation	Coefficient of Variation
Yellowfin Croaker	Mission Bay	3	122.9	53.4	43.5
Yellowfin Croaker	Newport Bay	3	9.1	2.0	22.3
Yellowfin Croaker	Oceanside Harbor	2	147.1	44.8	30.5
Yellowfin Croaker	SD South Bay	1	116.2	NA	NA
Yellowfin Croaker	South Santa Monica Bay	3	36.9	2.6	7.0
Yellowfin Croaker	Ventura to Rincon	3	35.6	2.1	5.9

Summary of Selenium Tissue Concentrations by Species and Zone

Units are ng/g ww.

Species	Fishing Zone	N	Mean Selenium	Standard Deviation	Coefficient of Variation
Barred Sand Bass	Crystal Cove to Santa Ana River	1	465.0	NA	NA
Barred Sand Bass	Dana Point Harbor	1	393.8	NA	NA
Barred Sand Bass	La Jolla to San Onofre	2	389.0	82.0	21.1
Barred Sand Bass	Middle Santa Monica Bay	1	318.0	NA	NA
Barred Sand Bass	North Santa Monica Bay	1	520.0	NA	NA
Barred Sand Bass	Oceanside Harbor	3	300.3	28.6	9.5
Barred Sand Bass	Pt Dume to Oxnard	1	359.0	NA	NA
Barred Sand Bass	Pt Loma to La Jolla	2	353.5	58.7	16.6
Barred Sand Bass	Rincon to Goleta	1	290.0	NA	NA
Barred Sand Bass	San Onofre to Crystal Cove	1	332.0	NA	NA
Barred Sand Bass	San Pedro Bay	2	330.5	62.9	19.0
Barred Sand Bass	SD North Bay	3	293.4	5.3	1.8
Barred Sand Bass	South Santa Monica Bay	2	342.5	10.6	3.1
Barred Sand Bass	TJ to North Island	3	334.7	19.7	5.9
California Halibut	Oceanside Harbor	1	197.2	NA	NA
Kelp Bass	Catalina Island	3	393.5	56.8	14.4
Kelp Bass	Crystal Cove to Santa Ana River	3	343.0	21.6	6.3
Kelp Bass	La Jolla to San Onofre	3	378.2	5.4	1.4
Kelp Bass	Long Beach	3	301.7	5.7	1.9
Kelp Bass	Middle Santa Monica Bay	3	316.3	41.5	13.1
Kelp Bass	North Santa Monica Bay	3	407.7	13.7	3.3
Kelp Bass	Northern Channel Islands	3	374.7	61.3	16.4
Kelp Bass	Orange County Oil Platforms	3	351.7	15.5	4.4
Kelp Bass	Palos Verdes	3	353.3	15.2	4.3
Kelp Bass	Pt Dume to Oxnard	3	271.3	15.7	5.8
Kelp Bass	Pt Loma	3	395.7	63.0	15.9
Kelp Bass	Pt Loma to La Jolla	3	347.8	29.0	8.3
Kelp Bass	Rincon to Goleta	3	263.8	7.8	3.0
Kelp Bass	San Onofre to Crystal Cove	3	329.7	25.5	7.7

Species	Fishing Zone	N	Mean Selenium	Standard Deviation	Coefficient of Variation
Kelp Bass	Santa Ana River to Seal Beach	3	332.0	41.1	12.4
Kelp Bass	Santa Barbara Channel Oil Platform	1	265.0	NA	NA
Kelp Bass	SD North Bay	3	318.8	13.7	4.3
Kelp Bass	South Santa Monica Bay	3	406.3	84.5	20.8
Pacific Chub Mackerel	Crystal Cove to Santa Ana River	3	343.0	55.9	16.3
Pacific Chub Mackerel	Dana Point Harbor	1	301.8	NA	NA
Pacific Chub Mackerel	La Jolla to San Onofre	3	374.3	25.0	6.7
Pacific Chub Mackerel	Long Beach	3	325.0	11.5	3.5
Pacific Chub Mackerel	Middle Santa Monica Bay	3	404.0	48.6	12.0
Pacific Chub Mackerel	North Santa Monica Bay	3	208.3	11.0	5.3
Pacific Chub Mackerel	Orange County Oil Platforms	3	394.0	96.6	24.5
Pacific Chub Mackerel	Pt Dume to Oxnard	3	308.3	27.4	8.9
Pacific Chub Mackerel	Pt Loma	3	351.0	71.6	20.4
Pacific Chub Mackerel	Pt Loma to La Jolla	3	329.3	33.3	10.1
Pacific Chub Mackerel	Rincon to Goleta	3	289.0	8.5	3.0
Pacific Chub Mackerel	San Onofre to Crystal Cove	3	401.7	12.0	3.0
Pacific Chub Mackerel	San Pedro Bay	3	286.0	9.8	3.4
Pacific Chub Mackerel	Santa Ana River to Seal Beach	3	384.0	16.7	4.3
Pacific Chub Mackerel	SD North Bay	3	360.6	31.0	8.6
Pacific Chub Mackerel	SD South Bay	1	418.8	NA	NA
Pacific Chub Mackerel	South Santa Monica Bay	3	242.3	29.4	12.1
Pacific Chub Mackerel	TJ to North Island	3	419.3	38.8	9.3
Pacific Chub Mackerel	Ventura to Rincon	3	285.5	22.8	8.0
Shiner Surfperch	Dana Point Harbor	1	240.5	NA	NA
Shiner Surfperch	Mission Bay	1	199.4	NA	NA
Shiner Surfperch	Oceanside Harbor	1	193.2	NA	NA
Shiner Surfperch	SD North Bay	1	176.4	NA	NA
Spotted Sand Bass	Dana Point Harbor	1	393.5	NA	NA
Spotted Sand Bass	Mission Bay	3	277.7	40.6	14.6
Spotted Sand Bass	Newport Bay	3	130.7	3.9	3.0
Spotted Sand Bass	Oceanside Harbor	3	258.7	2.6	1.0
Spotted Sand Bass	Santa Ana River to Seal Beach	2	362.0	58.0	16.0
Spotted Sand Bass	SD North Bay	3	328.8	19.7	6.0
Spotted Sand Bass	SD South Bay	3	461.0	38.0	8.2
White Croaker	Dana Point Harbor	3	153.2	7.1	4.6
White Croaker	Long Beach	3	209.2	7.2	3.4
White Croaker	Middle Santa Monica Bay	3	417.7	20.3	4.9
White Croaker	Pt Loma	3	227.7	9.0	4.0
White Croaker	San Pedro Bay	3	255.5	27.7	10.9
White Croaker	Santa Ana River to Seal Beach	1	411.0	NA	NA
White Croaker	Ventura to Rincon	3	286.3	38.9	13.6
Yellowfin Croaker	La Jolla to San Onofre	2	317.5	60.1	18.9

Species	Fishing Zone	N	Mean Selenium	Standard Deviation	Coefficient of Variation
Yellowfin Croaker	Middle Santa Monica Bay	3	293.3	13.2	4.5
Yellowfin Croaker	Mission Bay	3	284.3	11.3	4.0
Yellowfin Croaker	Newport Bay	3	105.0	24.2	23.0
Yellowfin Croaker	Oceanside Harbor	2	272.3	101.7	37.4
Yellowfin Croaker	SD South Bay	1	249.5	NA	NA
Yellowfin Croaker	South Santa Monica Bay	3	553.0	122.7	22.2
Yellowfin Croaker	Ventura to Rincon	3	252.7	7.4	2.9

Summary of Arsenic Tissue Concentrations by Species and Zone

Units are ng/g ww.

Species	Fishing Zone	N	Mean Arsenic	Standard Deviation	Coefficient of Variation
Barred Sand Bass	Crystal Cove to Santa Ana River	1	3030.0	NA	NA
Barred Sand Bass	Dana Point Harbor	1	2270.3	NA	NA
Barred Sand Bass	La Jolla to San Onofre	2	1550.0	1371.8	88.5
Barred Sand Bass	Middle Santa Monica Bay	1	684.0	NA	NA
Barred Sand Bass	North Santa Monica Bay	1	912.0	NA	NA
Barred Sand Bass	Oceanside Harbor	3	2004.5	1887.7	94.2
Barred Sand Bass	Pt Dume to Oxnard	1	854.0	NA	NA
Barred Sand Bass	Pt Loma to La Jolla	2	2040.0	622.3	30.5
Barred Sand Bass	Rincon to Goleta	1	1750.0	NA	NA
Barred Sand Bass	San Onofre to Crystal Cove	1	1520.0	NA	NA
Barred Sand Bass	San Pedro Bay	2	1159.0	652.0	56.3
Barred Sand Bass	SD North Bay	3	980.0	180.4	18.4
Barred Sand Bass	South Santa Monica Bay	2	865.8	727.3	84.0
Barred Sand Bass	TJ to North Island	3	1860.0	141.1	7.6
Kelp Bass	Catalina Island	3	999.7	258.4	25.8
Kelp Bass	Crystal Cove to Santa Ana River	3	1786.7	509.3	28.5
Kelp Bass	La Jolla to San Onofre	3	1355.0	179.0	13.2
Kelp Bass	Long Beach	3	1085.0	182.6	16.8
Kelp Bass	Middle Santa Monica Bay	3	600.7	66.4	11.1
Kelp Bass	North Santa Monica Bay	3	1025.3	159.2	15.5
Kelp Bass	Northern Channel Islands	3	2080.0	485.0	23.3
Kelp Bass	Orange County Oil Platforms	3	687.3	199.9	29.1
Kelp Bass	Palos Verdes	3	847.8	121.5	14.3
Kelp Bass	Pt Dume to Oxnard	3	2133.3	161.7	7.6
Kelp Bass	Pt Loma	3	1590.0	174.4	11.0
Kelp Bass	Pt Loma to La Jolla	3	1186.7	63.5	5.4
Kelp Bass	Rincon to Goleta	3	1650.0	95.4	5.8
Kelp Bass	San Onofre to Crystal Cove	3	1121.7	131.4	11.7

Species	Fishing Zone	N	Mean Arsenic	Standard Deviation	Coefficient of Variation
Kelp Bass	Santa Ana River to Seal Beach	3	1254.7	401.0	32.0
Kelp Bass	Santa Barbara Channel Oil Platform	1	1950.0	NA	NA
Kelp Bass	SD North Bay	3	1384.9	257.7	18.6
Kelp Bass	South Santa Monica Bay	3	735.7	59.0	8.0
Pacific Chub Mackerel	Crystal Cove to Santa Ana River	3	1126.3	216.5	19.2
Pacific Chub Mackerel	Dana Point Harbor	1	414.1	NA	NA
Pacific Chub Mackerel	La Jolla to San Onofre	3	378.0	15.1	4.0
Pacific Chub Mackerel	Long Beach	3	1686.7	212.0	12.6
Pacific Chub Mackerel	Middle Santa Monica Bay	3	1643.3	166.2	10.1
Pacific Chub Mackerel	North Santa Monica Bay	3	875.7	178.0	20.3
Pacific Chub Mackerel	Orange County Oil Platforms	3	2456.7	585.2	23.8
Pacific Chub Mackerel	Pt Dume to Oxnard	3	949.3	144.4	15.2
Pacific Chub Mackerel	Pt Loma	3	463.7	93.9	20.2
Pacific Chub Mackerel	Pt Loma to La Jolla	3	341.3	68.7	20.1
Pacific Chub Mackerel	Rincon to Goleta	3	893.7	31.4	3.5
Pacific Chub Mackerel	San Onofre to Crystal Cove	3	496.7	103.5	20.8
Pacific Chub Mackerel	San Pedro Bay	3	1038.3	31.8	3.1
Pacific Chub Mackerel	Santa Ana River to Seal Beach	3	1803.3	317.7	17.6
Pacific Chub Mackerel	SD North Bay	3	926.2	575.0	62.1
Pacific Chub Mackerel	SD South Bay	1	768.5	NA	NA
Pacific Chub Mackerel	South Santa Monica Bay	3	1039.0	130.9	12.6
Pacific Chub Mackerel	TJ to North Island	3	226.3	26.4	11.7
Pacific Chub Mackerel	Ventura to Rincon	3	844.7	80.1	9.5
Spotted Sand Bass	Dana Point Harbor	1	1160.1	NA	NA
Spotted Sand Bass	Mission Bay	3	711.2	72.3	10.2
Spotted Sand Bass	Newport Bay	3	72.7	24.2	33.3
Spotted Sand Bass	Oceanside Harbor	3	992.7	414.6	41.8
Spotted Sand Bass	Santa Ana River to Seal Beach	2	275.5	2.1	0.8
Spotted Sand Bass	SD North Bay	3	526.1	104.7	19.9
Spotted Sand Bass	SD South Bay	3	454.4	96.2	21.2
White Croaker	Dana Point Harbor	3	375.3	33.8	9.0
White Croaker	Long Beach	3	1032.7	167.2	16.2
White Croaker	Middle Santa Monica Bay	3	836.7	64.1	7.7
White Croaker	Pt Loma	3	758.0	18.7	2.5
White Croaker	San Pedro Bay	3	1666.7	130.5	7.8
White Croaker	Santa Ana River to Seal Beach	1	920.0	NA	NA
White Croaker	Ventura to Rincon	3	1077.7	223.8	20.8
Yellowfin Croaker	La Jolla to San Onofre	2	859.0	195.2	22.7
Yellowfin Croaker	Middle Santa Monica Bay	3	907.5	111.3	12.3
Yellowfin Croaker	Mission Bay	3	743.3	56.5	7.6
Yellowfin Croaker	Newport Bay	3	137.8	50.2	36.4
Yellowfin Croaker	Oceanside Harbor	2	659.4	172.4	26.1

Species	Fishing Zone	N	Mean Arsenic	Standard Deviation	Coefficient of Variation
Yellowfin Croaker	SD South Bay	1	1248.6	NA	NA
Yellowfin Croaker	South Santa Monica Bay	3	1776.7	291.4	16.4
Yellowfin Croaker	Ventura to Rincon	3	1290.0	78.1	6.1

Summary of Total DDTs Tissue Concentrations by Species and Zone

Units are ng/g ww.

Species	Fishing Zone	N	Mean DDTs	Standard Deviation	Coefficient of Variation
Barred Sand Bass	Crystal Cove to Santa Ana River	1	9.70	NA	NA
Barred Sand Bass	Dana Point Harbor	1	4.06	NA	NA
Barred Sand Bass	La Jolla to San Onofre	2	7.72	6.25	80.97
Barred Sand Bass	Middle Santa Monica Bay	1	30.17	NA	NA
Barred Sand Bass	North Santa Monica Bay	1	6.47	NA	NA
Barred Sand Bass	Oceanside Harbor	3	10.08	5.47	54.26
Barred Sand Bass	Pt Dume to Oxnard	1	37.17	NA	NA
Barred Sand Bass	Pt Loma to La Jolla	2	0.00	0.00	NA
Barred Sand Bass	Rincon to Goleta	1	2.09	NA	NA
Barred Sand Bass	San Onofre to Crystal Cove	1	5.46	NA	NA
Barred Sand Bass	San Pedro Bay	2	18.97	7.39	38.98
Barred Sand Bass	SD North Bay	5	1.85	0.13	6.88
Barred Sand Bass	South Santa Monica Bay	2	10.40	0.28	2.68
Barred Sand Bass	TJ to North Island	3	2.26	0.86	37.78
Kelp Bass	Catalina Island	3	2.73	1.84	67.66
Kelp Bass	Crystal Cove to Santa Ana River	3	2.40	1.67	69.56
Kelp Bass	La Jolla to San Onofre	3	1.00	1.73	173.21
Kelp Bass	Long Beach	3	20.23	1.50	7.42
Kelp Bass	Middle Santa Monica Bay	3	11.59	2.26	19.54
Kelp Bass	North Santa Monica Bay	3	2.78	0.17	5.94
Kelp Bass	Northern Channel Islands	3	6.56	3.07	46.76
Kelp Bass	Orange County Oil Platforms	3	14.70	12.75	86.77
Kelp Bass	Palos Verdes	3	12.32	4.36	35.41
Kelp Bass	Pt Dume to Oxnard	3	5.03	1.50	29.82
Kelp Bass	Pt Loma	3	2.18	0.53	24.49
Kelp Bass	Pt Loma to La Jolla	3	1.20	1.04	86.64
Kelp Bass	Rincon to Goleta	3	3.88	1.30	33.55
Kelp Bass	San Onofre to Crystal Cove	3	4.63	4.08	87.97
Kelp Bass	Santa Ana River to Seal Beach	2	13.02	10.34	79.48
Kelp Bass	Santa Barbara Channel Oil Platform	1	1.76	NA	NA
Kelp Bass	SD North Bay	3	8.24	1.96	23.81
Kelp Bass	South Santa Monica Bay	3	8.63	1.13	13.08

Species	Fishing Zone	N	Mean DDTs	Standard Deviation	Coefficient of Variation
Pacific Chub Mackerel	Crystal Cove to Santa Ana River	3	0.97	1.69	173.21
Pacific Chub Mackerel	Dana Point Harbor	1	11.20	NA	NA
Pacific Chub Mackerel	La Jolla to San Onofre	3	4.63	0.57	12.23
Pacific Chub Mackerel	Long Beach	3	13.32	7.99	59.96
Pacific Chub Mackerel	Middle Santa Monica Bay	3	16.68	3.98	23.84
Pacific Chub Mackerel	North Santa Monica Bay	3	9.26	1.44	15.50
Pacific Chub Mackerel	Orange County Oil Platforms	3	8.43	3.88	46.02
Pacific Chub Mackerel	Pt Dume to Oxnard	3	2.65	0.49	18.58
Pacific Chub Mackerel	Pt Loma	3	2.40	2.10	87.50
Pacific Chub Mackerel	Pt Loma to La Jolla	3	2.09	0.24	11.40
Pacific Chub Mackerel	Rincon to Goleta	3	16.40	7.98	48.66
Pacific Chub Mackerel	San Onofre to Crystal Cove	3	3.25	1.02	31.46
Pacific Chub Mackerel	San Pedro Bay	3	29.51	13.70	46.44
Pacific Chub Mackerel	Santa Ana River to Seal Beach	3	4.93	2.69	54.61
Pacific Chub Mackerel	SD North Bay	3	5.48	1.75	31.86
Pacific Chub Mackerel	SD South Bay	1	3.59	NA	NA
Pacific Chub Mackerel	South Santa Monica Bay	3	19.60	6.35	32.41
Pacific Chub Mackerel	TJ to North Island	3	2.80	0.67	23.96
Pacific Chub Mackerel	Ventura to Rincon	3	1.41	1.00	71.06
Spotted Sand Bass	Dana Point Harbor	1	1.96	NA	NA
Spotted Sand Bass	Mission Bay	3	0.55	0.14	26.01
Spotted Sand Bass	Newport Bay	3	16.71	11.75	70.34
Spotted Sand Bass	Oceanside Harbor	3	10.49	7.16	68.27
Spotted Sand Bass	Santa Ana River to Seal Beach	2	7.08	2.76	39.08
Spotted Sand Bass	SD North Bay	3	1.09	1.12	102.23
Spotted Sand Bass	SD South Bay	3	0.91	0.11	12.53
White Croaker	Dana Point Harbor	3	2.44	0.61	24.94
White Croaker	Long Beach	3	44.24	8.03	18.16
White Croaker	Middle Santa Monica Bay	3	22.95	12.64	55.06
White Croaker	Pt Loma	3	0.95	1.64	173.21
White Croaker	San Pedro Bay	3	94.58	26.31	27.82
White Croaker	Santa Ana River to Seal Beach	1	20.90	NA	NA
White Croaker	Ventura to Rincon	3	4.56	0.62	13.51
Yellowfin Croaker	La Jolla to San Onofre	2	12.83	0.78	6.12
Yellowfin Croaker	Middle Santa Monica Bay	3	2.54	0.50	19.53
Yellowfin Croaker	Mission Bay	3	3.34	0.64	19.16
Yellowfin Croaker	Newport Bay	3	17.53	5.07	28.92
Yellowfin Croaker	Oceanside Harbor	2	13.27	10.76	81.10
Yellowfin Croaker	SD South Bay	1	3.27	NA	NA
Yellowfin Croaker	South Santa Monica Bay	3	6.86	0.62	9.10
Yellowfin Croaker	Ventura to Rincon	3	2.52	1.13	45.03

Summary of Total PCBs Tissue Concentrations by Species and Zone

Units are ng/g ww.

Species	Fishing Zone	N	Mean PCBs	Standard Deviation	Coefficient of Variation
Barred Sand Bass	Crystal Cove to Santa Ana River	1	0.00	NA	NA
Barred Sand Bass	Dana Point Harbor	1	11.73	NA	NA
Barred Sand Bass	La Jolla to San Onofre	2	0.17	0.23	141.42
Barred Sand Bass	Middle Santa Monica Bay	1	11.38	NA	NA
Barred Sand Bass	North Santa Monica Bay	1	5.18	NA	NA
Barred Sand Bass	Oceanside Harbor	3	11.52	4.54	39.37
Barred Sand Bass	Pt Dume to Oxnard	1	9.75	NA	NA
Barred Sand Bass	Pt Loma to La Jolla	2	0.00	0.00	NA
Barred Sand Bass	Rincon to Goleta	1	10.17	NA	NA
Barred Sand Bass	San Onofre to Crystal Cove	1	3.78	NA	NA
Barred Sand Bass	San Pedro Bay	2	26.34	20.71	78.61
Barred Sand Bass	SD North Bay	5	26.71	0.15	0.55
Barred Sand Bass	South Santa Monica Bay	2	10.75	4.47	41.62
Barred Sand Bass	TJ to North Island	3	1.12	0.46	41.19
Kelp Bass	Catalina Island	3	0.00	0.00	NA
Kelp Bass	Crystal Cove to Santa Ana River	3	0.00	0.00	NA
Kelp Bass	La Jolla to San Onofre	3	0.00	0.00	NA
Kelp Bass	Long Beach	3	14.25	2.23	15.63
Kelp Bass	Middle Santa Monica Bay	3	3.79	1.12	29.57
Kelp Bass	North Santa Monica Bay	3	2.06	1.82	88.37
Kelp Bass	Northern Channel Islands	3	0.00	0.00	NA
Kelp Bass	Orange County Oil Platforms	3	1.32	2.28	173.21
Kelp Bass	Palos Verdes	3	14.41	1.48	10.26
Kelp Bass	Pt Dume to Oxnard	3	9.04	3.18	35.15
Kelp Bass	Pt Loma	3	3.27	4.96	151.73
Kelp Bass	Pt Loma to La Jolla	3	0.00	0.00	NA
Kelp Bass	Rincon to Goleta	3	6.12	2.79	45.61
Kelp Bass	San Onofre to Crystal Cove	3	1.87	3.24	173.21
Kelp Bass	Santa Ana River to Seal Beach	2	1.78	2.52	141.42
Kelp Bass	Santa Barbara Channel Oil Platform	1	0.00	NA	NA
Kelp Bass	SD North Bay	3	18.12	1.99	10.96
Kelp Bass	South Santa Monica Bay	3	7.95	1.68	21.19
Pacific Chub Mackerel	Crystal Cove to Santa Ana River	3	0.00	0.00	NA
Pacific Chub Mackerel	Dana Point Harbor	1	2.87	NA	NA
Pacific Chub Mackerel	La Jolla to San Onofre	3	0.00	0.00	NA
Pacific Chub Mackerel	Long Beach	3	5.99	6.03	100.61
Pacific Chub Mackerel	Middle Santa Monica Bay	3	5.66	3.28	57.86
Pacific Chub Mackerel	North Santa Monica Bay	3	1.15	0.65	56.21

Species	Fishing Zone	N	Mean PCBs	Standard Deviation	Coefficient of Variation
Pacific Chub Mackerel	Orange County Oil Platforms	3	0.00	0.00	NA
Pacific Chub Mackerel	Pt Dume to Oxnard	3	7.76	3.87	49.88
Pacific Chub Mackerel	Pt Loma	3	3.27	4.48	136.89
Pacific Chub Mackerel	Pt Loma to La Jolla	3	0.09	0.16	173.21
Pacific Chub Mackerel	Rincon to Goleta	3	11.72	1.02	8.72
Pacific Chub Mackerel	San Onofre to Crystal Cove	3	0.00	0.00	NA
Pacific Chub Mackerel	San Pedro Bay	3	11.97	4.37	36.54
Pacific Chub Mackerel	Santa Ana River to Seal Beach	3	0.00	0.00	NA
Pacific Chub Mackerel	SD North Bay	3	63.42	36.31	57.25
Pacific Chub Mackerel	SD South Bay	1	61.87	NA	NA
Pacific Chub Mackerel	South Santa Monica Bay	3	10.04	6.84	68.17
Pacific Chub Mackerel	TJ to North Island	3	0.00	0.00	NA
Pacific Chub Mackerel	Ventura to Rincon	3	7.45	2.00	26.90
Spotted Sand Bass	Dana Point Harbor	1	15.56	NA	NA
Spotted Sand Bass	Mission Bay	3	1.66	1.26	75.49
Spotted Sand Bass	Newport Bay	3	15.57	10.75	69.04
Spotted Sand Bass	Oceanside Harbor	3	10.47	6.31	60.27
Spotted Sand Bass	Santa Ana River to Seal Beach	2	0.60	0.84	141.42
Spotted Sand Bass	SD North Bay	3	21.63	9.82	45.41
Spotted Sand Bass	SD South Bay	3	23.50	5.32	22.62
White Croaker	Dana Point Harbor	3	0.65	0.81	124.52
White Croaker	Long Beach	3	53.03	5.84	11.01
White Croaker	Middle Santa Monica Bay	3	34.98	20.88	59.68
White Croaker	Pt Loma	3	4.41	5.42	122.96
White Croaker	San Pedro Bay	3	28.54	3.21	11.26
White Croaker	Santa Ana River to Seal Beach	1	0.00	NA	NA
White Croaker	Ventura to Rincon	3	6.04	0.10	1.68
Yellowfin Croaker	La Jolla to San Onofre	2	0.00	0.00	NA
Yellowfin Croaker	Middle Santa Monica Bay	3	3.66	1.42	38.75
Yellowfin Croaker	Mission Bay	3	31.31	34.64	110.63
Yellowfin Croaker	Newport Bay	3	8.16	1.80	22.06
Yellowfin Croaker	Oceanside Harbor	2	9.85	0.52	5.23
Yellowfin Croaker	SD South Bay	1	28.45	NA	NA
Yellowfin Croaker	South Santa Monica Bay	3	1.05	0.86	81.31
Yellowfin Croaker	Ventura to Rincon	3	3.57	0.18	4.96

Summary of Percentage of Lipids in Fish Tissues by Species and Zone

Units are % Lipids.

Species	Fishing Zone	N	Mean Lipids	Standard Deviation	Coefficient of Variation
Barred Sand Bass	Crystal Cove to Santa Ana River	1	0.52	NA	NA
Barred Sand Bass	Dana Point Harbor	1	0.63	NA	NA
Barred Sand Bass	La Jolla to San Onofre	2	0.30	0.09	29.31
Barred Sand Bass	Middle Santa Monica Bay	1	0.38	NA	NA
Barred Sand Bass	North Santa Monica Bay	1	1.11	NA	NA
Barred Sand Bass	Oceanside Harbor	3	1.01	0.47	46.11
Barred Sand Bass	Pt Dume to Oxnard	1	0.91	NA	NA
Barred Sand Bass	Pt Loma to La Jolla	2	0.25	0.01	3.51
Barred Sand Bass	Rincon to Goleta	1	0.85	NA	NA
Barred Sand Bass	San Onofre to Crystal Cove	1	0.54	NA	NA
Barred Sand Bass	San Pedro Bay	2	0.35	0.01	4.04
Barred Sand Bass	SD North Bay	3	0.40	0.02	6.05
Barred Sand Bass	South Santa Monica Bay	2	0.60	0.06	9.43
Barred Sand Bass	TJ to North Island	3	0.30	0.04	13.73
California Halibut	Oceanside Harbor	1	0.41	NA	NA
Kelp Bass	Catalina Island	3	0.47	0.11	23.27
Kelp Bass	Crystal Cove to Santa Ana River	3	0.62	0.00	0.00
Kelp Bass	La Jolla to San Onofre	3	0.18	0.07	36.57
Kelp Bass	Long Beach	3	0.42	0.11	26.51
Kelp Bass	Middle Santa Monica Bay	3	0.49	0.20	40.18
Kelp Bass	North Santa Monica Bay	3	0.61	0.08	12.35
Kelp Bass	Northern Channel Islands	3	0.93	0.13	13.48
Kelp Bass	Orange County Oil Platforms	3	0.49	0.22	43.73
Kelp Bass	Palos Verdes	3	0.86	0.06	7.02
Kelp Bass	Pt Dume to Oxnard	3	1.12	0.18	15.72
Kelp Bass	Pt Loma	3	0.18	0.04	21.77
Kelp Bass	Pt Loma to La Jolla	3	0.20	0.01	4.51
Kelp Bass	Rincon to Goleta	3	1.24	0.58	46.25
Kelp Bass	San Onofre to Crystal Cove	3	0.93	0.00	0.00
Kelp Bass	Santa Ana River to Seal Beach	2	0.55	0.00	0.00
Kelp Bass	Santa Barbara Channel Oil Platform	1	0.61	NA	NA
Kelp Bass	SD North Bay	3	1.18	0.29	24.85
Kelp Bass	South Santa Monica Bay	3	0.76	0.32	41.68
Pacific Chub Mackerel	Crystal Cove to Santa Ana River	3	1.38	0.39	28.29
Pacific Chub Mackerel	Dana Point Harbor	1	1.08	NA	NA
Pacific Chub Mackerel	La Jolla to San Onofre	3	0.29	0.07	25.62
Pacific Chub Mackerel	Long Beach	3	1.35	0.45	33.13

Species	Fishing Zone	N	Mean Lipids	Standard Deviation	Coefficient of Variation
Pacific Chub Mackerel	Middle Santa Monica Bay	3	1.90	0.34	17.94
Pacific Chub Mackerel	North Santa Monica Bay	3	1.89	0.55	29.35
Pacific Chub Mackerel	Orange County Oil Platforms	3	0.86	0.49	56.84
Pacific Chub Mackerel	Pt Dume to Oxnard	3	1.77	0.75	42.48
Pacific Chub Mackerel	Pt Loma	3	0.21	0.05	23.02
Pacific Chub Mackerel	Pt Loma to La Jolla	3	0.26	0.12	47.51
Pacific Chub Mackerel	Rincon to Goleta	3	3.73	1.33	35.67
Pacific Chub Mackerel	San Onofre to Crystal Cove	3	0.49	0.12	24.35
Pacific Chub Mackerel	San Pedro Bay	3	1.12	0.28	25.31
Pacific Chub Mackerel	Santa Ana River to Seal Beach	3	0.92	0.37	40.26
Pacific Chub Mackerel	SD North Bay	3	0.29	0.05	17.06
Pacific Chub Mackerel	SD South Bay	1	0.18	NA	NA
Pacific Chub Mackerel	South Santa Monica Bay	3	2.21	0.33	14.79
Pacific Chub Mackerel	TJ to North Island	3	0.24	0.03	14.50
Pacific Chub Mackerel	Ventura to Rincon	3	1.08	0.39	35.85
Shiner Surfperch	Dana Point Harbor	1	1.30	NA	NA
Shiner Surfperch	Mission Bay	1	2.39	NA	NA
Shiner Surfperch	Oceanside Harbor	1	4.36	NA	NA
Shiner Surfperch	SD North Bay	1	4.90	NA	NA
Spotted Sand Bass	Dana Point Harbor	1	0.43	NA	NA
Spotted Sand Bass	Mission Bay	3	0.40	0.07	16.72
Spotted Sand Bass	Newport Bay	3	0.49	0.13	25.67
Spotted Sand Bass	Oceanside Harbor	3	1.12	0.57	50.59
Spotted Sand Bass	Santa Ana River to Seal Beach	2	0.52	0.00	0.00
Spotted Sand Bass	SD North Bay	3	0.21	0.06	27.58
Spotted Sand Bass	SD South Bay	3	0.24	0.04	15.03
White Croaker	Dana Point Harbor	3	0.26	0.03	13.00
White Croaker	Long Beach	3	2.04	0.76	37.22
White Croaker	Middle Santa Monica Bay	3	1.83	0.35	19.30
White Croaker	Pt Loma	3	0.38	0.07	17.34
White Croaker	San Pedro Bay	3	2.41	0.64	26.55
White Croaker	Santa Ana River to Seal Beach	1	0.33	NA	NA
White Croaker	Ventura to Rincon	3	1.53	0.25	16.41
Yellowfin Croaker	La Jolla to San Onofre	2	0.25	0.03	10.42
Yellowfin Croaker	Middle Santa Monica Bay	3	0.64	0.14	21.14
Yellowfin Croaker	Mission Bay	3	0.44	0.07	16.33
Yellowfin Croaker	Newport Bay	3	0.41	0.03	7.46
Yellowfin Croaker	Oceanside Harbor	2	0.50	0.12	23.19
Yellowfin Croaker	SD South Bay	1	0.66	NA	NA
Yellowfin Croaker	South Santa Monica Bay	3	0.65	0.01	0.88

Species	Fishing Zone	N	Mean Lipids	Standard Deviation	Coefficient of Variation
Yellowfin Croaker	Ventura to Rincon	3	0.95	0.04	3.97