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NATIONAL STATUS AND TRENDS, MUSSEL WATCH PROGRAM

A 2018 Assessment of Contaminants of Emerging Concern in the Southern California Bight

April 2023

NOAA TECHNICAL MEMORANDUM NOS NCCOS 316

NOAA NCCOS Monitoring and Assessment Branch

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A 2018 Assessment of Contaminants of Emerging Concern in the Southern California Bight

April 2023

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NOAA Technical Memorandum NOS NCCOS 316

United States Department of Commerce	National Oceanic and Atmospheric Administration	National Ocean Service
Gina M. Raimondo Secretary	Richard W. Spinrad Under Secretary	Nicole LeBoeuf Assistant Administrator

EXECUTIVE SUMMARY

In 2018, in collaboration with the Southern California Coastal Water Research Program (SCWRPP), the California Ocean Protection Council, and the Channel Islands National Marine Sanctuary (CINMS), the National Mussel Watch Program (MWP) assessed the magnitude and distribution of contaminants of emerging concern (CECs) in coastal waters in the Southern California Bight. Using mussels (*Mytilus* species) and sediment as indicators of contamination, mussel tissue and sediment samples were analyzed for alkylphenol compounds (APs), alternative flame retardants (AFRs), polybrominated flame retardants (BFRs) such as polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs), current-use pesticides (CUPs), per- and polyfluoroalkyl substances (PFASs), and pharmaceutical and personal care products (PPCPs). The mussel and sediment samples were collected at historic MWP monitoring sites located within the Southern California Bight. Sample collection was conducted by SCWRPP and CINMS following standard protocols (Apeti et al., 2012). Mussel tissue and/or sediment samples were collected from a total of 35 monitoring sites and were assessed for a suite of 142 – 281 individual CEC contaminants, depending on the sample matrix and site location.

The results indicated that CECs are present at varying degrees of concentration in coastal bivalves and sediments in the Southern California Bight. Contaminants were detected in either mussel tissue and/or sediment samples at all but two sites assessed in this region, emphasizing the ubiquity of these contaminants in coastal waters. However, it was observed that out of the 281 contaminants analyzed, only a small subset of contaminants represented the majority of detections within each chemical class. The accumulation of CECs in organisms and sediments are often contaminant and location dependent. Thus, the presence and concentration of a specific contaminant are heavily influenced by its chemistry, sources, fate, and transport.

Broadly, the MWP provides unique data that is vital to evaluating the health of the nations' coasts through temporal and spatial evaluation of chemical contamination. Studies such as this not only provide needed data and information for the MWP but also address CEC data gaps that are relevant to coastal managers as they develop long-term policies to protect ecosystem services provided by the coastal environment within the Southern California Bight.

KEY FINDINGS

1. Alkylphenols in the Southern California Bight in 2018:
    - 2 out of 4 analyzed AP compounds were detected in mussel tissue at 17 out of 33 sites analyzed
    - 2 out of 4 analyzed AP compounds were detected in sediment at 10 out of 10 sites analyzed

2. Alternative Flame Retardants (AFRs) in the Southern California Bight in 2018:
    - 1 out of 3 analyzed AFR compounds were detected in mussel tissue at 2 out of 33 sites analyzed
    - 2 out of 3 analyzed AFR compounds were detected in sediment at 3 out of 10 sites analyzed

3. Brominated Flame Retardants (BFRs) in the Southern California Bight in 2018:
    - No PBB compounds were detected in either mussel tissue or sediment at any site analyzed
    - 20 out of 51 analyzed PBDE compounds were detected in mussel tissue at 16 out of 34 sites
    - 15 out of 51 analyzed PBDE compounds were detected in sediment at 10 out of 10 sites analyzed

4. Current Use Pesticides (CUPs) in the Southern California Bight in 2018:
    - 1 out of 30 analyzed CUP compounds was detected in mussel tissue at 2 out of 33 sites analyzed
    - 1 out of 32 analyzed CUP compounds was detected in sediment at 2 out of 10 sites analyzed

5. Per- and polyfluoroalkyl Substances (PFASs) in the Southern California Bight in 2018:
    - 8 out of 33 analyzed PFAS compounds were detected in mussel tissue at 26 out of 33 sites analyzed
    - 5 out of 33 analyzed PFAS compounds were detected in sediment at 3 out of 10 sites analyzed

6. Pharmaceutical and Personal Care Products (PPCPs) in the Southern California Bight in 2018:
    - 24 out of 141 analyzed PPCP compounds were detected in mussel tissue at 10 out of 10 sites analyzed

7. 2 out of 34 mussel tissue sites had no detects of any CEC (although SANM was only analyzed for BFRs). Both of these sites are located on the Channel Islands, farther from large human populations.

8. 1 out of 34 mussel tissue sites (LARM) and 2/10 sediment sites (SDHI and MDSJ) were categorized as having "very high" contamination compared to all sites analyzed in this study. All three of these sites are located near large human populations in Los Angeles, CA and San Diego, CA.

Table of Contents

COMMONLY USED ACRONYMS

NOAA	National Oceanic and Atmospheric Administration
NCCOS	National Centers for Coastal Ocean Science
NS&T	National Status & Trends
MWP	Mussel Watch Program
SCCWRP	Southern California Coastal Water Research Project
CINMS	Channel Islands National Marine Sanctuary
US	United States
CA	California
AP	Alkylphenol compound
AFR	Alternative flame retardant
BFR	Polybrominated flame retardant
CUP	Current-use pesticide
HBCD	Hexabromocyclododecanes
MRES	Multi Residue Pesticides
PBB	Polybrominated biphenyl
PBDE	Polybrominated diphenyl ether
PFAS	Per-and polyfluoroalkyl substances
PPCP	Pharmaceutical and personal care product
dw	dry weight
ww	wet weight
g	gram
ng	nanogram
MDL	Method detection limit
SD	standard deviation

Introduction

1.0 HISTORY OF MUSSEL WATCH PROGRAM

The National Mussel Watch Program (MWP), which began in 1986, was designed by the National Oceanic and Atmospheric Administration (NOAA) to monitor the nation's coastal waters for chemical contaminants and biological indicators of water quality. The MWP was established in response to a legislative mandate under Section 202 of Title II of the Marine Protection, Research and Sanctuaries Act (MPRSA) (33 USC 1442), which called on the Secretary of Commerce to initiate a continuous monitoring program, among other activities. The MWP design is based on the periodic collection and analysis of bivalves (oysters and mussels) and sediment from a network of monitoring sites located throughout the nation's coastal zones. To date, NOAA's MWP is one of the longest running, continuous coastal monitoring programs.

The MWP monitoring sites are found along all of the US coastlines including Alaska, the Great Lakes, Hawaii, and in territories such as Puerto Rico. Different target bivalves are used as sentinel species. Mussels and oysters are sessile organisms that filter and accumulate particles from water; therefore, measuring contaminant levels in their tissue is a good indicator of local chemical contamination. Mussels (*Mytilus* species) are collected from the North Atlantic and Pacific coasts, oysters (*Crassostrea virginica*) are collected from the mid-Atlantic (Delaware Bay) southward and along the Gulf Coast, the invasive zebra and quagga mussels (*Dreissena* species) are collected from the Great Lakes, mangrove oysters (*Crassostrea rhizophorae*) are collected from Puerto Rico, and Hawaiian oysters (*Dendostrea sandvicensis*) are collected from Hawaii.

A fundamental challenge faced by any long-term environmental monitoring program is how (or whether) to evolve in response to changing conditions and drivers. In 2013, due to budgetary constraints, the National Centers for Coastal Ocean Science (NCCOS) undertook the task of re-designing the MWP, moving from a nationwide annual monitoring approach to the rotating regional monitoring model that is currently employed. The regional approach allows the program to improve its presence in coastal communities by increasing interaction with local stakeholders, integrating inputs from coastal resource managers, and providing specific data needs to help fill local data gaps. By making adaptive changes and leveraging regional partnerships, the program has increased its scientific relevance and reputation, and has evolved to include more than 300 monitoring sites (Figure 1) and nearly 600 chemical contaminants including metals, legacy organic compounds, and contaminants of emerging concern (CECs).

The MWP provides unique data that is vital to evaluating the health of the nation's estuarine and coastal waters, particularly describing the levels of chemical contamination. The MWP dataset allows for temporal and spatial evaluation of regional and national changes in chemical distribution, including CECs as their potential risks are identified. The programs' long-term data supports the assessment of impacts of unforeseen events such as oil spills and hurricanes, the evaluation of sanctuary statuses, the analysis of resource and ecosystem service trends, and the evaluation of the effectiveness of regulations that ban toxic chemicals or support legislation such as the Clean Air and Clean Water Acts.

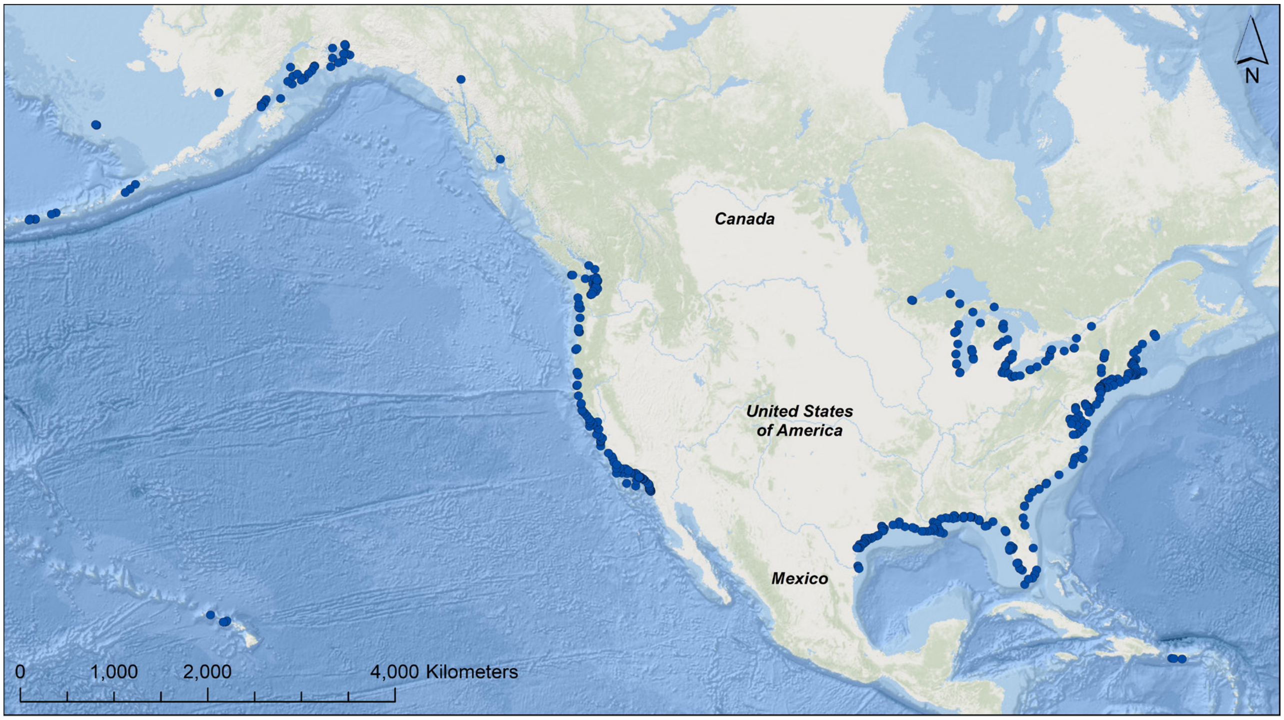

Figure 1. National Mussel Watch sites.

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2.0 INTRODUCTION

The MWP has long-term monitoring sites spanning the length of the California coast and a subset of these, from north of Santa Barbara to south of San Diego (Figure 2), were analyzed in this study. California has complex physical and biological oceanographic features impacted by both the southerly flowing California Current, which causes strong upwelling in the northern part of the region, and the northerly-flowing Southern California Countercurrent, which defines the southern California biogeographic boundary (Scarborough et al., 2022). California marine ecosystems are some of the best studied in the world and have human-ecosystem interactions dating back 13,000 years to when native coastal peoples began developing complex fishing, hunting, and economic trade systems (Scarborough et al., 2022). California's current ocean economy is dominated by tourism and recreation, marine transportation, and offshore mineral extraction (NOAA Office for Coastal Management, 2015). With nearly two-thirds of the California population residing in coastal counties, the health and water quality of coastal ecosystems is heavily tied to human activities in the region (NOAA Office for Coastal Management, 2015). A study by Halpern et al. (2009) assessed the cumulative effects of a series of anthropogenic stressors on the California coast. In the central California area, land-based drivers (e.g. nutrient input, organic and inorganic pollution, coastal engineering), ocean-based commercial activities (e.g. coastal power plants, commercial shipping, oil rigs), climate change (e.g. SST, UV, ocean acidification), and fishing (e.g. recreational, pelagic, demersal) all had a medium to high impact on the overall health of the waters of the Southern California Bight. Additionally, a study conducted in 2016 reported that ecosystem services including sense of place, consumptive recreation, non-consumptive recreation, food supply, and maritime heritage all had fair-good ratings, with human dimensions indicators increasing or stable (Office of National Marine Sanctuaries, 2019).

Coastal chemical pollution along the west coast of the United States (US) has been assessed and monitored by state, regional, and federal organizations for resource and ecosystem management and production. At the federal level, the National Oceanic and Atmospheric Administration (NOAA) National Status and Trends Program (NS&T) has conducted contaminant assessment and monitoring along the coast since 1986 (Kimbrough et al., 2007). The Channel Islands National Marine Sanctuary (CINMS) was designated in 1980 by NOAA to protect sanctuary resources and promote ecosystem conservation, protect cultural resources, and support compatible human uses (CINMS, 2022). At the state and regional level, the Southern California Coastal Water Research Project (SCCWRP) applies innovations in science to improve management of aquatic systems in Southern California and has been assisting the development of strategies, tools, and technologies for water quality management since its inception in 1969 (SCCWRP, 2022). Additionally, the California Ocean Protection Council ensures that California maintains healthy, resilient, and productive ocean and coastal ecosystems for the benefit of current and future generations (OPC, 2023). Programs such as these, which value the collection and assessment of long-term water quality monitoring, have provided relevant data and information to coastal managers and the scientific community, but have historically been focused on legacy contaminants. These legacy contaminants include trace elements (*i.e.,* heavy metals), polycyclic aromatic hydrocarbons (PAHs), and persistent organic pollutants such as butyltins (BTs), dieldrins, chlordanes, hexachlorocyclohexanes (HCHs), dichlorodiphenyltrichloroethane (DDT), chlorobenzenes, endosulfans, chlorpyrifos, and polychlorinated biphenyls (PCBs).

As management and policy decisions have helped decrease the prevalence and impact of many legacy contaminants, monitoring agencies have begun to focus on the assessment and potential impacts of new and less regulated contaminants, known as contaminants of emerging concerns (CECs), many of which are manufactured to replace other banned chemicals. The scope and impact of these CECs are largely unknown and potentially vast (Diamond et al., 2011) which makes prioritizing the list of CECs to monitor challenging. Based on EPA recommendations as described in Ankley et al., (2008), classes of CECs to consider for monitoring should include 1) persistent organic pollutants such as flame retardants, current-use pesticides, and industrial byproducts; 2) pharmaceutical and personal care products such as prescription, illegal, over the counter drugs, sunscreens, and synthetic musks; 3) veterinary medicines such as antimicrobials, antibiotics, antifungals, and growth hormones for animals; 4) endocrine-disrupting chemicals and other compounds capable of modulating normal hormone functions and steroidal synthesis; and 5) nanoparticles such as carbon nanotubes or nano-scale particulates, of which little is known about either their environmental fate or effects. Additionally, diverse classes of CECs were evaluated in a variety of matrices (sediment, water, fish, and bivalves) during the Southern California Bight project in 2009-2010 and the resulting studies provided insight about the detection and concentrations of CECs in different environmental media (Dodder et al., 2014; Maruya et al., 2016). Based on these data inputs and considerations, the MWP CEC list includes contaminants for which methods are established and for which literature indicates their potential environmental persistence and ecological and human toxicity.

In 2018, the MWP collaborated with SCCWRP, California OPC, and CINMS to conduct a comprehensive assessment of CECs in the Southern California Bight on the west coast of the US. The study was designed within the framework of the MWP regional monitoring approach, which balances flexibility in study design with the cost of broad CEC surveys. The objectives of this study were to 1) assess the presence and distribution of alkylphenol compounds, flame retardants, current-use pesticides, pharmaceutical and personal care products, and per- and polyfluoroalkyl substances associated with human activity that may bioaccumulate in the Southern California Bight; 2) compare contamination in the Southern California Bight in 2018 to previous studies in the same and other regions; and 3) make the data electronically available to coastal resource managers in the west coast region.

3.0 METHODS

3.1 Study Area and Sampling Design

The MWP has 39 long-term monitoring sites in coastal waters in the Southern California Bight (Figure 2). Monitoring sites were historically selected in locations with abundant bivalve populations to allow for repetitive sampling and to convey information about the degree of chemical contamination in the general area over time. The sites were not randomly selected nor designed to target specific pollution sources.

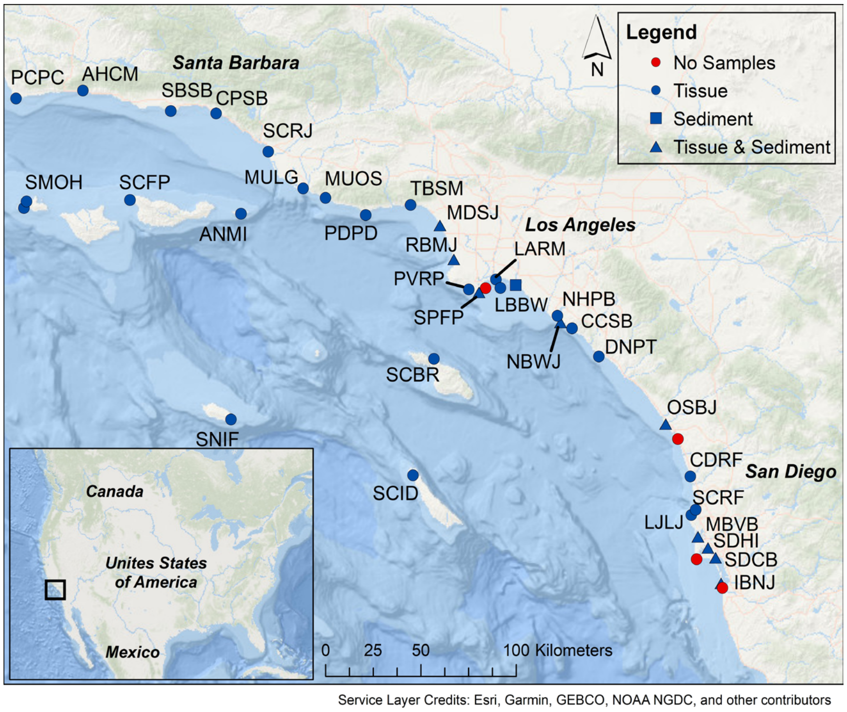


Figure 2. Map of Mussel Watch sites in the US Southern California Bight region and their respective matrices sampled in 2018.

Sample collection at these sites was conducted by SCCWRP and CINMS following standard protocols utilized by the MWP (Apeti et al., 2012) in primarily November 2018 - April 2019 with a few sites sampled in July 2018 and May 2019. In 2018, mussel samples (*Mytilus* species) were collected via hand picking from 34 sites and sediment samples were collected via Van Veen grab from 10 sites. Tissue samples collected from site SANM (San Miguel Island Tyler Bight) were not abundant enough for all analyses, so only PBB and PBDE analyses were conducted.

Out of the 39 established sites, LATI was the only site not attempted for sampling in 2018 (Table 1). The LATI site wasn't established until 2010 and mussels were originally kept in cages; therefore, this site was not suitable for repeat sampling in 2018. Sampling at four additional sites (ABWJ, AHLG, PLLH, and TJRE) was attempted in 2018 but no mussels were found (Table 1). Of those four sites, ABWJ was still sampled for sediment (Table 1).

In this study, several classes of CECs were analyzed in mussel tissue and sediment samples. In mussel tissue, analyses of alkylphenol compounds (4), alternative flame retardants (3), current use pesticides (30), and per- and polyfluoroalkyl substances (33), were conducted for 33 sites, analyses of pharmaceutical and personal pare products (141) were conducted for 10 sites, and analyses of brominated flame retardants (70) were conducted for 34 sites (Table 2). Pharmaceuticals and personal care products were only analyzed at a subset of 10 sites due to logistic limitations. For sediment samples, analyses of alkylphenol compounds (4), alternative flame retardants (3), brominated flame retardants (70), current use pesticides (32), and pre- and polyfluoroalkyl substances (33) were conducted for 10 sites (Table 2).

3.2 Analytical Methods

Analyses for this study were conducted by three laboratories (Table 2). Detailed descriptions of analytical methods for CECs analyzed in this study by TDI Brooks (PBDEs and PBBs) can be found in Kimbrough et al. (2007). Detailed descriptions of analytical methods for CECs analyzed in this study by AXYS (AFRs, CUPs, PFASs, and PPCPs) are proprietary and confidential so the specific method name used in the analysis is mentioned in the “Chemical Description” section of each contaminant class along with the lab contact information here (SGS AXYS Analytical Services LTD., 2045 Mills Road

Table 1. Mussel Watch sites selected for 2018 Southern California Bight survey. ● signifies the matrix sampled at that site.

Site	General Location	Specific Location	Latitude	Longitude	Tissue Sampled?	Sediment Sampled?
ABWJ	Anaheim Bay	West Jetty	33.73350	-118.10100		●
AHCM	Arroyo Hondo	Canyon Mouth	34.47338	-120.14220	●	
AHLG	Agua Hedionda	Lagoon	33.14397	-117.33688		
ANMI	Anacapa Island	Anacapa Island	34.00593	-119.39648	●	
CCSB	Crystal Cove	State Beach	33.56862	-117.83588	●	
CDRF	Cardiff Reef	Cardiff Reef	32.99988	-117.27867	●	
CPSB	Carpenteria State Beach	Carpenteria State Beach	34.38712	-119.51400	●	
DNPT	Dana Point	Dana Point	33.46027	-117.70950	●	
IBNJ	Imperial Beach	North Jetty	32.58767	-117.13350	●	●
LARM	Los Angeles	River mouth	33.75525	-118.19498	●	
LBBW	Long Beach	Breakwater	33.72317	-118.17350	●	
LJLJ	La Jolla	Point La Jolla	32.85150	-117.27383	●	
MBVB	Mission Bay	Ventura Bridge	32.76750	-117.24200	●	●
MDSJ	Marina Del Rey	South Jetty	33.96183	-118.45800	●	●
MULG	Point Mugu Lagoon	Point Mugu Lagoon	34.10230	-119.10390	●	
MUOS	Point Mugu	Old Stairs	34.06618	-118.99823	●	
NBWJ	Newport Beach	West Jetty	33.59100	-117.89000	●	●
NHPB	Newport Bay	PCH Bridge	33.61660	-117.90485	●	
OSBJ	Oceanside	Municipal Beach Jetty	33.20167	-117.39367	●	●
PCPC	Point Conception	Point Conception	34.44383	-120.45700	●	
PDPD	Point Dume	Point Dume	34.00100	-118.80883	●	
PLLH	Point Loma	Lighthouse	32.68050	-117.24883		
PVRP	Palos Verdes	Royal Palms County Pk.	33.71700	-118.32267	●	
RBMJ	Redondo Beach	Municipal Jetty	33.83200	-118.39283	●	●
SANM	San Miguel Island	Tyler Bight	34.02800	-120.41933	●	
SBSB	Point Santa Barbara	Point Santa Barbara	34.39567	-119.72750	●	
SCBR	South Catalina Island	Bird Rock	33.45167	-118.48733	●	
SCFP	Santa Cruz Island	Fraser Point	34.05800	-119.92033	●	
SCID	San Clemente Island	Darter	33.00431	-118.58558	●	
SCRF	Scripps Reef	Scripps Reef	32.87162	-117.25318	●	
SCRJ	Santa Clara	River Jetty	34.24220	-119.26850	●	
SDCB	San Diego Bay	Coronado Bridge	32.68650	-117.15917	●	●
SDHI	San Diego Bay	Harbor Island	32.72467	-117.19467	●	●
SMOH	San Miguel Island	Otter Harbor	34.05230	-120.40735	●	
SNIF	San Nichols Island	Freighter Dock	33.21933	-119.44382	●	
SPFP	San Pedro Harbor	Fishing Pier	33.70667	-118.27417	●	●
TBSM	Las Tunas Beach	Santa Monica Bay	34.03900	-118.59717	●	
TJRE	Tijuana River	Estuary	32.56982	-117.12693		

W., Sidney, BC, Canada, V8L 5X2. Tel. (250) 655-5800, Fax (250) 655-5811) for further reference. Detailed descriptions of analytical methods for CECs analyzed in this study by NCCOS' Ecotoxicology Laboratory in Charleston (APs) can be found in Petrovic et al. (2002), Loyo-Rosales et al. (2003), and Apeti et al. (2018). For all contaminant classes, a background summary (“Chemical Description”) and analysis summary (“Results Summary”) can be found within this document.

Table 2. Laboratories at which analyses were conducted for the 2018 Southern California Bight survey.

Chemical Class	Matrix	Number of Sites	Laboratory
AP	Tissue	33	Ecotox Lab
	Sediment	10	Ecotox Lab
AFR (HBCD)	Tissue	33	AXYS
	Sediment	10	AXYS
BFR (PBB, PBDE)	Tissue	34	TDI
	Sediment	10	TDI
MRES (CUP)	Tissue	33	AXYS
	Sediment	10	AXYS
PFAS	Tissue	33	AXYS
	Sediment	10	AXYS
PPCP	Tissue	10	AXYS

3.3 Data Analysis

Data management and analysis were conducted using a combination of R version 4.1.2 (R Core Team, 2013), Microsoft Excel (Microsoft Corporation, 2018), ArcGIS (ESRI, 2011), and JMP12 Software (JMP, 2022).

AXYS report data in wet weight (ng/g ww), whereas TDI Brooks and the NCCOS Ecotoxicology Laboratory (Ecotox Lab) in Charleston, SC report data in dry weight (ng/g dw). All contaminant concentrations were converted to wet weight (ng/g ww) using percent moisture content measured by TDI Brooks for consistency throughout this document (Table A1).

Concentrations of all CEC classes were blank corrected and any values below the Method Detection Limit (MDL) were categorized as undetected and were assigned a value of 0. The MDLs for PBB and PBDE were also converted to wet weight units. The MDL is defined as the lowest concentration able to be detected by the analytical instrument or method. Sediment contaminant concentration data was normalized by total organic content (TOC) due to the tendency of some organic contaminants to preferentially bind to organic content (Mount, 2010) (Table A1). Sediment data in this study could not be normalized to grain size, as is typical in Mussel Watch reports, due to an error in sample preservation. However, the correlation of organic contaminants associating with finer-grained sediments is well established (McDonald et. al., 2006) and as sediments with higher TOC also tend to be finer-grained, normalization by TOC should be sufficient for these analyses. The MDLs for sediment data were normalized by TOC as well.

Overall site contamination analysis was done using a multivariate cluster analysis (using the Ward Method) for both mussel tissue and sediment samples. Sums of contaminant concentrations within each of the 14 contaminant classes were calculated and a clustering analysis was conducted on each class. In each contaminant class, only sites where the sum of contaminant concentrations was not 0 were included in this analysis so that sites where contaminants were not detected were kept separate and did not skew the resulting clusters. For each contaminant class, sites were clustered into 3 groups to represent high contamination (value=3), medium contamination (value=2), and low contamination (value=1) in addition to absent (or non-detected) contamination (value=0). In a few instances, there were 3 or fewer sites with contaminants detected for a given chemical class. Due to the low frequency of contamination from these chemical classes across this study, the detection of these is significant regardless of the concentration, so all of these sites were weighted as high (value=3) to maximize their impact on the overall contamination score. Once each site had a cluster value for each contaminant class, the sum of all classes was calculated for each site. Since only a subset of sites were analyzed for PPCP contaminants, the final sum at each site was normalized by the maximum value possible at that site (*i.e.,* (sum cluster values)/(# chemical classes analyzed * 3)×100). These normalized values were again clustered using the Ward Method to generate 5 groups of sites with statistically different degrees of overall contamination within this study.

4.0 RESULTS - ALKYLPHENOL COMPOUNDS (APs)

4.1 APs Chemical Description

Alkylphenols (APs) are a class of chemicals used in detergents and surfactants in industrial processes. Some household detergents (*i.e.,* laundry soaps) also include APs. The most common sources of APs to aquatic systems are wastewater and septic system discharges (Ying et al., 2002). These compounds tend to be persistent in the environment, have a strong affinity for suspended particles, and are well preserved in bottom sediments (Ying et al., 2002). In the environment, alkylphenol ethoxylate surfactants biodegrade into more environmentally stable metabolites, such as the alkylphenol n-ethoxylates, alkylphenoxy acetic, alkylphenoxy polyethoxy acetic acids, and alkylphenols (EPA, 2014a). This study focused on four AP metabolites in mussel tissues (Table 3). The compounds 4-nonylphenol (4-NP) and 4-noctylphenol (4-n-OP) are degradation products of 4-nonylphenol mono-ethoxylate (NP1E0) and 4-nonylphenol di-ethoxylate (NP2E0), which are byproducts of the parent alkylphenol polyethoxylate. These degradation products are reported to be more toxic than the parent compounds and act as hormone mimics (Ying et al., 2002). APs are shown to have estrogenic endocrine-disrupting effects on vertebrate organisms, and they have been linked to severe decreases in lobster larval survival and juvenile lobster hormonal changes (Laufer et al., 2013). In this study, the MWP measured two NPEO and two NP compounds (Table 3) for which analytical methods are well established. These four compounds were included in the EPA New Use Rules list of 15 toxic AP compounds (EPA, 2014a).

AP analyses were conducted by the NCCOS Ecotoxicology Laboratory in Charleston, SC.

Table 3. AP compounds tested (4).

Chemical Code	Chemical Name	Application
4-NP	4-n-octylphenol	Manufacture AP ethoxylates (detergents, cleaners)
4n-OP	4-nonylphenol	Intermediate chemical for thermal stabilization
NP1EO	4-nonylphenol mono-ethoxylate	Used in cleaners, adhesives, paints, food packaging
NP2EO	4-nonylphenol di-ethoxylate	Used in cleaners, adhesives, paints, food packaging

4.2 Presence, Distribution, and Contamination Level of APs in Mussel Tissue

NUMBER OF COMPOUNDS DETECTED:
2 / 4

NUMBER OF SITES WITH DETECTS:
17 / 33

MOST DETECTED COMPOUND:
4n-OP

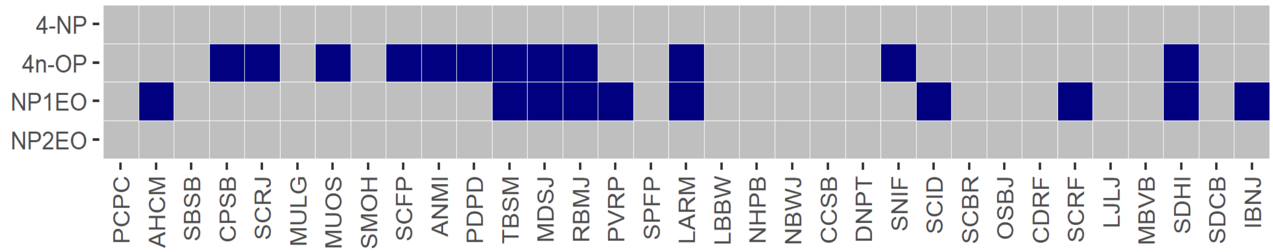


Figure 3. Distribution map showing presence ( ) and absence ( ) of AP compounds measured in mussel tissues in the Southern California Bight. Sites are listed geographically from north to south, following the coastline.

Table 4. Coastwide frequency of AP compound detection in mussel tissue when compound was detected at least once.

Compound	# Detects	# Sites Sampled	Frequency (%)
4n-OP	12	33	36.4
NP1EO	10	33	30.3
TOTAL	**22**	**132**	**16.7**

Table 5. Number of AP compound detects in mussel tissue at each site when at least one compound was detected.

Site	# Detects	# Compounds Analyzed	Frequency (%)
LARM	2	4	50.0
MDSJ	2	4	50.0
RBMJ	2	4	50.0
SDHI	2	4	50.0
TBSM	2	4	50.0
AHCM	1	4	25.0
ANMI	1	4	25.0
CPSB	1	4	25.0
IBNJ	1	4	25.0
MUOS	1	4	25.0
PDPD	1	4	25.0
PVRP	1	4	25.0
SCFP	1	4	25.0
SCID	1	4	25.0
SCRF	1	4	25.0
SCRJ	1	4	25.0
SNIF	1	4	25.0

Results - APs

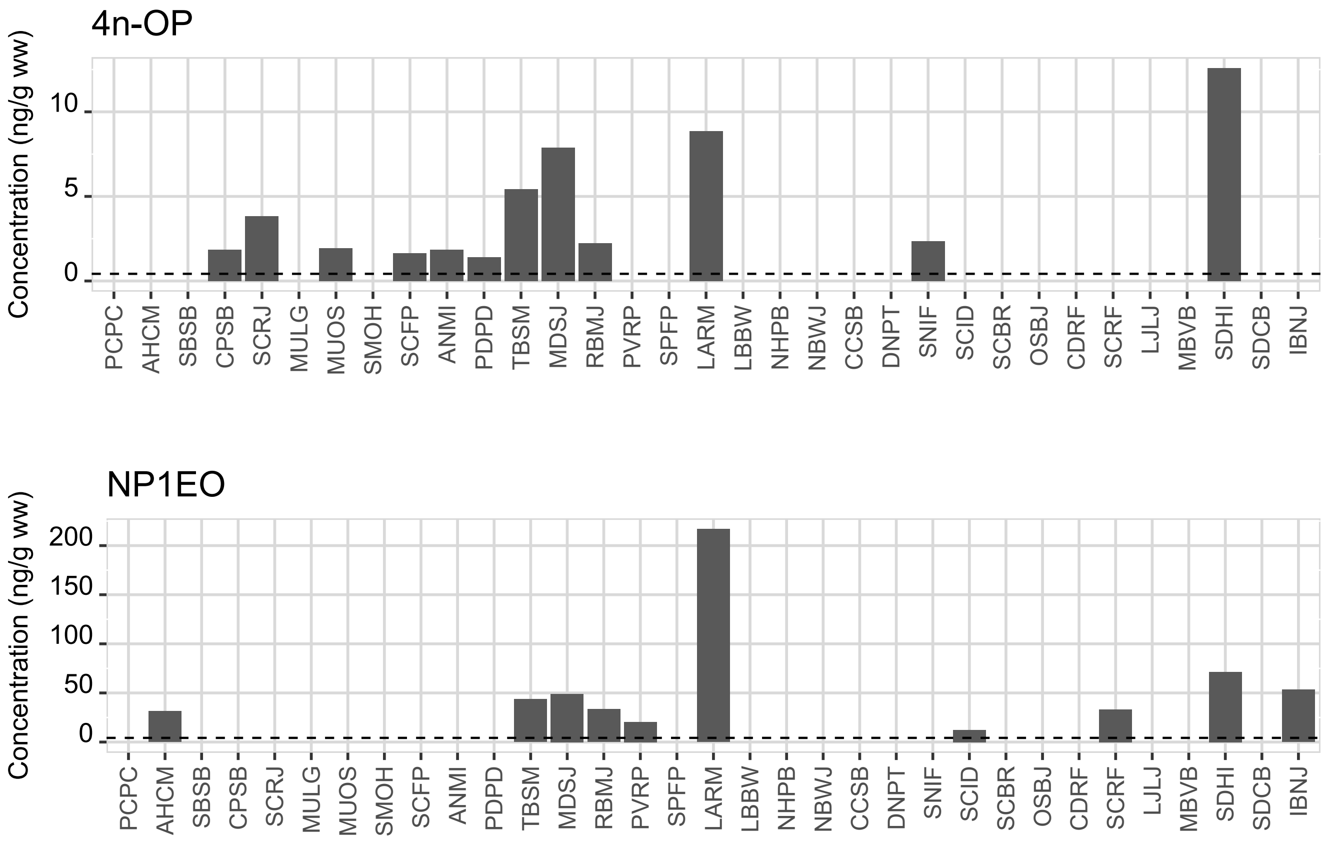


Figure 4. Bar graphs showing magnitude of AP compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.

4.3 Presence, Distribution, and Contamination Level of APs in Sediment

NUMBER OF COMPOUNDS DETECTED:
2 / 4

NUMBER OF SITES WITH DETECTS:
10 / 10

MOST DETECTED COMPOUND:
4N-OP

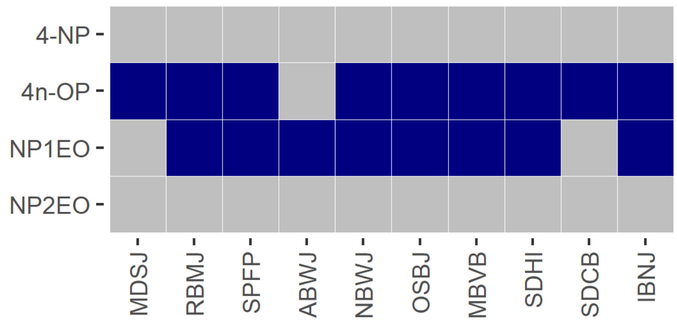


Figure 5. Distribution map showing presence ( ) and absence ( ) of AP compounds measured in sediment in the Southern California Bight. Sites are listed geographically from north to south, following the coastline.

Table 6. Coastwide frequency of AP compound detection in sediment when compound was detected at least once.

Compound	# Detects	# Sites Sampled	Frequency (%)
4n-OP	9	10	90.0
NP1EO	8	10	80.0

Table 7. Number of AP compound detects in sediment at each site when at least one compound was detected.

Site	# Detects	# Compounds Analyzed	Frequency (%)
IBNJ	2	4	50.0
MBVB	2	4	50.0
NBWJ	2	4	50.0
OSBJ	2	4	50.0
RBMJ	2	4	50.0
SDHI	2	4	50.0
SPFP	2	4	50.0
ABWJ	1	4	25.0
MDSJ	1	4	25.0
SDCB	1	4	25.0

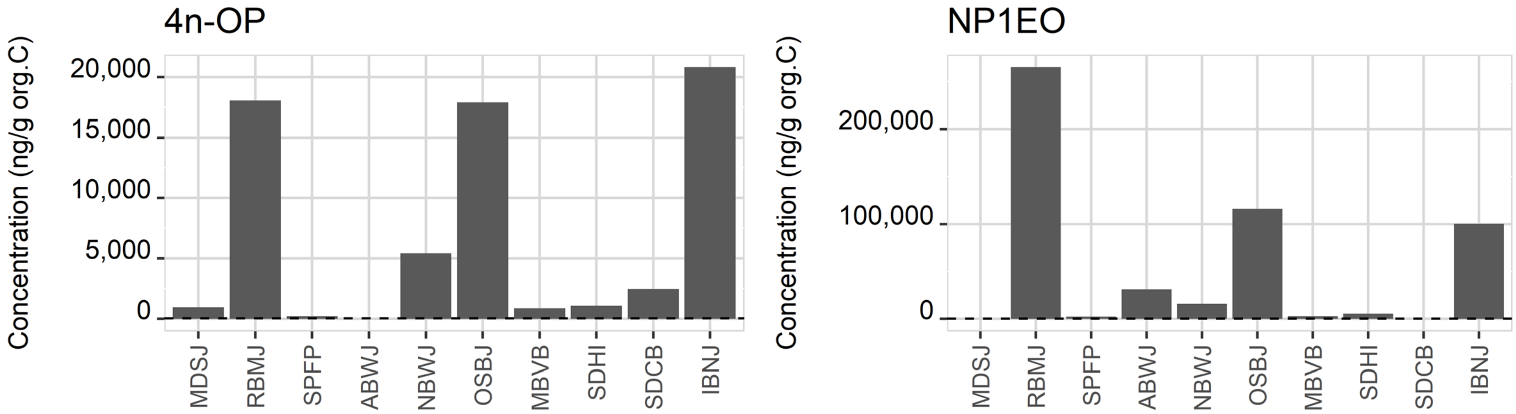


Figure 6. Bar graphs showing magnitude of AP compounds detected in sediment in the Southern California Bight. Dotted line represents the minimum TOC corrected detection limit. Sites are listed geographically from north to south, following the coastline.

4.4 APs Results Summary

Mussel Tissue
- APs were analyzed at 33 out of 34 tissue sites
  - Not analyzed at site SANM due to insufficient sample mass
- 2/4 AP compounds were detected at least once
- 4n-OP was the most commonly detected AP compound with a frequency of 36.4%
- Minimum concentration detected was 1.40 ng/g ww of 4n-OP at site PDPD
- Maximum concentration detected was 216.82 ng/g ww of NP1EO at LARM
- Overall, APs were detected 22/132 possible times (4 compounds x 33 sites) for an overall 16.7% frequency of detection in the Southern California Bight

Sediment
- APs were analyzed at 10 out of 10 sediment sites
- 2/4 AP compounds were detected at least once
- 4n-OP was the most commonly detected AP compound with a frequency of 90.0%
- Minimum concentration detected was 196.74 ng/g organic Carbon of 4n-OP at site SPFP
- Maximum concentration detected was 265,149.25 ng/g organic Carbon of NP1EO at site RBMJ
- Overall, APs were detected 17/40 possible times (4 compounds x 10 sites) for an overall 42.5% frequency of detection in the Southern California Bight

General Observations
- APs in mussel tissue were widely distributed in the Southern California Bight
- APs detected in sediment do not consistently match APs detected in mussel tissue (*e.g.,* APs at site OSBJ not detected in mussel tissue but one of highest concentrations detected in sediments)
- APs are more consistently detected in sediments compared to tissues

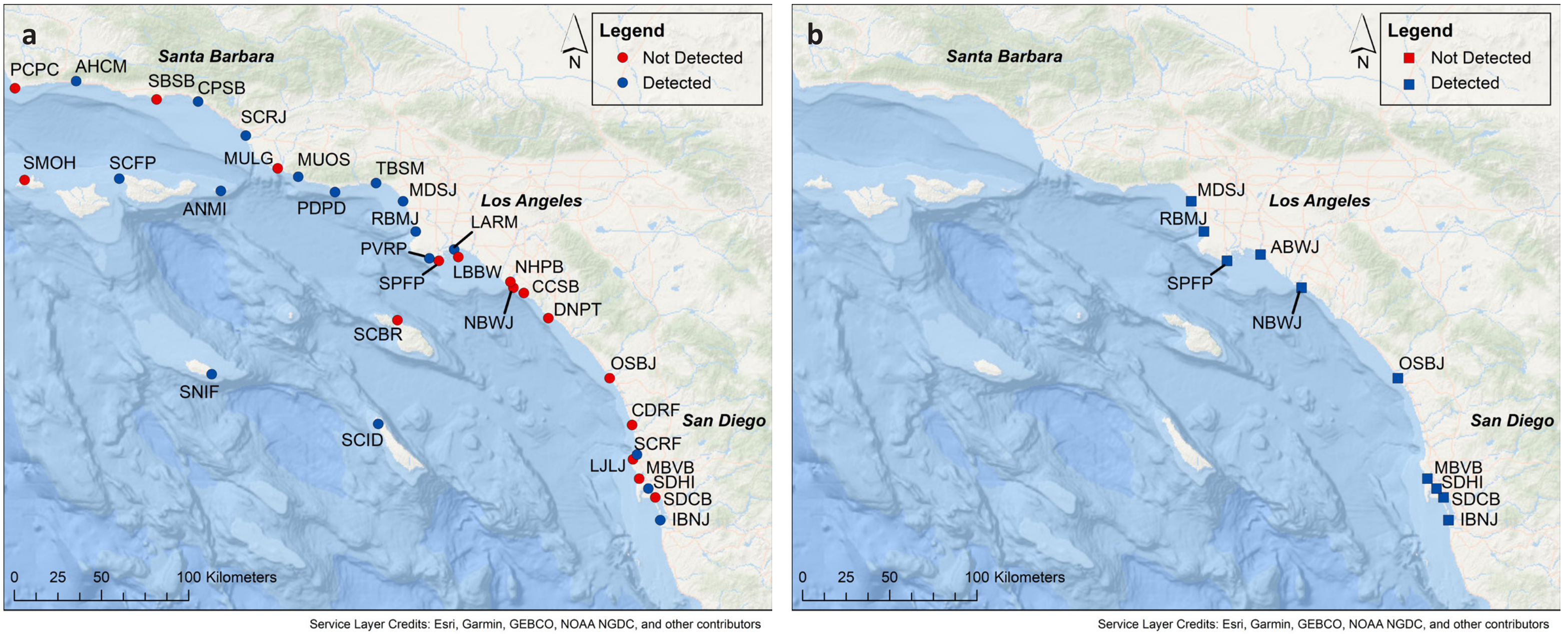


Figure 7. Map of Mussel Watch sites in the Southern California Bight highlighting locations of sites with AP compounds detected in (a) mussel tissue and (b) sediment.

5.0 RESULTS - ALTERNATIVE FLAME RETARDANTS (AFRs)

5.1 AFRs Chemical Description

Alternative Flame Retardants (AFRs) are added to a wide variety of industrial and consumer products such as textiles, rugs, furniture and plastics (de Wit, 2002). There are several groups of chemicals characterized as AFRs including hexabromocyclododecanes (HBCDs) and chlorinated organophosphate chemicals (CPP); however, only HBCDs were analyzed in this study (Table 8). Although brominated, HBCDs are classified here as an “Alternative Flame Retardant” because they were originally introduced as an alternative to Brominated Flame Retardants such as PBBs and PBDEs, but have since been banned themselves. HBCDs are primarily used in household consumer products such as upholstery, polystyrene, and textiles. HBCDs are ubiquitous in the environment, but their ecotoxicity is not well understood (de Wit, 2002).

AFR analyses were conducted by SGS AXYS Analytical Services LTD. The analytical method used was MLA-070 Rev 02.

Table 8. AFR compounds tested (3).

Chemical Code	Chemical Name
alpha-HBCD	α-hexabromocyclododecane
beta-HBCD	β-hexabromocyclododecane
gamma-HBCD	γ-hexabromocyclododecane

5.2 Presence, Distribution, and Contamination Level of AFRs in Mussel Tissue

NUMBER OF COMPOUNDS DETECTED:
1 / 3

NUMBER OF SITES WITH DETECTS:
2 / 33

MOST DETECTED COMPOUND:
alpha-hexabromocyclododecane

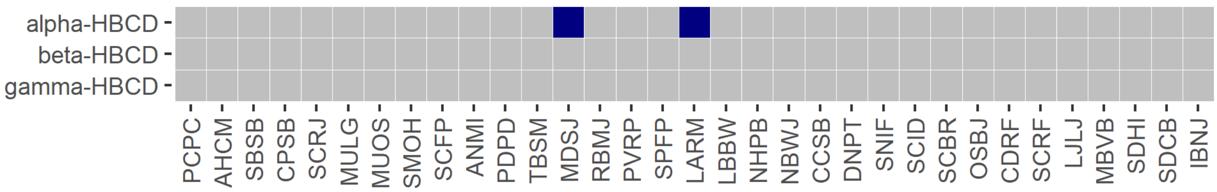


Figure 8. Distribution map showing presence ( ) and absence ( ) of AFR compounds measured in mussel tissues in the Southern California Bight. Sites are listed geographically from north to south, following the coastline.

Table 9. Coastwide frequency of AFR compound detection in mussel tissue when compound was detected at least once.

Compound	# Detects	# Sites Sampled	Frequency (%)
alpha-HBCD	2	33	6.1

Table 10. Number of AFR compound detects in mussel tissue at each site when at least one compound was detected.

Site	# Detects	# Compounds Analyzed	Frequency (%)
MDSJ	1	3	33.3
LARM	1	3	33.3

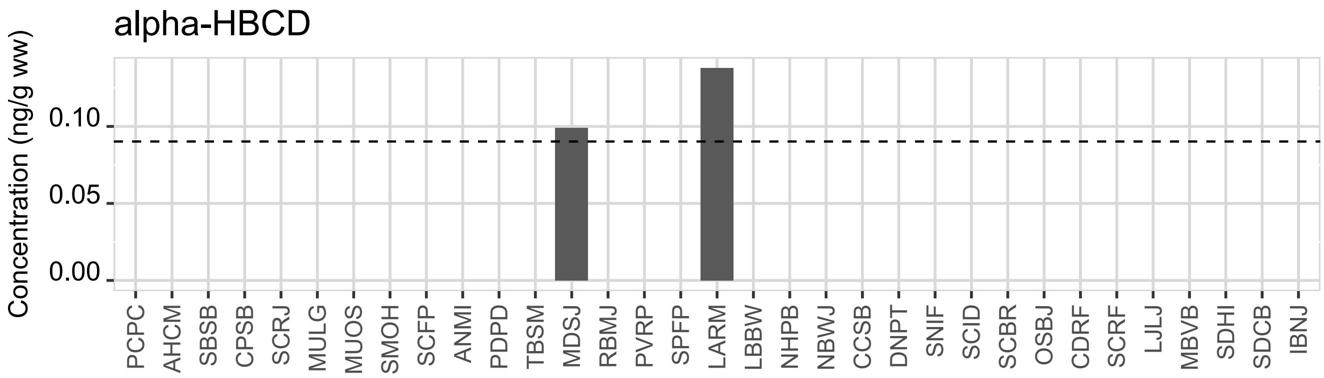


Figure 9. Bar graph showing magnitude of AFR compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.

5.3 Presence, Distribution, and Contamination Level of AFRs in Sediment

NUMBER OF COMPOUNDS DETECTED:
2 / 3

NUMBER OF SITES WITH DETECTS:
3 / 10

MOST DETECTED COMPOUND:
gamma-hexabromocyclododecane

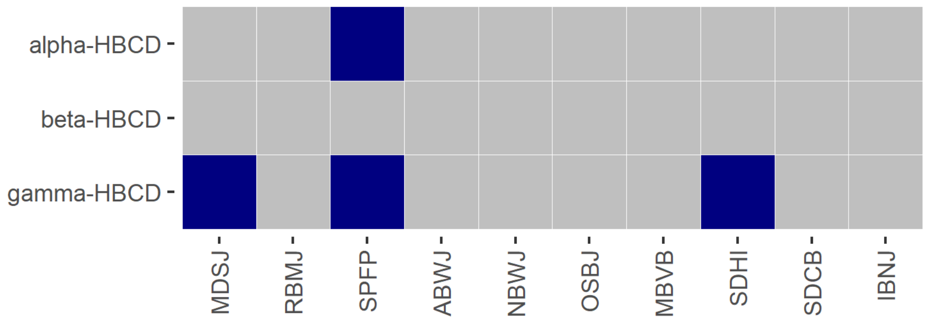


Figure 10. Distribution map showing presence ( ) and absence ( ) of AFR compounds measured in sediment in the Southern California Bight. Sites are listed geographically from north to south, following the coastline.

Table 11. Coastwide frequency of AFR compound detection in sediment when compound was detected at least once.

Compound	# Detects	# Sites Sampled	Frequency (%)
gamma-HBCD	3	10	30.0
alpha-HBCD	1	10	10.0

Table 12. Number of AFR compound detects in sediment at each site when at least one compound was detected.

Site	# Detects	# Compounds Analyzed	Frequency (%)
SPFP	2	3	66.6
MDSJ	1	3	33.3
SDHI	1	3	33.3

Results - AFRs

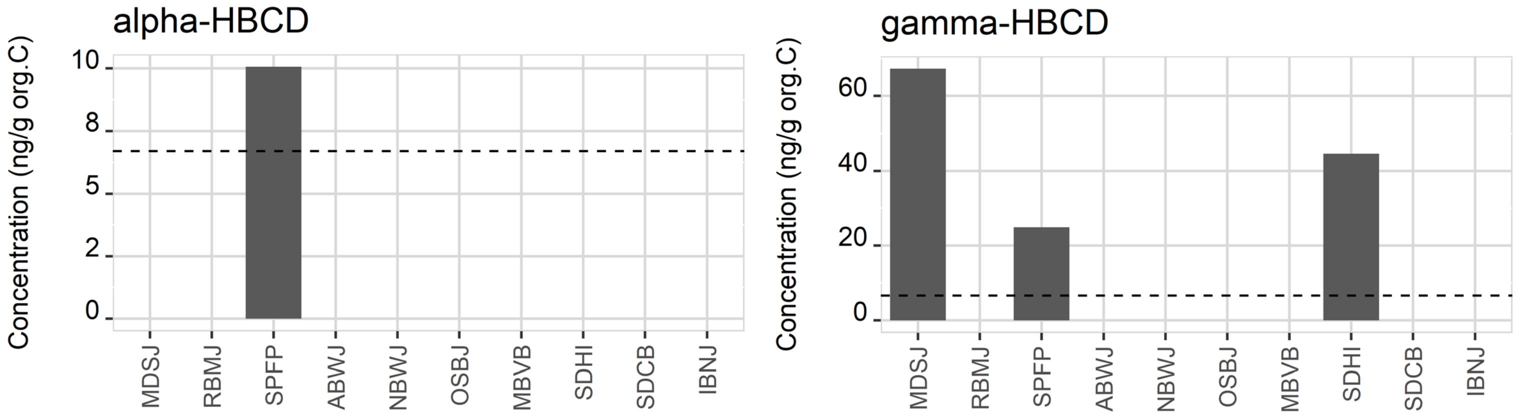


Figure 11. Bar graphs showing magnitude of AFR compounds detected in sediment in the Southern California Bight. Dotted line represents the minimum TOC corrected detection limit. Sites are listed geographically from north to south, following the coastline.

5.4 AFRs Results Summary

Mussel Tissue

- AFRs were analyzed at 33 out of 34 tissue sites
  - Not analyzed at site SANM due to insufficient sample mass
- 1/3 AFR compounds were detected at least once
- alpha-hexabromocyclododecane was the most commonly detected AFR compound with a frequency of 6.1%
- Minimum concentration detected was 0.10 ng/g ww of alpha-hexabromocyclododecane at site MDSJ
- Maximum concentration detected was 0.14 ng/g ww of alpha-hexabromocyclododecane at site LARM
- Overall, AFRs were detected 2/99 possible times (3 compounds x 33 sites) for an overall 2.0% frequency of detection in the Southern California Bight

Sediment

- AFRs were analyzed at 10 out of 10 sediment sites
- 2/3 AFR compounds were detected at least once
- gamma-hexabromocyclododecane was the most commonly detected AFR compound with a frequency of 30.0%
- Minimum concentration detected was 10.07 ng/g organic Carbon of alpha-hexabromocyclododecane at site SFPF
- Maximum concentration detected was 67.27 ng/g organic Carbon of gamma -hexabromocyclododecane at site MDSJ
- Overall, AFRs were detected 4/30 possible times (3 compounds x 10 sites) for an overall 13.3% frequency of detection in the Southern California Bight

General Observations

- AFRs were not detected at a high proportion of sites analyzed in the Southern California Bight in both mussel tissue and sediment
- In mussel tissue, both instances of detection were located near marinas and next to creek/river sources, while there were no detects near the San Diego Harbor despite anthropogenic influence
- There are mild inconsistencies with AFR detection in mussel tissue compared to sediment but, generally, AFRs were detected in similar areas (*e.g.,* AFRs were detected at SPFP in sediments but not mussel tissue, but were detected in mussel tissue at the nearby site LARM)

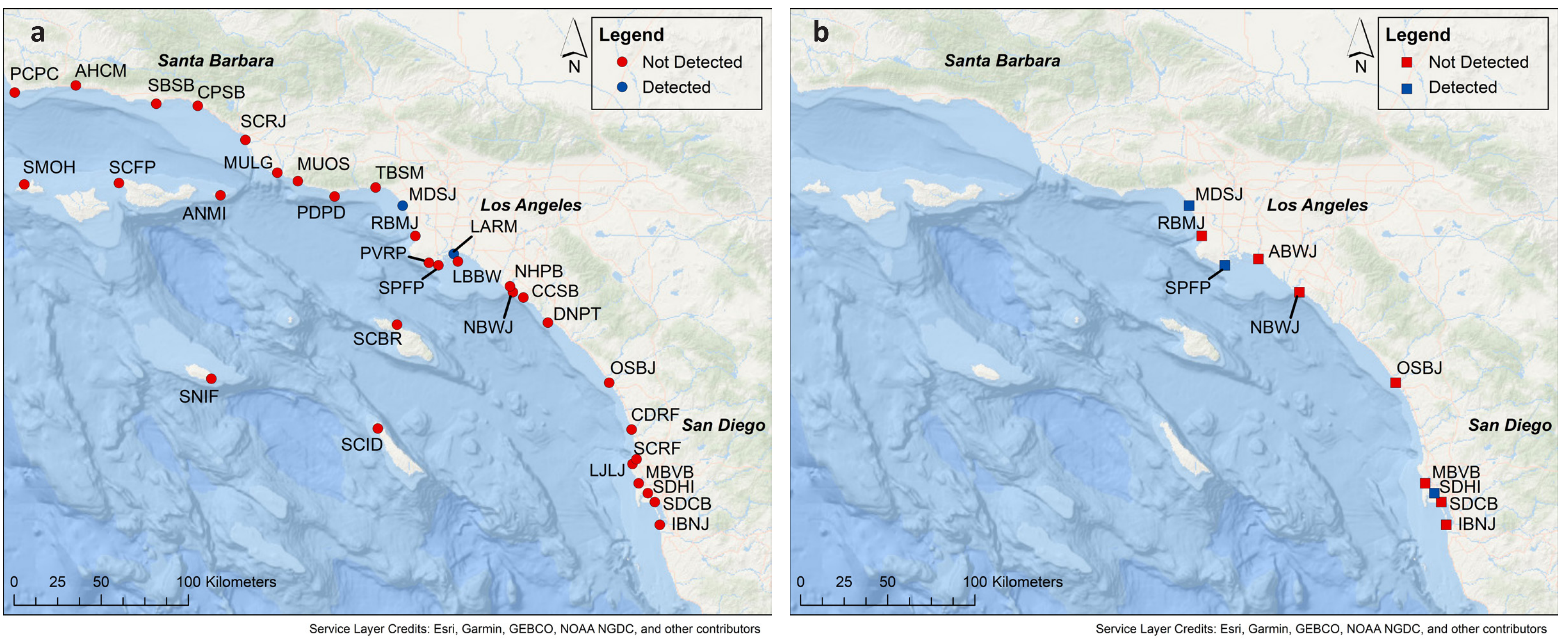


Figure 12. Map of Mussel Watch sites in the Southern California Bight highlighting locations of sites with AFR compounds detected in (a) mussel tissue and (b) sediment.

6.0 RESULTS - BROMINATED FLAME RETARDANTS (BFRs)

6.1 BFRs Chemical Description

Brominated Flame Retardants (BFRs), such as polybrominated diphenyl ethers (PBDEs) and polybrominated biphenyls (PBBs), are a group of chemicals with 209 possible unique congeners that are used in firefighting materials and in consumer and household products to reduce flammability. A subset of these congeners was analyzed in this study (19 PBBs and 51 PBDEs). Commercially, three types of PBDE industrial mixtures have been available, the pentabromodiphenyl ether (penta-BDE), octabromodiphenyl ether (octa-BDE) and the decabromodiphenyl ether (deca-BDE) mixtures (EPA, 2014b). As the products that contain these compounds age and degrade or are discarded, PBDEs leach into the environment. PBDEs have become ubiquitous in the environment and are detected in materials including household dust, human breast milk, sediment, and wildlife (Agency for Toxic Substances and Disease Registry (ATSDR), 2015). The less brominated PBDEs, like tetra-, penta- and hexa-BDE, demonstrate high affinity for lipids and tend to bioaccumulate in animals and humans, while highly brominated PBDEs like deca-BDE tend to absorb more into sediment and soil. The toxicology of PBDEs is not well understood, but PBDEs have been associated with tumors, neurodevelopmental toxicity, and thyroid hormone imbalance (Siddiqi et. al., 2003). Some PBDE congeners have hepatotoxic and mutagenic effects while others may act as estrogen receptor agonists *in vitro* (Meerts et al., 2001). Due to their ubiquitous distribution, persistence and potential for toxicity, the manufacturing of the penta- and octa- BDE mixtures began to be phased out in 2004, and the deca- mixture in 2013 (EPA, 2014b; Schreder and La Guardia, 2014).

Polybrominated biphenyls (PBBs) are manufactured chemicals primarily used in firefighting materials. Like PBDEs, PBBs are classified as persistent organic pollutants; however, their environmental impacts are not well understood. Although it is not definitively known whether PBBs can cause cancer in human beings, cancer in lab mice exposed to very high concentrations has been observed. As a result of these animal tests, the United States Department of Health and Human Services has concluded that PBBs might reasonably be characterized as carcinogens (Wang, 2009). The application of PBB in firefighting materials is now controlled as a hazardous substance (Safe, 1984).

BFR analyses were performed by TDI-Brooks International Inc. following procedures used by the NOAA NS&T Program (Kimbrough et al., 2007). PBDEs and PBBs were kept separate in this report (Table 13, Table 14).

No PBBs were detected in either mussel tissue or sediment in this study, so these results were not displayed.

Table 13. PBB compounds tested (19).

Chemical Code	Chemical Name
PBB 1	PBB 1 (2-MonoBB)
PBB 2	PBB 2 (3-MonoBB)
PBB 3	PBB 3 (4-MonoBB)
PBB 4	PBB 4 (2,2'-DiBB)
PBB 7	PBB 7 (2,4-DiBB)
PBB 9	PBB 9 (2,5-DiBB)
PBB 10	PBB 10 (2,6-DiBB)
PBB 15	PBB 15 (4,4'-DiBB)
PBB 18	PBB 18 (2,2',5-TriBB)
PBB 26	PBB 26 (2,3',5-TriBB)
PBB 30	PBB 30 (2,4,6-TriBB)
PBB 31	PBB 31 (2,4',5-TriBB)
PBB 49	PBB 49 (2,2',4,5'-TetraBB)
PBB 52	PBB 52 (2,2',5,5'-TetraBB)
PBB 53	PBB 53 (2,2',5,6'-TetraBB)
PBB 77	PBB 77 (3,3',4,4'-TetraBB)
PBB 80	PBB 80 (3,3',5,5'-TetraBB)
PBB 103	PBB 103 (2,2',4,5',6-PentaBB)
PBB 155	PBB 155 (2,2',4,4',6,6'-HexaBB)

Results - BFRs

Table 14. PBDE compounds tested (51).

Chemical Code	Chemical Name
PBDE-1	BDE 1 (2-MonoBDE)
PBDE-2	BDE 2 (3-MonoBDE)
PBDE-3	BDE 3 (4-MonoBDE)
PBDE-7	BDE 7 (2,4-DiBDE)
PBDE-8	BDE 8 (2,4'-DiBDE)
PBDE-10	BDE 10 (2,6-DiBDE)
PBDE-11	BDE 11 (3,3'-DiBDE)
PBDE-12	BDE 12 (3,4-DiBDE)
PBDE-13	BDE 13 (3,4'-DiBDE)
PBDE-15	BDE 15 (4,4'-DiBDE)
PBDE-17	BDE 17 (2,2',4-TriBDE)
PBDE-25	BDE 25 (2,3',4-TriBDE)
PBDE-28	BDE 28 (2,4,4'-TriBDE)
PBDE-30	BDE 30 (2,4,6-TriBDE)
PBDE-32	BDE 32 (2,4',6-TriBDE)
PBDE-33	BDE 33 (2',3,4-TriBDE)
PBDE-35	BDE 35 (3,3',4-TriBDE)
PBDE-37	BDE 37 (3,4,4'-TriBDE)
PBDE-47	BDE 47 (2,2',4,4'-TetraBDE)
PBDE-66	BDE 66 (2,3',4,4'-TetraBDE)
PBDE-71_49	BDE 49/71 (2,2',4,5'-TetraBDE/ 2,3',4',6-TetraPDE)
PBDE-75	BDE 75 (2,4,4',6-TetraBDE)
PBDE-77	BDE 77 (3,3',4,4'-TetraBDE)
PBDE-85	BDE 85 (2,2',3,4,4'-PentaBDE)
PBDE-99	BDE 99 (2,2',4,4',5-PentaBDE)

Chemical Code	Chemical Name
PBDE-100	BDE 100 (2,2',4,4',6-PentaBDE)
PBDE-116	BDE 116 (2,3,4,5,6-PentaBDE)
PBDE-118	BDE 118 (2,3',4,4',5-PentaBDE)
PBDE-119	BDE 119 (2,3',4,4',6-PentaBDE)
PBDE-126	BDE 126 (3,3',4,4',5-PentaBDE)
PBDE-138	BDE 138 (2,2',3,4,4',5'-HexaBDE)
PBDE-153	BDE 153 (2,2',4,4',5,5'-HexaBDE)
PBDE-154	BDE 154 (2,2',4,4',5,6'-HexaBDE)
PBDE-155	BDE 155 (2,2',4,4',6,6'-HexaBDE)
PBDE-166	BDE 166 (2,3,4,4',5,6-HexaBDE)
PBDE-181	BDE 181 (2,2',3,4,4',5,6-HeptaBDE)
PBDE-183	BDE 183 (2,2',3,4,4',5',6-HeptaBDE)
PBDE-190	BDE 190 (2,3,3',4,4',5,6-HeptaBDE)
PBDE-194	BDE 194 (2,2',3,3',4,4',5,5'-OctaBDE)
PBDE-195	BDE 195 (2,2',3,3',4,4',5,6-OctaBDE)
PBDE-196	BDE 196 (2,2',3,3',4,4',5,6'-OctaBDE)
PBDE-197	BDE 197 (2,2',3,3',4,4',6,6'-OctaBDE)
PBDE-198_199_203_200	BDE 198/199/203/200 (OctaBDE)
PBDE-201	BDE 201 (2,2',3,3',4,5',6,6'-OctaBDE)
PBDE-202	BDE 202 (2,2',3,3',5,5',6,6'-OctaBDE)
PBDE-204	BDE 204 (2,2',3,4,4',5,6,6'-OctaBDE)
PBDE-205	BDE 205 (2,3,3',4,4',5,5',6-OctaBDE)
PBDE-206	BDE 206 (2,2',3,3',4,4',5,5',6-NonaBDE)
PBDE-207	BDE 207 (2,2',3,3',4,4',5,6,6'-NonaBDE)
PBDE-208	BDE 208 (2,2',3,3',4,5,5',6,6-NonaBDE)
PBDE-209	BDE 209 (2,2',3,3',4,4',5,5',6,6'-DecaBDE)

6.2 Presence, Distribution, and Contamination Level of BFRs in Mussel Tissue

NUMBER OF COMPOUNDS DETECTED:
20 / 51

NUMBER OF SITES WITH DETECTS:
16 / 34

MOST DETECTED COMPOUNDS:
PBDE-47, PBDE-99

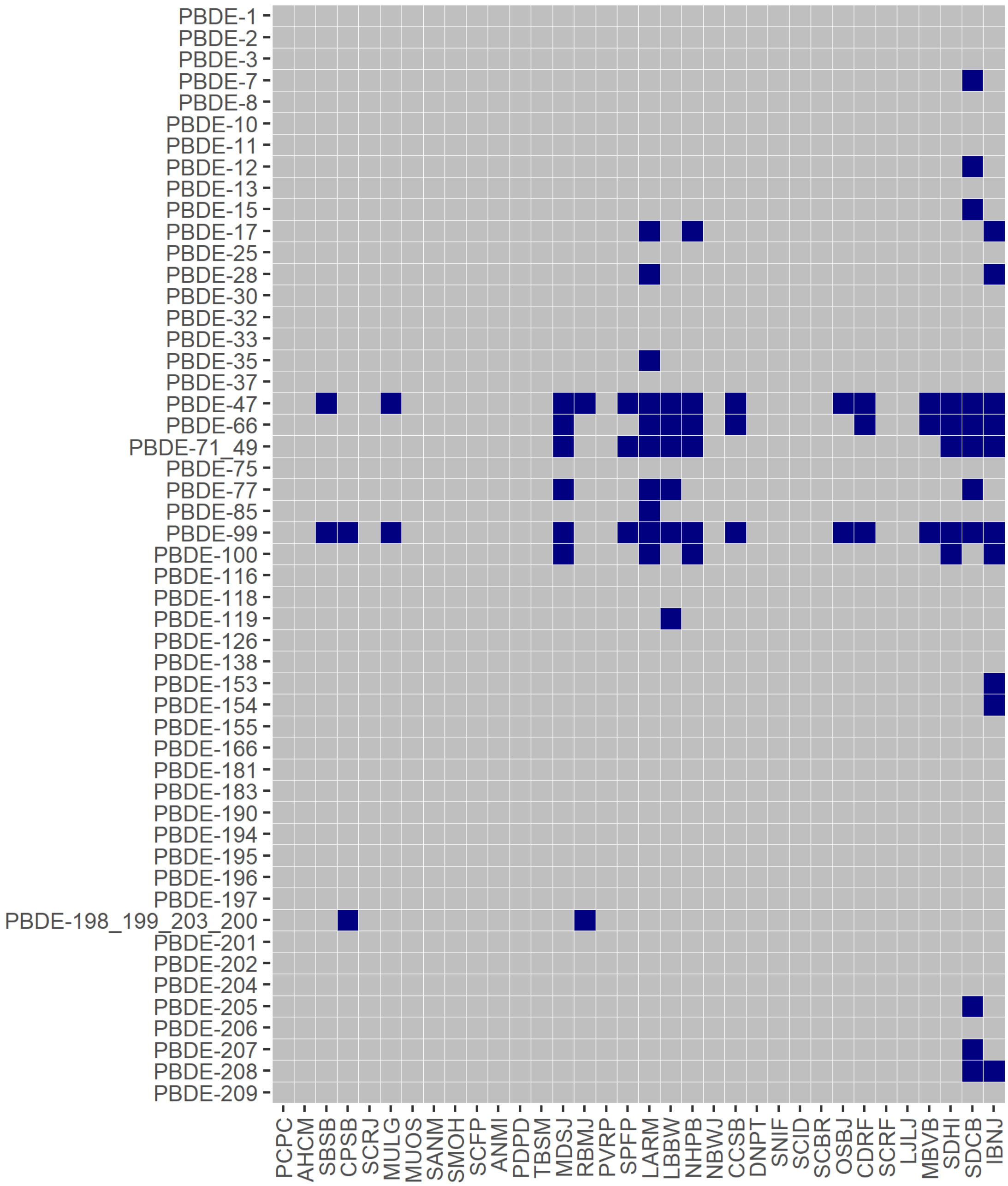


Figure 13. Distribution map showing presence ( ) and absence ( ) of PBDE compounds measured in mussel tissues in the Southern California Bight. Sites are listed geographically from north to south, following the coastline.

Table 15. Coastwide frequency of PBDE compound detection in mussel tissue when compound was detected at least once.

Compound	# Detects	# Sites Sampled	Frequency (%)
PBDE-47	15	34	44.1
PBDE-99	15	34	44.1
PBDE-66	10	34	29.4
PBDE-71_49	8	34	23.5
PBDE-100	5	34	14.7
PBDE-77	4	34	11.8
PBDE-17	3	34	8.8
PBDE-198_199_203_200	2	34	5.9
PBDE-208	2	34	5.9
PBDE-28	2	34	5.9
PBDE-119	1	34	2.9
PBDE-12	1	34	2.9
PBDE-15	1	34	2.9
PBDE-153	1	34	2.9
PBDE-154	1	34	2.9
PBDE-205	1	34	2.9
PBDE-207	1	34	2.9
PBDE-35	1	34	2.9
PBDE-7	1	34	2.9
PBDE-85	1	34	2.9

Table 16. Number of PBDE compound detects in mussel tissue at each site when at least one compound was detected.

Site	# Detects	# Compounds Analyzed	Frequency (%)
SDCB	11	51	21.6
IBNJ	10	51	19.6
LARM	10	51	19.6
LBBW	6	51	11.8
MDSJ	6	51	11.8
NHPB	6	51	11.8
SDHI	5	51	9.8
CCSB	3	51	5.9
CDRF	3	51	5.9
MBVB	3	51	5.9
SPFP	3	51	5.9
CPSB	2	51	3.9
MULG	2	51	3.9
OSBJ	2	51	3.9
RBMJ	2	51	3.9
SBSB	2	51	3.9

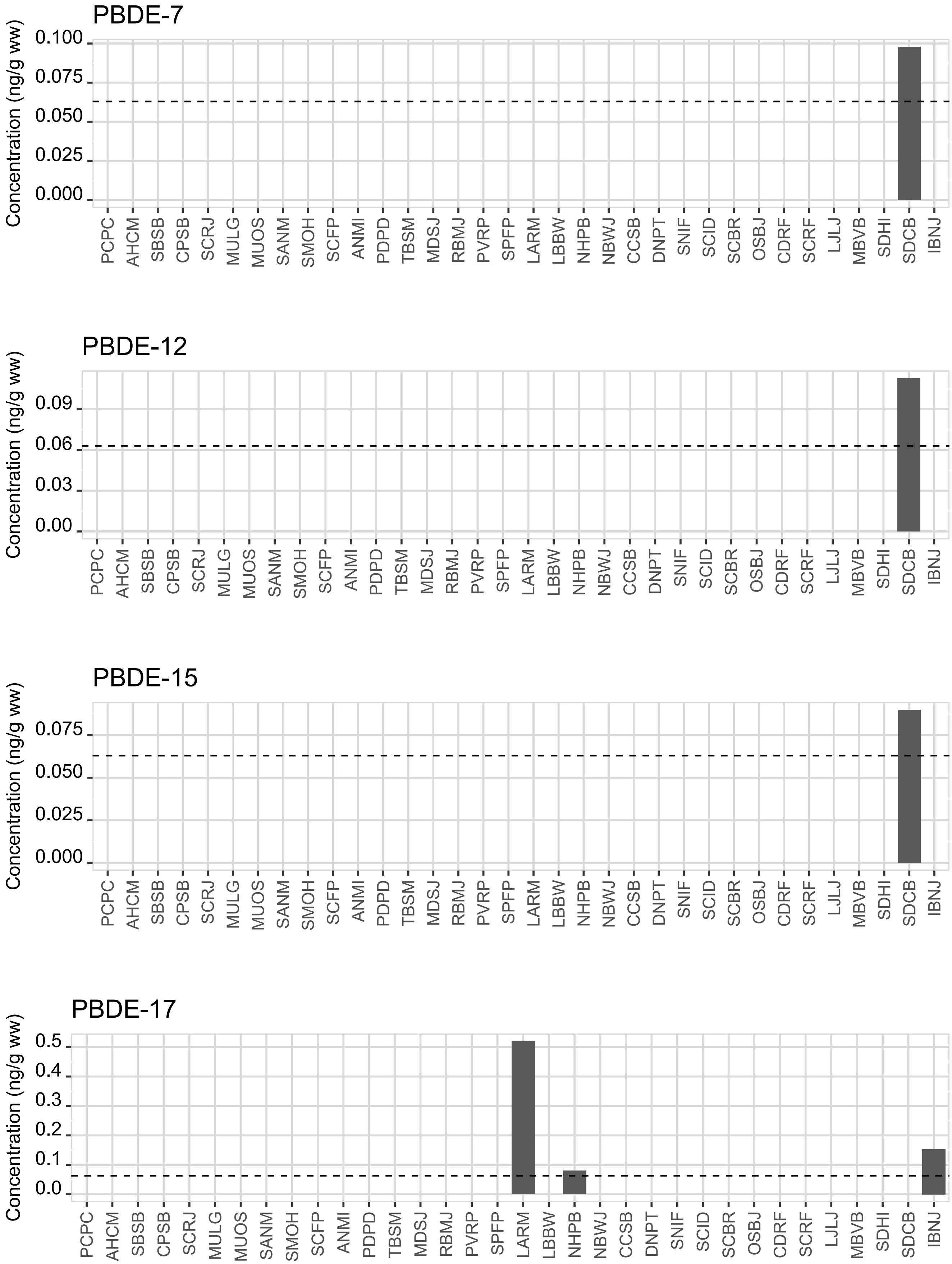


Figure 14. Bar graph showing magnitude of PBDE compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.

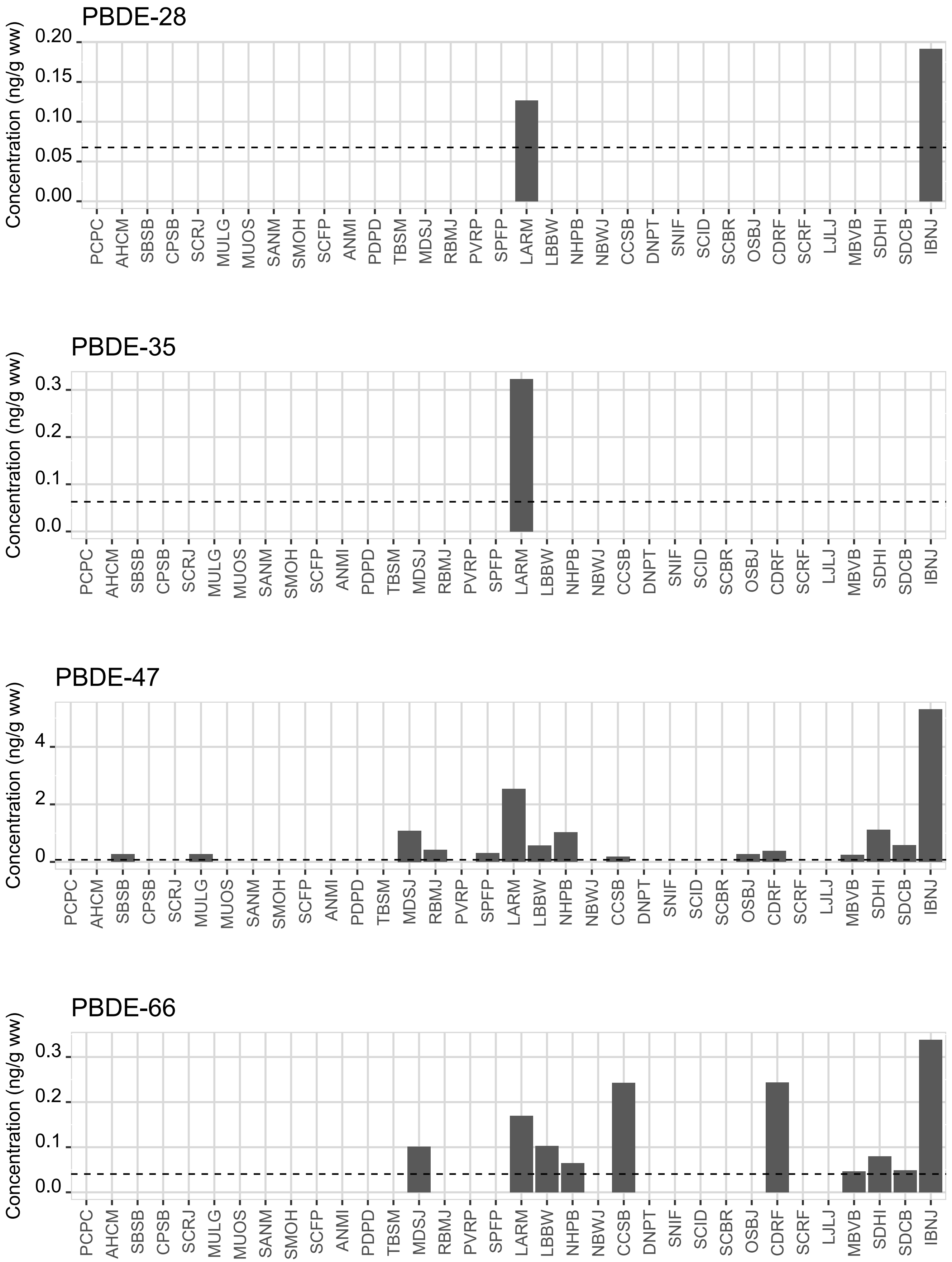


Figure 14 cont. Bar graph showing magnitude of PBDE compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.

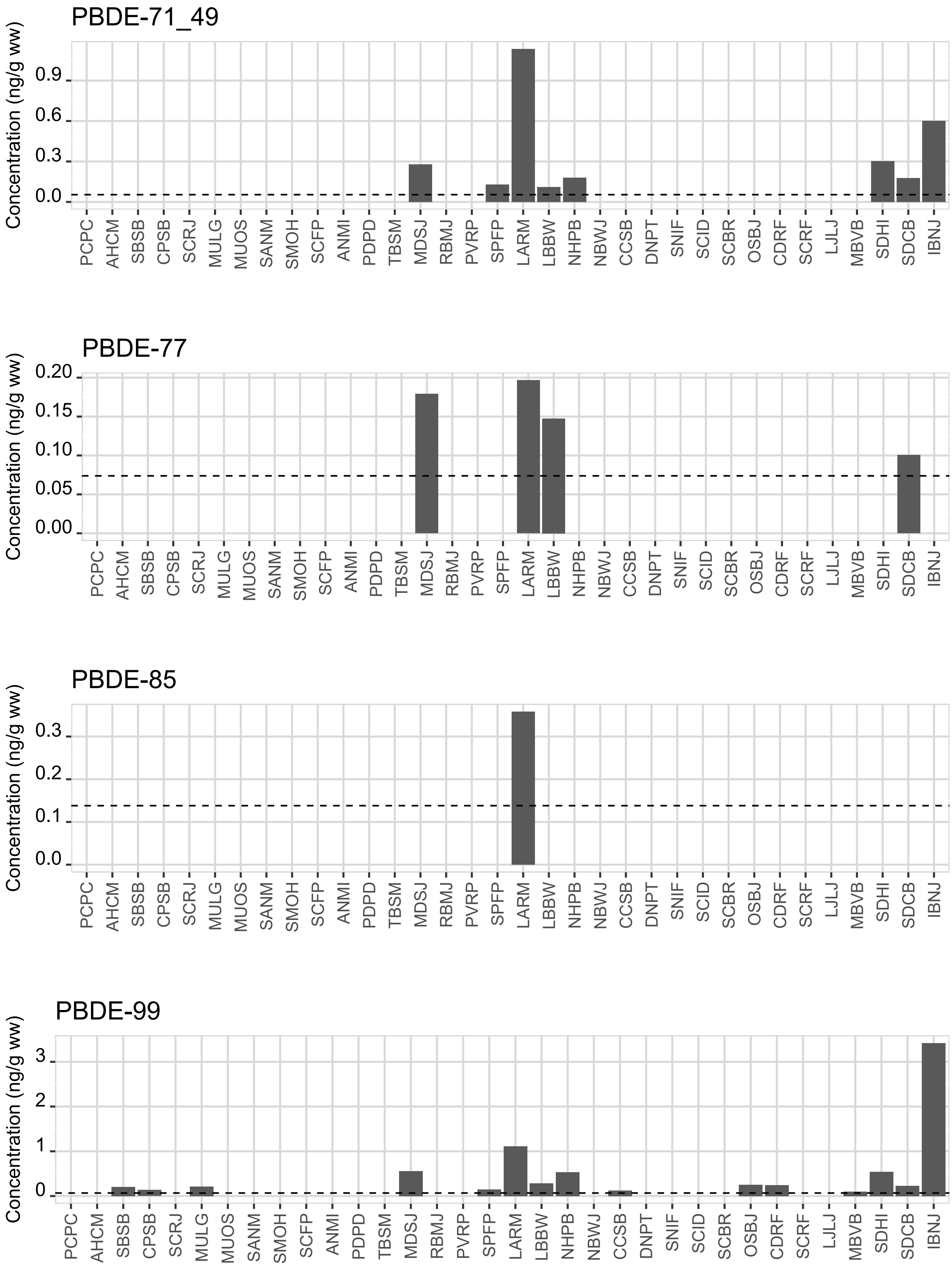
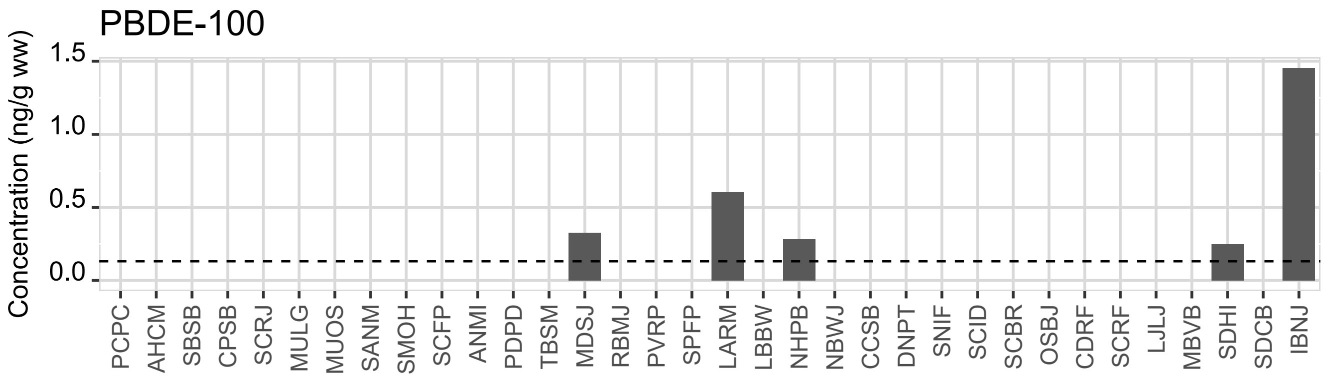
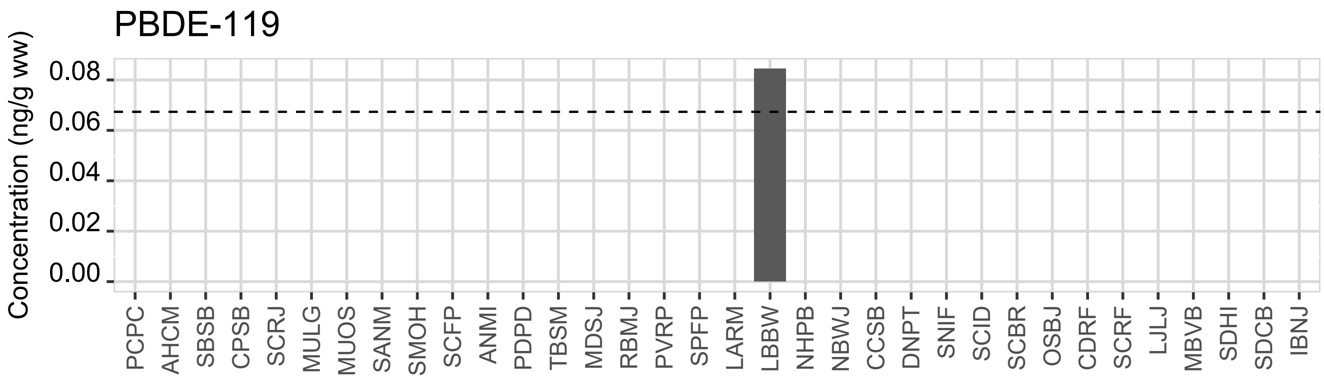
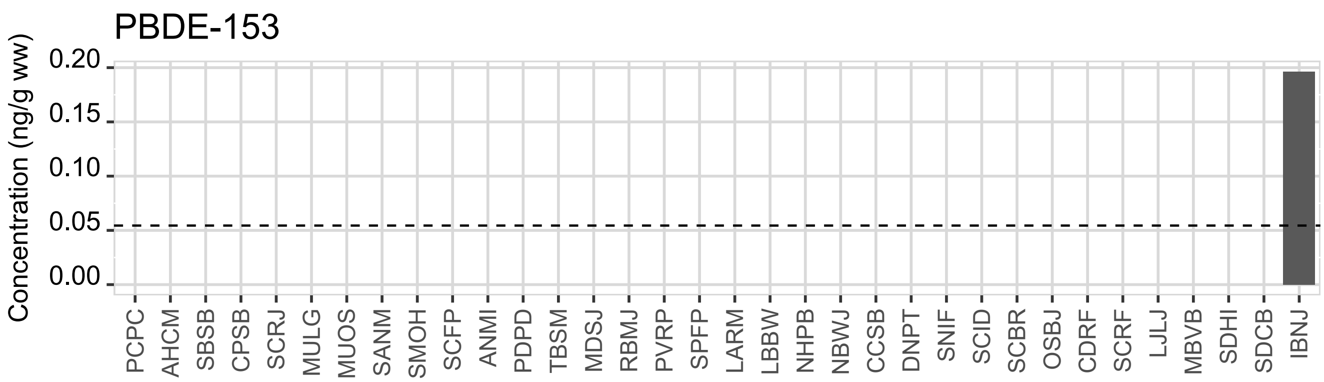


Figure 14 cont. Bar graph showing magnitude of PBDE compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.







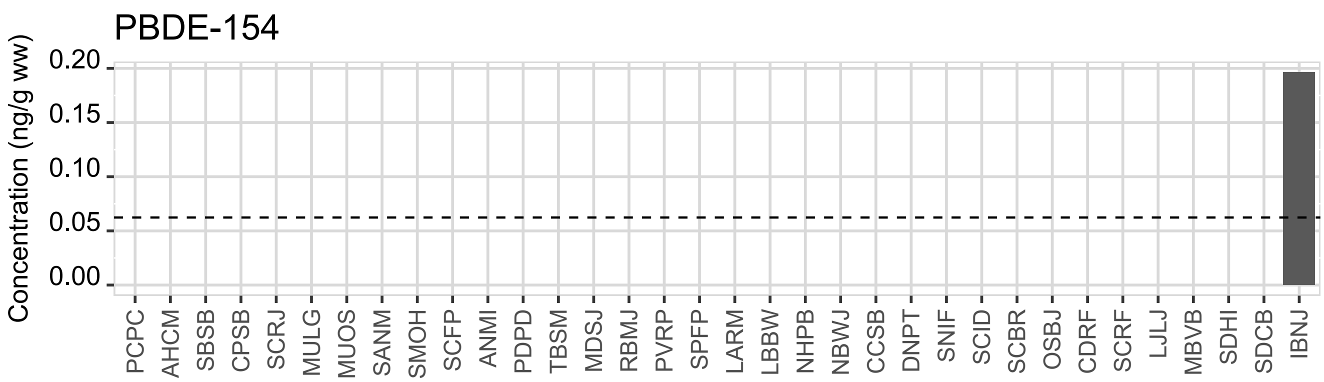


Figure 14 cont. Bar graph showing magnitude of PBDE compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.

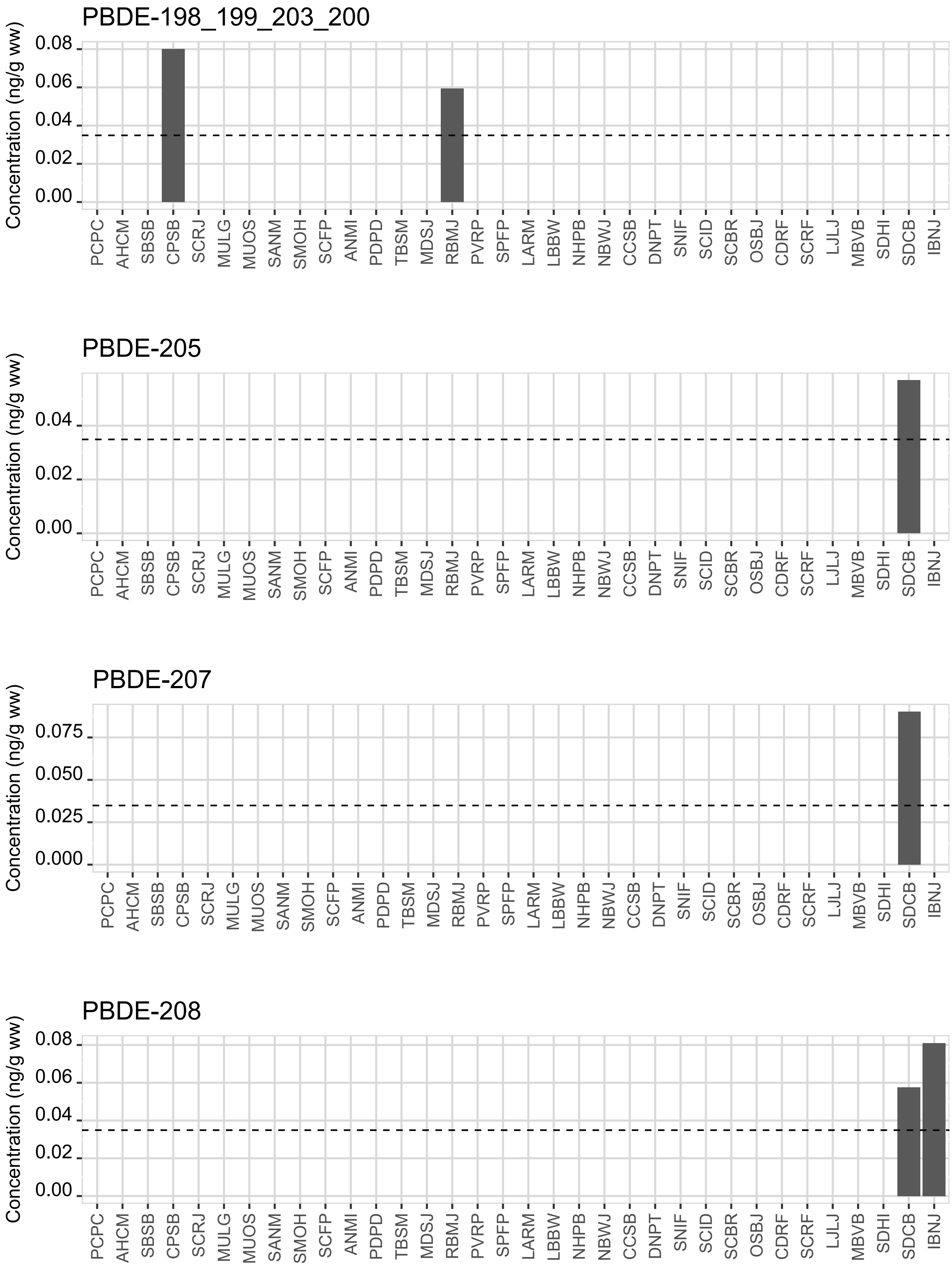


Figure 14 cont. Bar graph showing magnitude of PBDE compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.

6.3 Presence, Distribution, and Contamination Level of BFRs in Sediment

NUMBER OF COMPOUNDS DETECTED:
15 / 51

NUMBER OF SITES WITH DETECTS:
10 / 10

MOST DETECTED COMPOUNDS:
PBDE-206, PBDE-207

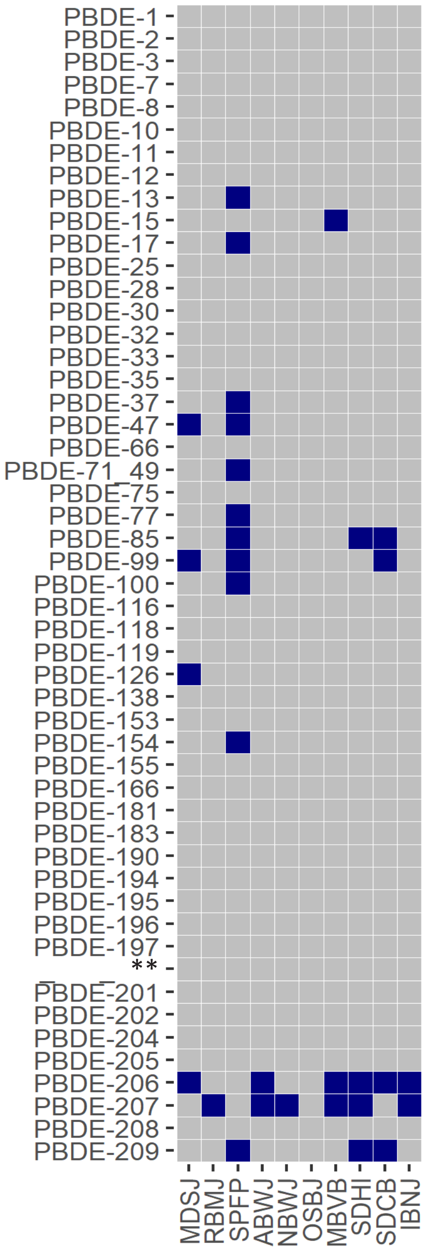


Figure 15. Distribution map showing presence ( ) and absence ( ) of PBDE compounds measured in sediment in the Southern California Bight. Sites are listed geographically from north to south, following the coastline.

*Compound indicated by ** is PBDE-198_199_203_200.*

Table 17. Coastwide frequency of PBDE compound detection in sediment when compound was detected at least once.

Compound	# Detects	# Sites Sampled	Freq (%)
PBDE-206	6	10	60.0
PBDE-207	6	10	60.0
PBDE-209	3	10	30.0
PBDE-85	3	10	30.0
PBDE-99	3	10	30.0
PBDE-47	2	10	20.0
PBDE-100	1	10	10.0
PBDE-126	1	10	10.0
PBDE-13	1	10	10.0
PBDE-15	1	10	10.0
PBDE-154	1	10	10.0
PBDE-17	1	10	10.0
PBDE-37	1	10	10.0
PBDE-71_49	1	10	10.0
PBDE-77	1	10	10.0

Table 18. Number of PBDE compound detects in sediment at each site when at least one compound was detected.

Site	# Detects	# Compounds Analyzed	Freq (%)
SPFP	11	51	21.6
MDSJ	4	51	7.8
SDCB	4	51	7.8
SDHI	4	51	7.8
MBVB	3	51	5.9
ABWJ	2	51	3.9
IBNJ	2	51	3.9
NBWJ	1	51	2.0
RBMJ	1	51	2.0

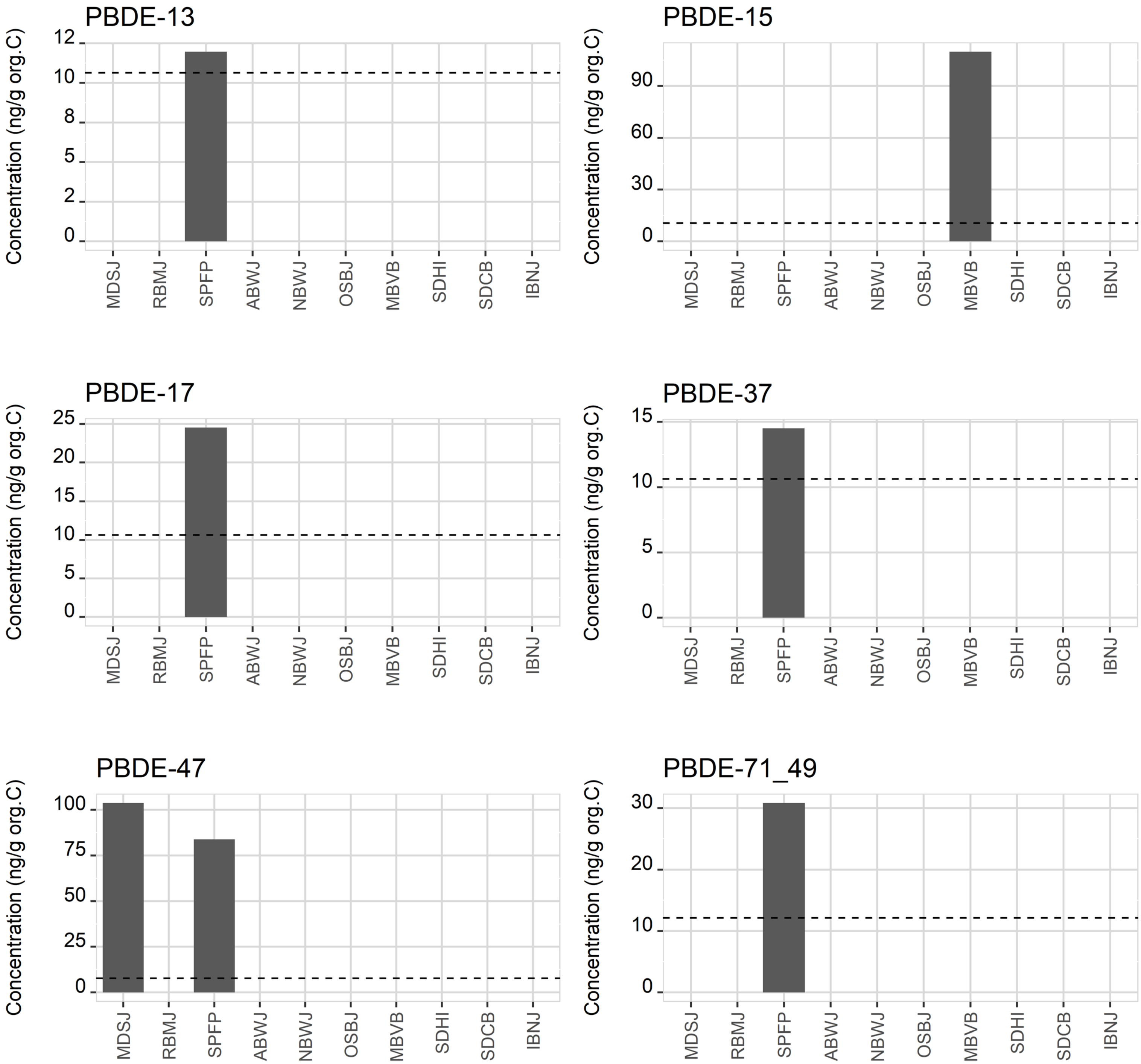


Figure 16. Bar graph showing magnitude of PBDE compounds detected in sediment in the Southern California Bight. Dotted line represents the minimum TOC corrected detection limit. Sites are listed geographically from north to south, following the coastline.

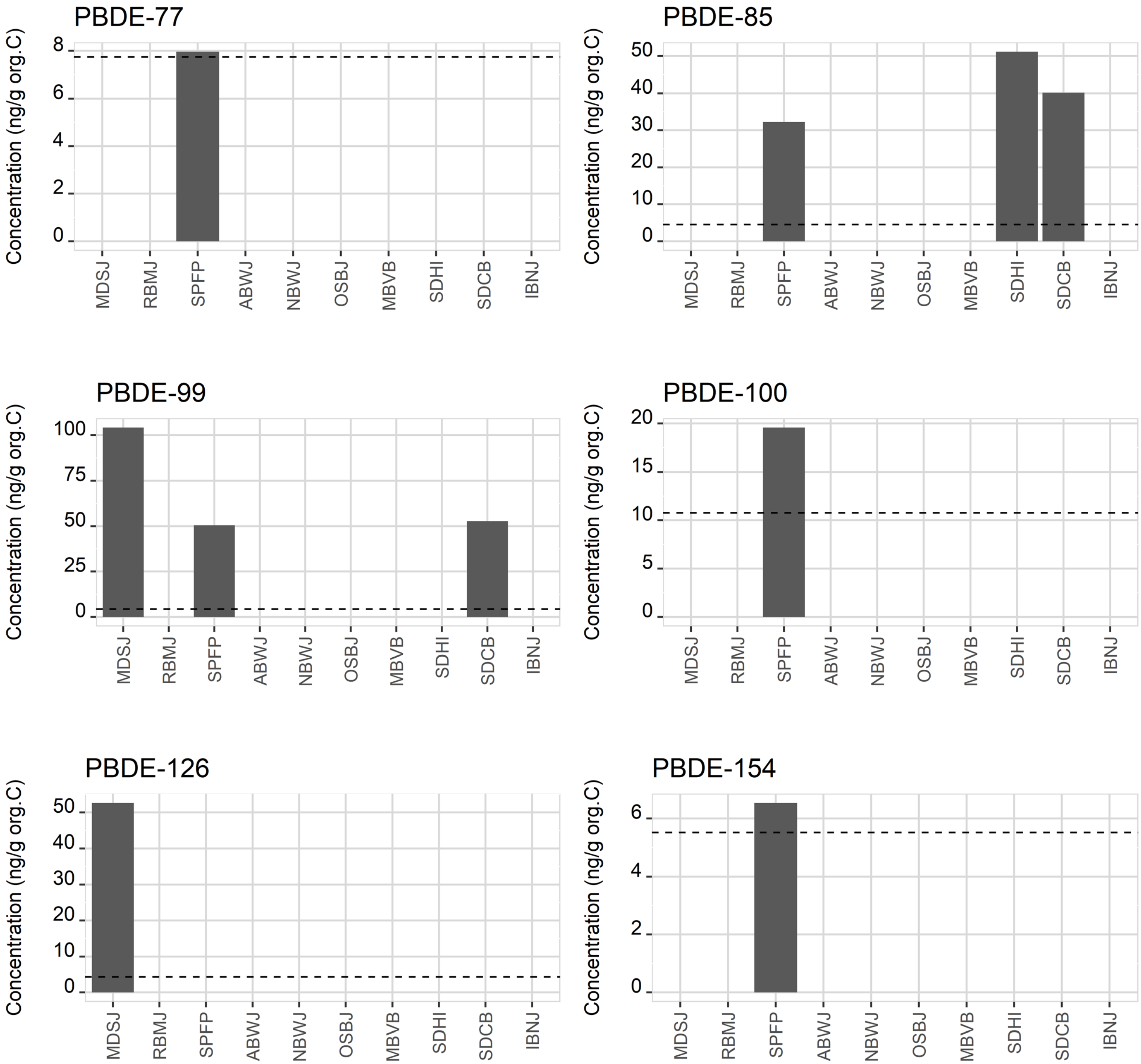


Figure 16 cont. Bar graph showing magnitude of PBDE compounds detected in sediment in the Southern California Bight. Dotted line represents the minimum TOC corrected detection limit. Sites are listed geographically from north to south, following the coastline.

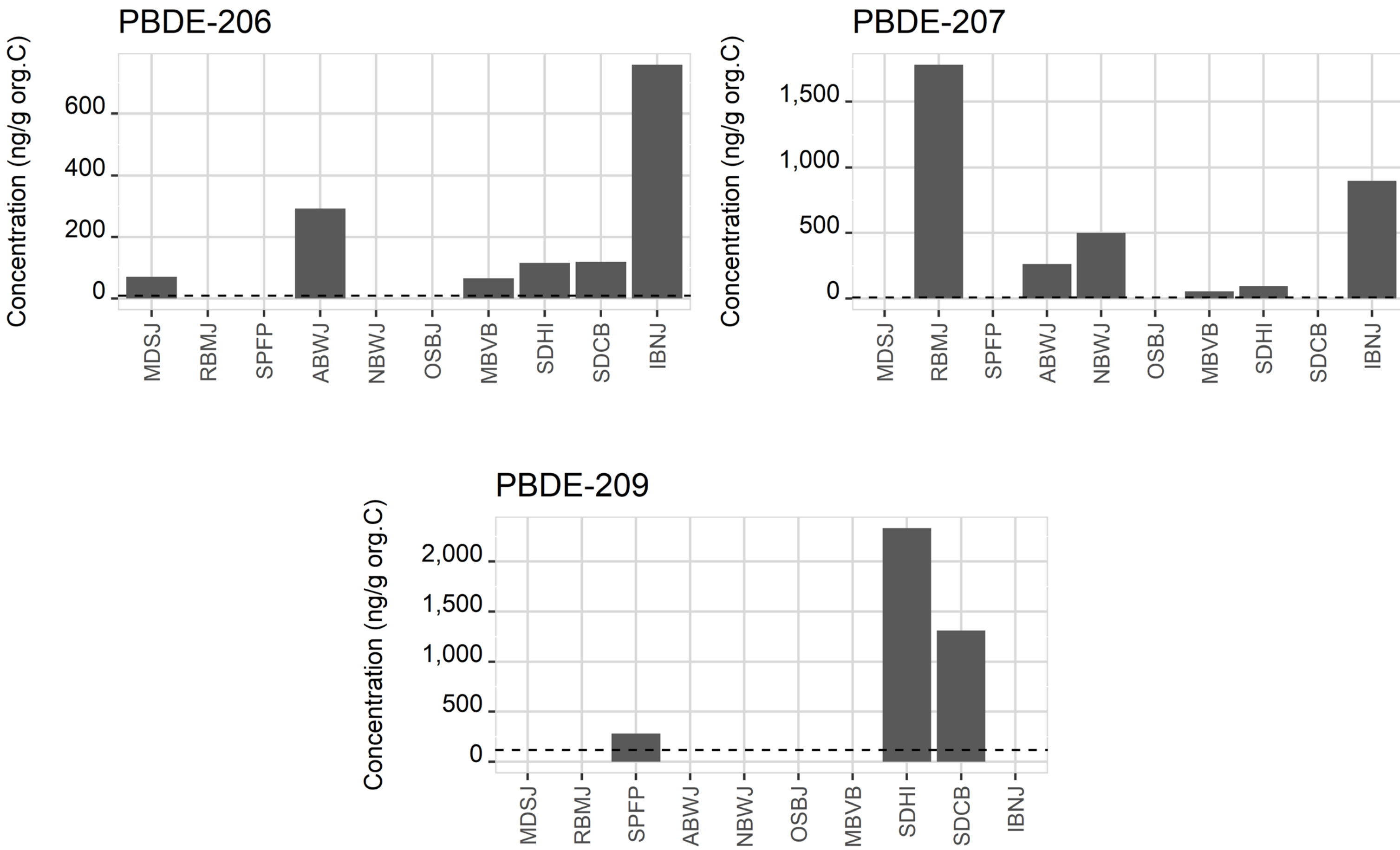


Figure 16 cont. Bar graph showing magnitude of PBDE compounds detected in sediment in the Southern California Bight. Dotted line represents the minimum TOC corrected detection limit. Sites are listed geographically from north to south, following the coastline.

6.4 BFRs Results Summary

Mussel Tissue

- BFRs were analyzed at 34 out of 34 tissue sites
- No PBB compounds were detected
- 20/51 PBDE compounds were detected at least once
- PBDE-47 and PBDE-99 were the most commonly detected PBDE compounds with frequencies of 44.1%
- Minimum concentration detected was 0.05 ng/g ww of PBDE-66 at site MBVB
- Maximum concentration detected was 5.31 ng/g ww of PBDE-47 at site IBNJ
- Overall, PBDEs were detected 76/1734 possible times (51 compounds x 34 sites) for an overall 4.4% frequency of detection in the Southern California Bight

Sediment

- BFRs were analyzed at 10 out of 10 sediment sites
- No PBB compounds were detected
- 15/51 PBDE compounds were detected at least once
- PBDE-206 and PBDE-207 were the most commonly detected PBDE compounds with frequencies of 60.0%
- Minimum concentration detected was 6.53 ng/g organic Carbon of PBDE-154 at site SPFP
- Maximum concentration detected was 2,331.42 ng/g organic Carbon of PBDE-209 at site SDHI
- Overall, PBDEs were detected 32/510 possible times (51 compounds x 10 sites) for an overall 6.3% frequency of detection in the Southern California Bight

General Observations

- BFRs in mussel tissue were widely distributed within the Southern California Bight
- BFR detection in mussel tissue is mostly consistent with BFR detection in sediment (with the exception of site OSBJ)
- BFRs were not detected on the offshore islands or in areas with lower population densities

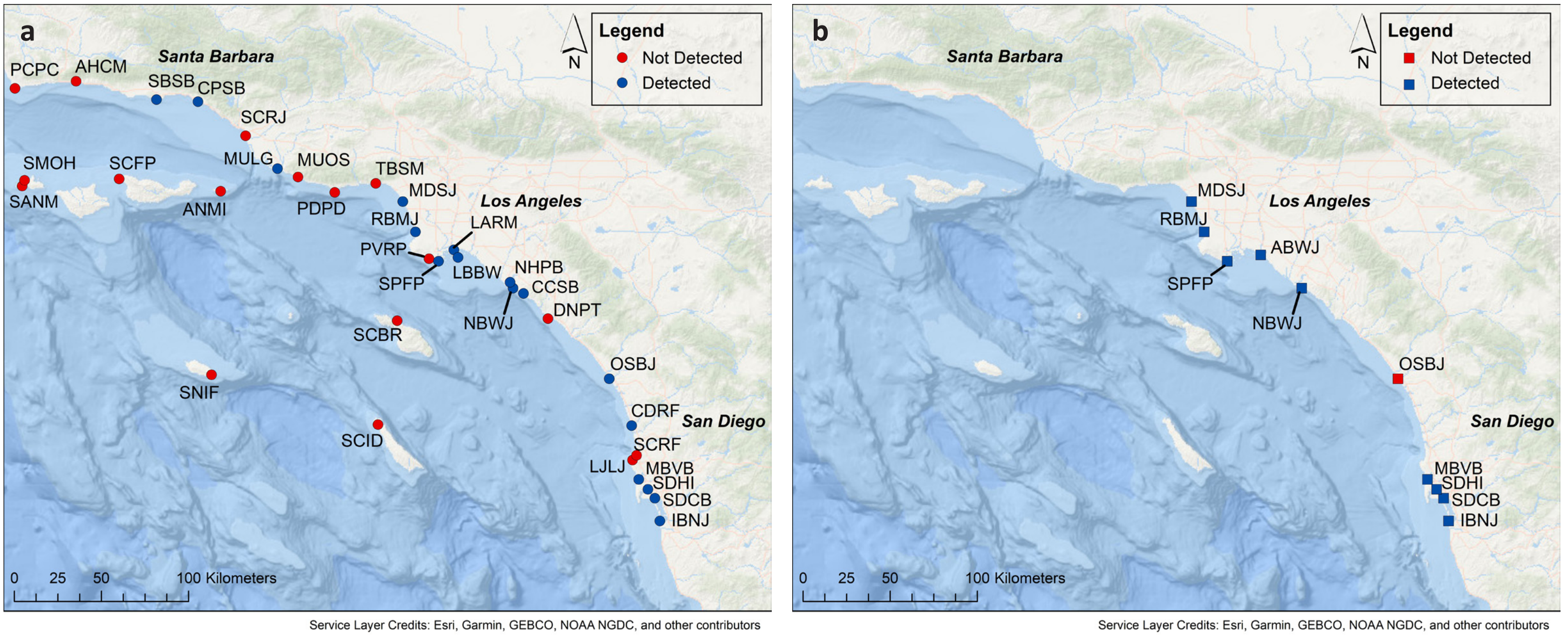


Figure 17. Map of Mussel Watch sites in the Southern California Bight highlighting locations of sites with PBDE compounds detected in (a) mussel tissue and (b) sediment. Maps of PBB compounds are not depicted as no compounds were detected coast wide in mussel tissue or sediment.

7.0 RESULTS - CURRENT USE PESTICIDES (CUPs)

7.1 CUPs Chemical Description

Primary examples of current-use pesticides (CUPs) include organophosphates, neonicotinoids, pyrethroids, n-methyl carbamates, and insect growth regulator hormones. CUPs are generally a group of semi-volatile chemicals that span multiple chemical classes and can be analyzed concurrently. In this report, CUP chemicals include pesticides and their associated degradation products. These pesticides are typically more water-soluble than legacy organochlorine pesticides, such as DDT and chlordane, and often do not bioaccumulate in organisms. It has been estimated that in 2007, over 565 million kg of current-use pesticides were used in the USA (EPA, 2011). Among pesticides, herbicides accounted for 40% of total usage and insecticides accounted for 17% (EPA, 2011). While agricultural application accounts for over 60% of pesticides used, urban usage is increasing (EPA, 2011). Pesticides enter the environment seasonally through surface run-off, pesticide drift, direct discharge, and atmospheric long-range transport (USGS, 1999; Federighi, 2008). The list of CUP chemicals measured in this study is limited by available analytical methods (Table 19). Out of the CUP compounds tested, Ametryn, Phorate, and Terbufos data were flagged by the lab as Non-Quantifiable for all tissue analyses and Diazinon Oxon data was flagged as non-quantifiable for all sediment analyses, so are not included in this report.

CUP analyses were conducted by SGS AXYS Analytical Services LTD. The analytical method used was MLA-035 Rev 07.

Table 19. CUP compounds tested (33).

Chemical Name	Application
Ametryn	Herbicide (control broadleaf and grass weeds in corn, pineapple, and sugarcane fields)
Atrazine	Herbicide (control pre- and postemergence broadleaf weeds in crops)
Azinphos-Methyl	Broad spectrum organophosphate acetylcholinesterase inhibitor insecticide
Captan	Fungicide
Chlorothalonil	Broad spectrum non-systemic fungicide
Cyanazine	Herbicide
Cypermethrin	Insecticide (used in large-scale commercial agricultural applications)
Dacthal	Pre-emergent herbicide (used to kill grass and many common weeds)
Desethylatrazine	Herbicide (breakdown product of atrazine)
Diazinon	Nonsystemic organophosphate insecticide (control cockroaches, silverfish, ants, and fleas)
Diazinon-Oxon	Nonsystemic organophosphate insecticide (control cockroaches, silverfish, ants, and fleas)
Dimethoate	Organophosphate acetylcholinesterase inhibitor (used as an insecticide and acaricide)
Disulfoton	Organophosphate acetylcholinesterase inhibitor (used as an insecticide)
Disulfoton Sulfone	Organophosphate acetylcholinesterase inhibitor (used as an insecticide)
Ethion	Organophosphate insecticide
Fenitrothion	Phosphorothioate (organophosphate) insecticide
Fonofos	Organothiophosphate insecticide (primarily used on corn)
Hexazinone	Organic compound (used as a broad spectrum herbicide)
Malathion	Pesticide (widely used in agriculture and residential landscaping)
Methoxychlor	Insecticide (used to protect crops, ornamentals, livestock, and pets)
Metribuzin	Herbicide (used pre- and post-emergence in crops (soy bean, potatoes, tomatoes sugarcane))
Octachlorostyrene	By-product of industrial chemical processes (PVC recycling, Al refining, solvent degreasing)
Parathion-Ethyl	Organothiophosphate insecticide (known as "Folidol")
Parathion-Methyl	Insecticide (used on crops (*e.g.,* cotton))
Permethrin	Medication and insecticide (treat scabies and lice; sprayed on clothing or mosquito nets)
Perthane	Insecticide
Phorate	Insecticide (control chewing insects, leafhoppers, mites, nematodes, and rootworms)
Phosmet	Non-systemic organophosphate insecticide (used on plants and animals)
Pirimiphos-Methyl	Phosphorothioate (used as an insecticide)
Quintozene	Fungicide
Simazine	Herbicide of the triazine class (used to control broad-leaved weeds and annual grasses)
Tecnazene	Fungicide
Terbufos	Insecticide and nematicide (used on corn, sugar beets, and grain sorghum)

7.2 Presence, Distribution, and Contamination Level of CUPs in Mussel Tissue

NUMBER OF COMPOUNDS DETECTED:
1 / 30

NUMBER OF SITES WITH DETECTS:
2 / 33

MOST DETECTED COMPOUND:
Dacthal

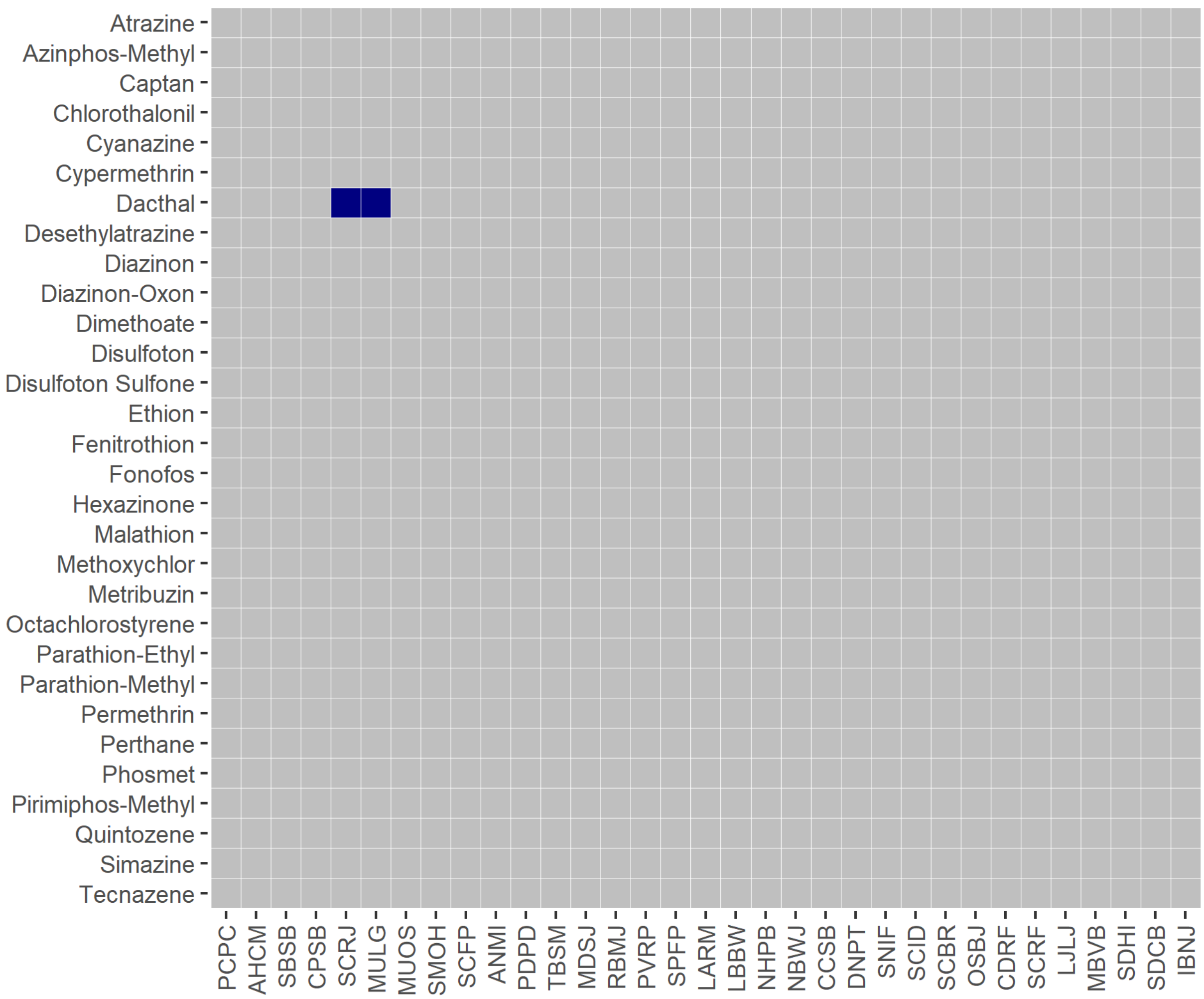


Figure 18. Distribution map showing presence ( ) and absence ( ) of MRES compounds measured in mussel tissues in the Southern California Bight. Sites are listed geographically from north to south, following the coastline.

Table 20. Coastwide frequency of MRES compound detection in mussel tissue when compound was detected at least once.

Compound	# Detects	# Sites Sampled	Frequency (%)
Dacthal	2	33	6.1

Table 21. Number of MRES compound detects in mussel tissue at each site when at least one compound was detected.

Site	# Detects	# Compounds Analyzed	Frequency (%)
SCRJ	1	33	3.0
MULG	1	33	3.0

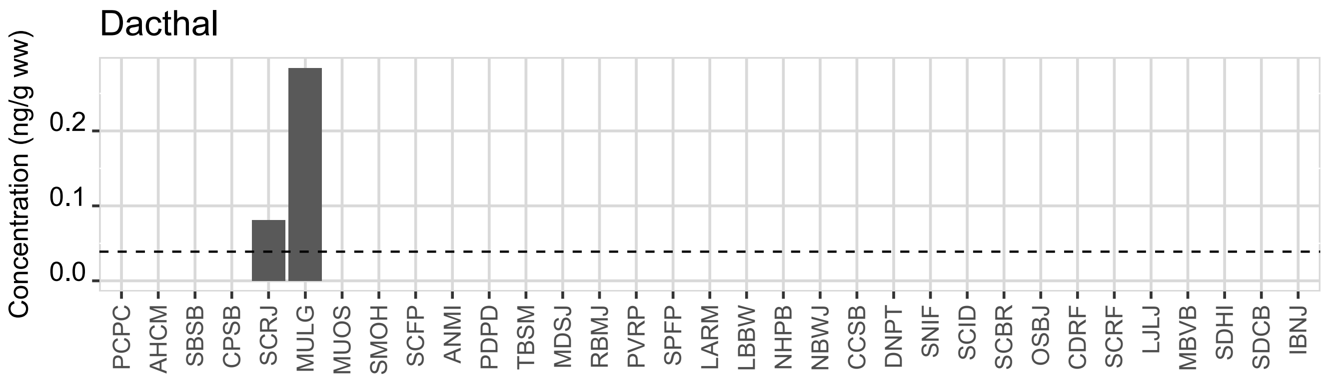


Figure 19. Bar graph showing magnitude of CUP compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.

7.3 Presence, Distribution, and Contamination Level of CUPs in Sediment

NUMBER OF COMPOUNDS DETECTED:
1 / 32

NUMBER OF SITES WITH DETECTS:
2 / 10

MOST DETECTED COMPOUND:
Permethrin

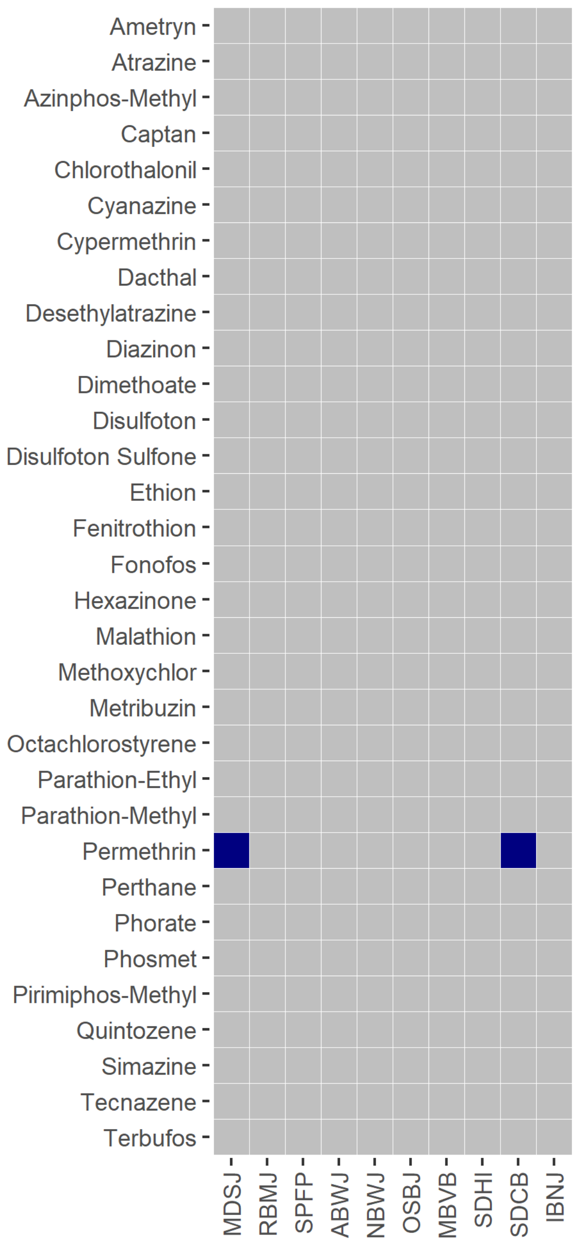


Figure 20. Distribution map showing presence ( ) and absence ( ) of MRES compounds measured in sediment in the Southern California Bight. Sites are listed geographically from north to south, following the coastline.

Table 22. Coastwide frequency of MRES compound detection in sediment when compound was detected at least once.

Compound	# Detects	# Sites Sampled	Frequency (%)
Permethrin	2	10	20.0

Table 23. Number of MRES compound detects in sediment at each site when at least one compound was detected.

Site	# Detects	# Compounds Analyzed	Frequency (%)
MDSJ	1	32	3.1
SDCB	1	32	3.1

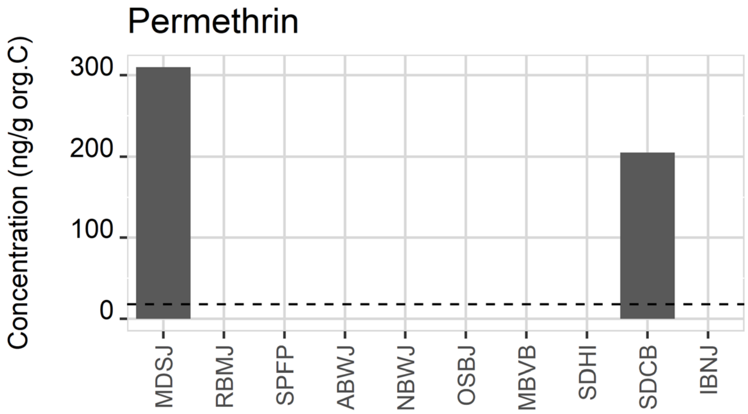


Figure 21. Bar graph showing magnitude of CUP compounds detected in sediment in the Southern California Bight. Dotted line represents the minimum TOC corrected detection limit. Sites are listed geographically from north to south, following the coastline.

7.4 CUPs Results Summary

Mussel Tissue

- CUPs were analyzed at 33 out of 34 tissue sites
  - Not analyzed at site SANM due to insufficient sample mass
- 1/30 CUP compounds were detected at least once
- Dacthal was the most commonly detected CUP compound with a frequency of 6.1%
- Minimum concentration detected was 0.08 ng/g ww of Dacthal at site SCRJ
- Maximum concentration detected was 0.28 ng/g ww of Dacthal at site MULG
- Overall, CUPs were detected 2/990 possible times (30 compounds x 33 sites) for an overall 0.2% frequency of detection in the Southern California Bight

Sediment

- CUPs were analyzed at 10 out of 10 sediment sites
- 2/35 CUP compounds were detected at least once
- Permethrin was the most commonly detected CUP compound with a frequency of 20.0%
- Minimum concentration detected was 205.24 ng/g organic Carbon of Permethrin at site SDCB
- Maximum concentration detected was 310.00 ng/g organic Carbon of Permethrin at site MDSJ
- Overall, CUPs were detected 3/320 possible times (32 compounds x 10 sites) for an overall 0.9% frequency of detection in the Southern California Bight

General Observations

- CUPs were not detected at a high proportion of sites analyzed in the Southern California Bight in both mussel tissue and sediment
- CUPs detected in sediment do not consistently match CUPs detected in mussel tissue (*e.g.,* CUPs at sites MDSJ and SDCB not detected in mussel tissue but were detected in sediments)
- Both instances of CUP detection in mussel tissue were located adjacent to two major agricultural watersheds

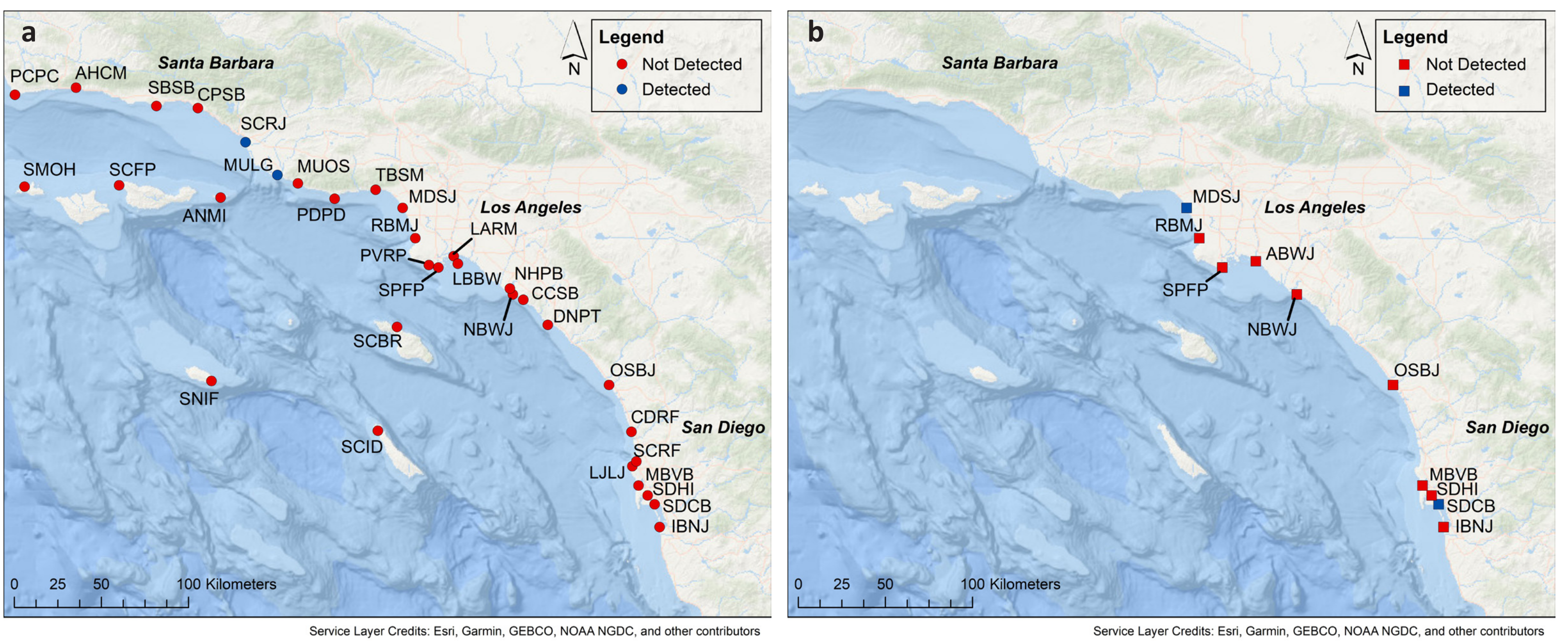


Figure 22. Map of Mussel Watch sites in the Southern California Bight highlighting locations of sites with CUP compounds detected in (a) mussel tissue and (b) sediment.

8.0 RESULTS - PER- AND POLYFLUOROALKYL SUBSTANCES (PFASs)

8.1 PFASs Chemical Description

Per- and polyfluoroalkyl substances (PFASs) are a group of fluorine-containing compounds used in industrial processes related to surface protection/coatings, fire-fighting foam, insecticides, and commercial polymer manufacturing. Typically, PFASs enter the aquatic environment through aqueous effluent from fire training/fire response sites, industrial sites, wastewater treatment plants, and runoff from the land application of contaminated biosolids (ATSDR, 2018). This class of chemicals appears to accumulate in the environment and, because of their widespread use, they are becoming ubiquitous in sediment and tissue samples in coastal habitats (Chen et al., 2012; CDC, 2018). When they are taken up by organisms, PFASs are suspected to be endocrine disruptors and can cause developmental problems in animals (Grun and Blumberg, 2009). Perfluorooctane sulfonic acid (PFOS) is one of the most toxic PFAS contaminants, according to available toxicological data. It has been linked to liver damage, cancer, and immune system suppression in humans (CDC, 2018). Thus, this class of CECs has garnered increasing interest in the past 10-15 years. While the manufacturing of PFOS and PFOA has been phased out in the US, the EPA and several states have started developing health-based guidelines for PFOS and PFOA in drinking water (Corder et al., 2018). There are thousands of PFAS pollutants, but only a few are becoming more routinely monitored in the environment. The MWP program measures 33 PFASs (Table 24) which are considered toxic and for which methodologies are well developed.

PFAS analyses were conducted by SGS AXYS Analytical Services LTD. The analytical method used was MLA-110 Rev 02.

Table 24. PFAS compounds tested (33).

Chemical Code	Chemical Name
11Cl-PF3OUdS	11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid
4-2 FTS	4:2 Fluorotelomer sulfonic acid
6-2 FTS	6:2 Fluorotelomer sulfonic acid
8-2 FTS	8:2 Fluorotelomer sulfonic acid
9Cl-PF3ONS	Perfluoro(2-((6-chlorohexyl)oxy)ethanesulfonic acid)
ADONA	Trade name for 4,8-dioxa-3H-perfluorononanoate
EtFOSAA	Ethylperfluorooctane sulfonamidoacetic acid
HFPO-DA	Hexafluoropropylene oxide-dimer acid
MeFOSAA	Methylperfluorooctane sulfonamidoacetic acid
N-EtFOSA	N-ethyl perfluorooctane sulfonamide
N-EtFOSE	N-ethyl perfluorooctane sulfonamido ethanol
N-MeFOSA	N-methyl perfluorooctane sulfonamide
N-MeFOSE	N-methyl perfluorooctane sulfonamido ethanol
PFBA	Perfluorobutanoic acid
PFBS	Perfluorobutane sulfonic acid
PFDA	Perfluorodecanoic acid
PFDoA	Perfluorododecanoic acid
PFDoS	Perfluorododecane sulfonic acid
PFDS	Perfluorodecane sulfonic acid
PFHpA	Perfluoroheptanoic acid
PFHpS	Perfluoroheptane sulfonic acid
PFHxA	Perfluorohexanoic acid
PFHxS	Perfluorohexane sulfonic acid
PFNA	Perfluorononanoic acid
PFNS	Perfluorononane sulfonic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonic acid
PFOSA	Perfluorooctane sulfonamide
PFPeA	Perfluoropentanoic acid
PFPeS	Perfluoropentane sulfonic acid
PFTeDA	Perfluorotetradecanoic acid
PFTrDA	Perfluorotridecanoic acid
PFUnA	Perfluoroundecanoic acid

8.2 Presence, Distribution, and Contamination Level of PFASs in Mussel Tissue

NUMBER OF COMPOUNDS DETECTED:
8 / 33

NUMBER OF SITES WITH DETECTS:
26 / 33

MOST DETECTED COMPOUND:
PFTeDA

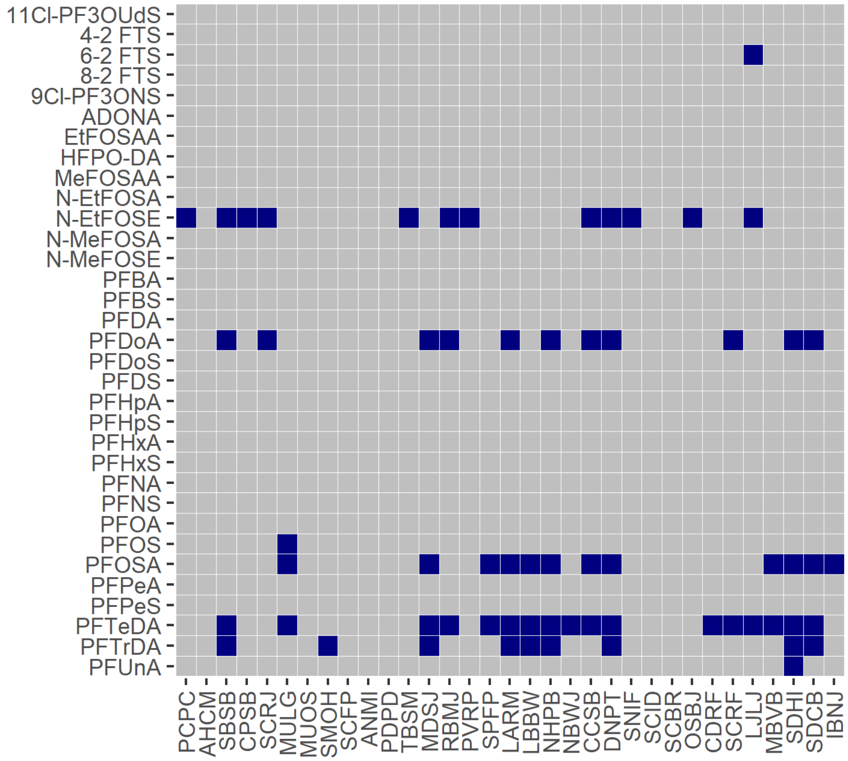


Figure 23. Distribution map showing presence (■) and absence (■) of PFAS compounds measured in mussel tissues in the Southern California Bight. Sites are listed geographically from north to south, following the coastline.

Table 25. Coastwide frequency of PFAS compound detection in mussel tissue when compound was detected at least once.

Compound	# Detects	# Sites Sampled	Frequency (%)
PFTeDA	17	33	51.5
N-EtFOSE	12	33	36.4
PFOSA	12	33	36.4
PFDoA	11	33	33.3
PFTrDA	9	33	27.3
6-2 FTS	1	33	3.0
PFOS	1	33	3.0
PFUnA	1	33	3.0

Table 26. Number of PFAS compound detects in mussel tissue at each site when at least one compound was detected.

Site	# Detects	# Compounds Analyzed	Frequency (%)
DNPT	5	33	15.2
SDHI	5	33	15.2
CCSB	4	33	12.1
LARM	4	33	12.1
MDSJ	4	33	12.1
NHPB	4	33	12.1
SBSB	4	33	12.1
SDCB	4	33	12.1
LBBW	3	33	9.1
LJLJ	3	33	9.1
MULG	3	33	9.1
RBMJ	3	33	9.1
MBVB	2	33	6.1
SCRF	2	33	6.1
SCRJ	2	33	6.1
SPFP	2	33	6.1
CDRF	1	33	3.0
CPSB	1	33	3.0
IBNJ	1	33	3.0
NBWJ	1	33	3.0
OSBJ	1	33	3.0
PCPC	1	33	3.0
PVRP	1	33	3.0
SMOH	1	33	3.0
SNIF	1	33	3.0
TBSM	1	33	3.0

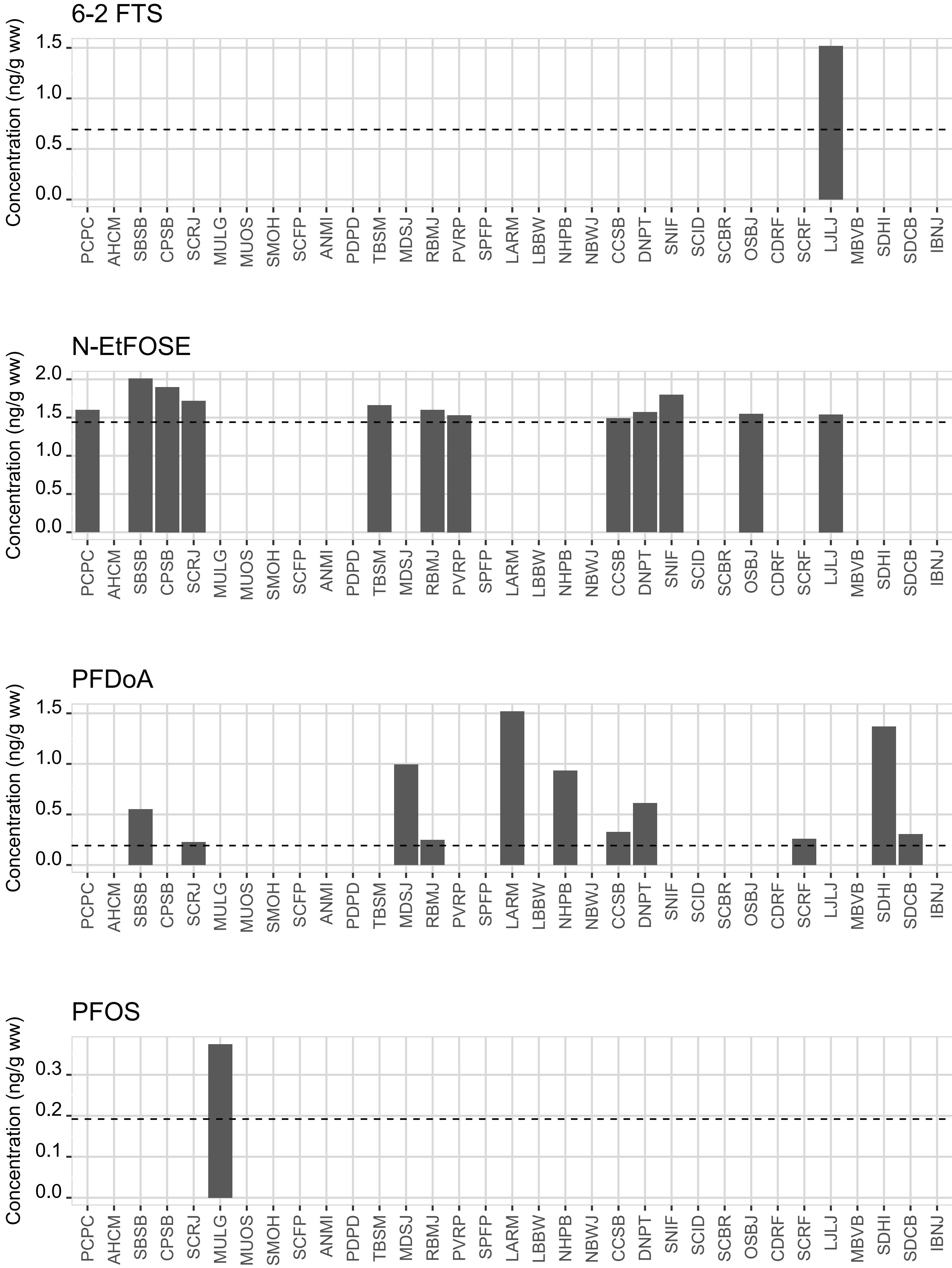


Figure 24. Bar graph showing magnitude of PFAS compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.

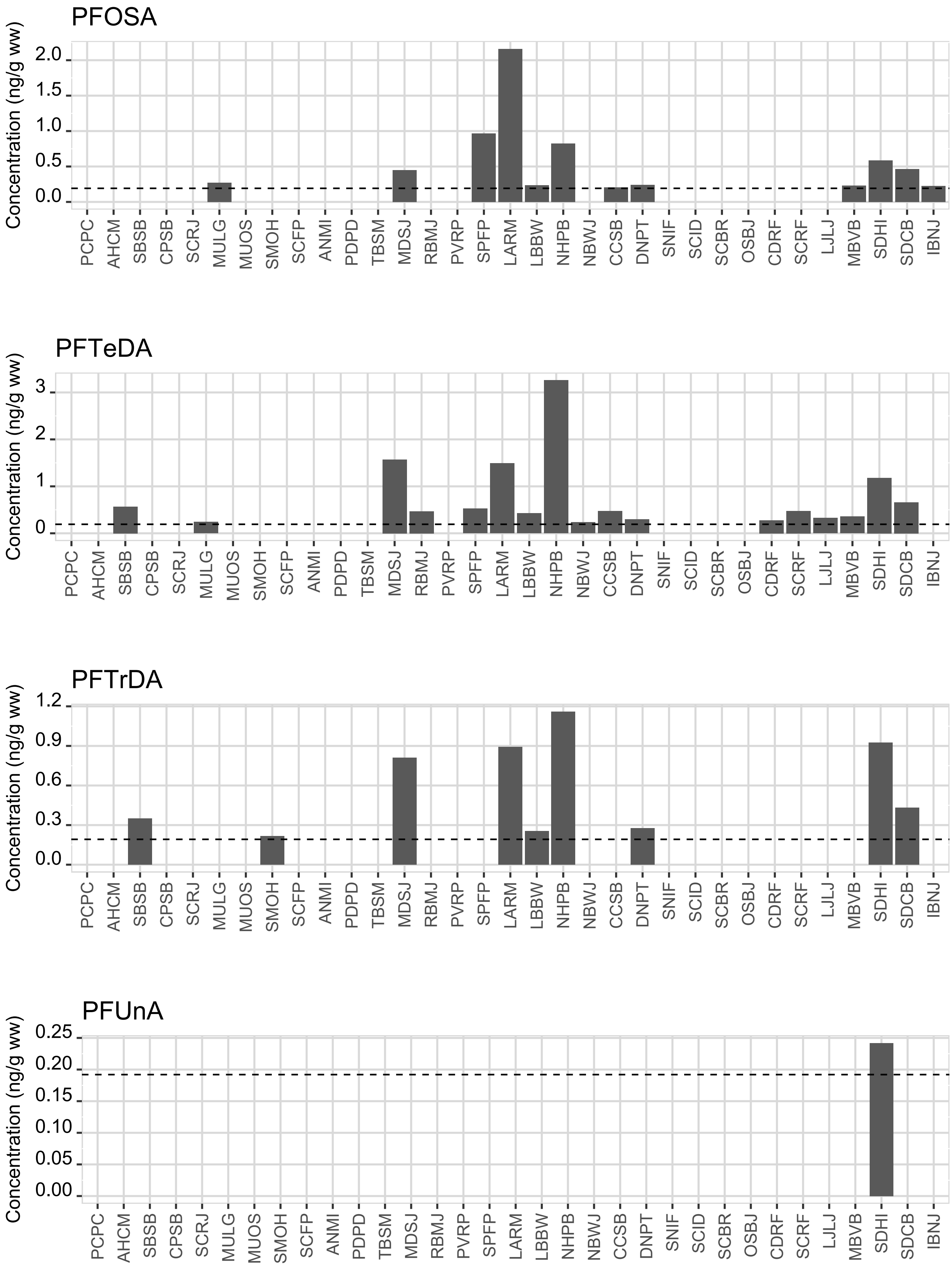


Figure 24 cont. Bar graph showing magnitude of PFAS compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.

8.3 Presence, Distribution, and Contamination Level of PFASs in Sediment

NUMBER OF COMPOUNDS DETECTED:
5 / 33

NUMBER OF SITES WITH DETECTS:
3 / 10

MOST DETECTED COMPOUNDS:
PFDoA, PFTrDA

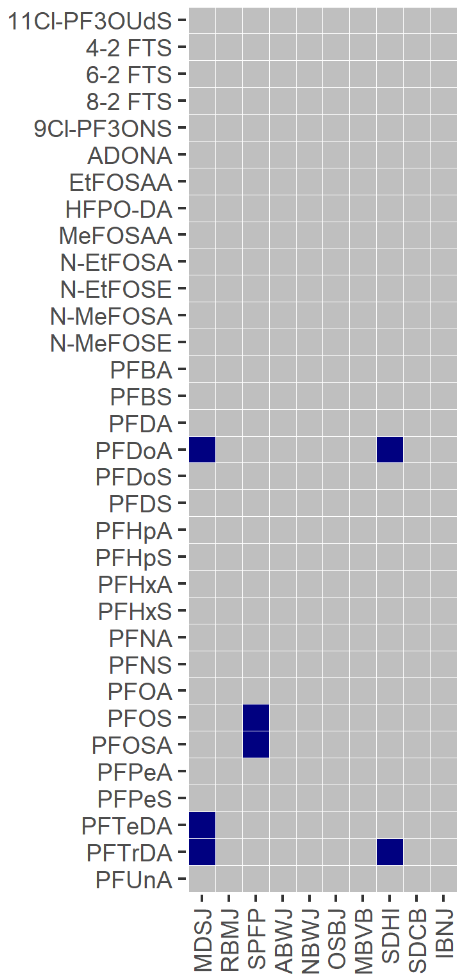


Figure 25. Distribution map showing presence ( ) and absence ( ) of PFAS compounds measured in sediment in the Southern California Bight. Sites are listed geographically from north to south, following the coastline.

Table 27. Coastwide frequency of PFAS compound detection in sediment when compound was detected at least once.

Compound	# Detects	# Sites Sampled	Frequency (%)
PFDoA	2	10	20.0
PFTrDA	2	10	20.0
PFOS	1	10	10.0
PFOSA	1	10	10.0
PFTeDA	1	10	10.0

Table 28. Number of PFAS compound detects in sediment at each site when at least one compound was detected.

Site	# Detects	# Compounds Analyzed	Frequency (%)
MDSJ	3	33	9.4
SPFP	2	33	6.3
SDHI	2	33	6.3

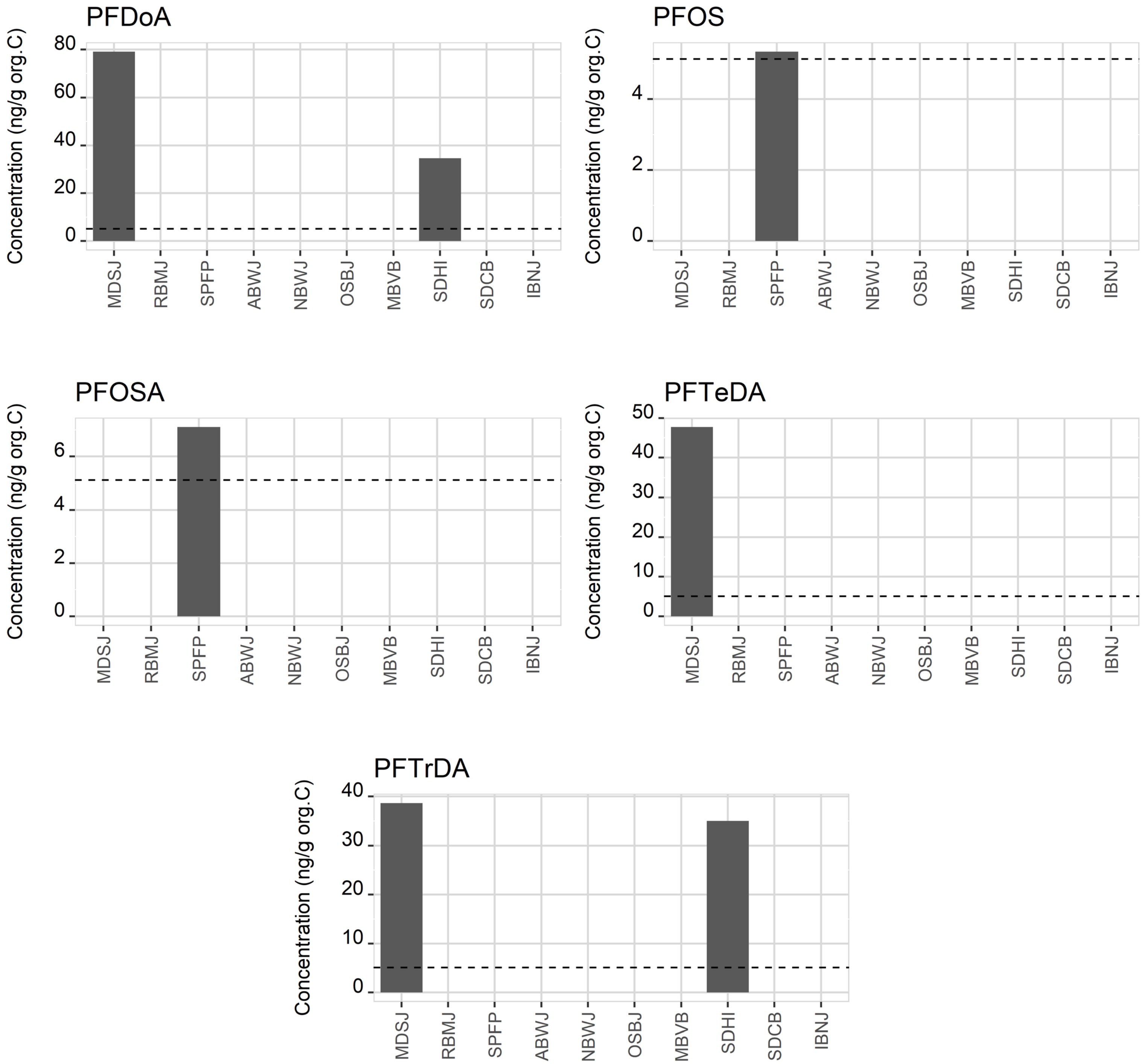


Figure 26. Bar graph showing magnitude of PFAS compounds detected in sediment in the Southern California Bight. Dotted line represents the minimum TOC corrected detection limit. Sites are listed geographically from north to south, following the coastline.

8.4 PFASs Results Summary

Mussel Tissue

- PFASs were analyzed at 33 out of 34 tissue sites
    - Not analyzed at site SANM due to insufficient sample mass
- 8/33 PFAS compounds were detected at least once
- PFTeDA was the most commonly detected PFAS compound with a frequency of 51.5%
- Minimum PFAS compound concentration detected was 0.20 ng/g ww of PFOSA at site CCSB
- Maximum PFAS compound concentration detected was 3.26 ng/g ww of PFTeDA at site NHPB
- Overall, PFASs were detected 64/1089 possible times (33 compounds x 33 sites) for an overall 5.9% frequency of detection in the Southern California Bight

Sediment

- PFASs were analyzed at 10 out of 10 sediment sites
- 5/33 PFAS compounds were detected at least once
- PFDoA and PFTrDA were the most commonly detected PFAS compounds with frequencies of 20.0%
- Minimum concentration detected was 5.33 ng/g organic Carbon of PFOS at site SPFP
- Maximum concentration detected was 79.09 ng/g organic Carbon of PFDoA at site MDSJ
- Overall, PFASs were detected 7/330 possible times (33 compounds x 10 sites) for an overall 2.1% frequency of detection in the Southern California Bight

General Observations

- PFASs in mussel tissue were widely distributed in the Southern California Bight in relatively low concentrations
- At the three sites where PFASs were detected in sediment, they were also detected in mussel tissue; however, PFASs were often detected in mussel tissue but not detected in sediment at the same site
- PFASs are more consistently detected in mussel tissue compared to sediment

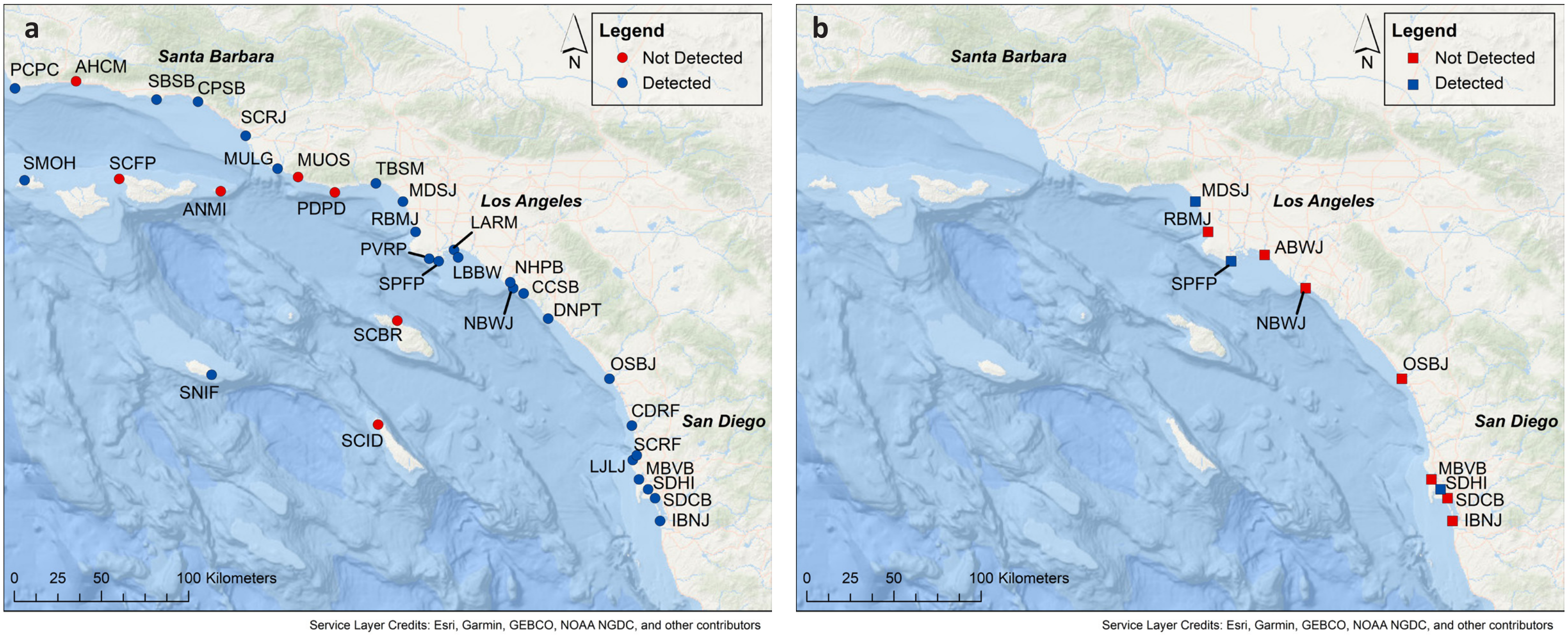


Figure 27. Map of Mussel Watch sites in the Southern California Bight highlighting locations of sites with PFAS compounds detected in (a) mussel tissue and (b) sediment.

9.0 RESULTS - PHARMACEUTICAL AND PERSONAL CARE PRODUCTS (PPCPs)

9.1 PPCPs Chemical Description

Environmental detections of pharmaceuticals and personal care products (PPCPs) include a wide spectrum of therapeutic and consumer-use compounds such as prescription and over-the-counter medications, hormones, synthetic fragrances, detergents, disinfectants, insect repellants, and antimicrobial agents. In 2009, an estimated 3.9 billion prescriptions were written for the top 300 pharmaceuticals in the US (Lundy, 2010). Pharmaceutical companies produce over 22.6 million kg (50 million pounds) of antibiotics annually in the US with approximately 60% for human use and 40% for animal agriculture use (Levy, 1998). There are numerous pathways by which PPCPs are introduced into the environment, although the primary routes include wastewater discharge or improper disposal of unused drugs (Daughton and Ternes, 1999). Because pharmaceuticals are designed with the intention of having a biological effect, the major concerns associated with PPCPs in the environment are their potential ecotoxicity and unintentional human health impacts. Potential impacts of PPCPs in the environment include abnormal physiological effects, impaired reproduction, and increased cancer rates (Boyd and Furlong, 2002). According to the US EPA, many CECs including PPCPs are suspected to be endocrine disruptors, which alter the normal functions of hormones resulting in a variety of health effects (Ankley et al., 2008). PPCPs represent a diverse class of emerging contaminants and the PPCPs analyzed in this study are grouped by broad usage including Rx Antibiotics, Rx Cardiovascular, Rx Psychiatric, Rx Hormone, Rx Steroid, Recreational and Personal Care Drugs and Products, Rx Misc., and Other (Tables 29 – 36).

PPCP analyses were conducted by SGS AXYS Analytical Services LTD. The analytical method used was MLA-075 Rev 07.

Table 29. PPCP Prescription Drugs (Antibiotic) compounds tested (49).

Chemical Name	Application	Chemical Name	Application
4-Epianhydrochlortetracycline	Chlorotetracycline degradate	Moxifloxacin	Antibiotic
4-Epianhydrotetracycline	Chlorotetracycline degradate	Norfloxacin	Quinoline antibiotic
4-Epichlortetracycline	Chlorotetracycline degradate	Ofloxacin	Quinoline antibiotic
4-Epioxytetracycline	Oxytetracycline degradate	Ormetoprim	Macrolide antibiotic
4-Epitetracycline	Tetracycline degradate	Oxacillin	β-lactam antibiotics
Anhydrochlortetracycline	Chlorotetracycline degradate	Oxolinic Acid	Quinolone antibiotic
Anhydrotetracycline	Chlorotetracycline degradate	Oxytetracycline	Tetracycline antibiotic
Azithromycin	Macrolide antibiotic	Penicillin G	β-lactam antibiotics
Carbadox	Quinoxaline antibiotic	Penicillin V	β-lactam antibiotics
Cefotaxime	Cephalosporin antibiotic	Roxithromycin	Macrolide antibiotic
Chlortetracycline	Tetracycline antibiotic	Sarafloxacin	Fluoroquinolone antibiotic
Ciprofloxacin	Quinoline antibiotic	Sulfachloropyridazine	Sulfonamide antibiotic
Clarithromycin	Macrolide antibiotic	Sulfadiazine	Sulfonamide antibiotic
Clinafloxacin	Quinoline antibiotic	Sulfadimethoxine	Sulfonamide antibiotic
Cloxacillin	β-lactam antibiotics	Sulfamerazine	Sulfonamide antibiotic
Demeclocycline	Tetracycline antibiotic	Sulfamethazine	Sulfonamide antibiotic
Doxycycline	Tetracycline antibiotic	Sulfamethizole	Sulfonamide antibiotic
Enrofloxacin	Quinolone antibiotic	Sulfamethoxazole	Sulfonamide antibiotic
Erythromycin-H2O	Macrolide antibiotic	Sulfanilamide	Sulfonamide antibiotic
Flumequine	Quinolone antibiotic	Sulfathiazole	Sulfonamide antibiotic
Isochlortetracycline	Chlorotetracycline degradate	Tetracycline	Tetracycline antibiotic
Lincomycin	Lincosamide antibiotic	Trimethoprim	Pyrimidine antibiotic
Lomefloxacin	Quinoline antibiotic	Tylosin	Macrolide antibiotic
Metronidazole	Antimicrobial	Virginiamycin M1	Macrolide antibiotic
Minocycline	Tetracycline antibiotic		

Results - PPCPs

Table 30. PPCP Prescription Drugs (Cardiovascular) compounds tested (18).

Chemical Name	Application
Albuterol	Antiasthmatic
Amlodipine	Calcium Channel Blocker
Atenolol	Beta Blocking Agent
Atorvastatin	HMG-CoA reductase inhibitors
Clonidine	Sedative; Anti-hypertensive
Dehydronifedipine	Nifedipine metabolite
Digoxin	Cardiac glycoside
Diltiazem	Antihypertensive
Enalapril	Antihypertensive drug
Gemfibrozil	Antilipemic
Metoprolol	Beta Blocking Agent
Norverapamil	Antihypertensive
Propranolol	Beta Blocking Agent
Rosuvastatin	Cholesterol reducer
Simvastatin	HMG-CoA reductase inhibitors
Valsartan	Angiotensin receptor blockers
Verapamil	Beta Blocking Agent
Warfarin	Anticoagulant

Table 31. PPCP Prescription Drugs (Psychiatric) compounds tested (13).

Chemical Name	Application
10-hydroxy-amitriptyline	Antidepressant Metabolite
Alprazolam	Anxiolytic; Sedative
Amitriptyline	Antidepressant
Amphetamine	Stimulant
Citalopram	Antidepressant; SSRI
Diazepam	Anti-anxiety; Sedative
Fluoxetine	Antidepressant; SSRI
Meprobamate	Sedative; Anti-anxiety (anxiolytic)
Norfluoxetine	Antidepressant
Oxazepam	Antidepressant
Paroxetine	Antidepressant; SSRI
Sertraline	Antidepressant; SSRI
Venlafaxine	Antidepressant

Table 32. PPCP Prescription Drugs (Hormone) compounds tested (4).

Chemical Name	Application
Drospirenone	Hormones
Medroxyprogesterone Acetate	Progestin; Birth control
Norgestimate	Hormonal contraceptives
Tamoxifen	Hormone; Antiestrogen

Table 33. PPCP Prescription Drugs (Steroid) compounds tested (10).

Chemical Name	Application
Betamethasone	Steroid
Digoxigenin	Immunohistochemical marker
Fluocinonide	Steroid; Corticosteroid
Fluticasone propionate	Steroid
Hydrocortisone	Steroid
Methylprednisolone	Steroid; Corticosteroid
Prednisolone	Steroid
Prednisone	Steroid; Corticosteroid
Trenbolone	Anabolic steroid
Trenbolone acetate	Anabolic steroid

Table 34. PPCP Recreational and Personal Care Drugs & Products compounds tested (17).

Chemical Name	Application
1,7-Dimethylxanthine	Antispasmodic, caffeine metabolite
2-Hydroxy-ibuprofen	Analgesic metabolite; NSAID
Acetaminophen	Antipyretic; Analgesic
Benzoylecgonine	Metabolite of cocaine
Caffeine	Stimulant
Cimetidine	Anti-acid reflux
Clotrimazole	Antifungal
Cocaine	Stimulant
Cotinine	Nicotine metabolite
DEET	Insect repellent
Diphenhydramine	Antihistamine
Ibuprofen	Analgesic
Miconazole	Antifungal agent
Naproxen	Non-steroidal anti-inflammatory drug
Ranitidine	Anti-acid reflux
Triclocarban	Antimicrobial; Disinfectant
Triclosan	Antimicrobial; Disinfectant

Table 35. PPCP Prescription (Misc.) compounds tested (27).

Chemical Name	Application
Amsacrine	Chemotherapeutic agent
Azathioprine	Immunosuppressive drugs
Benztropine	Anticholinergic; Antiparkinson
Busulfan	Antineoplastic; Alkylating agent
Carbamazepine	Anticonvulsant
Codeine	Opioid; Analgesic
Colchicine	Anti-gout
Cyclophosphamide	Immunosuppressor
Daunorubicin	Antineoplastic; Chemotherapy
Desmethyldiltiazem	Antianginal; Antihypertensive
Doxorubicin	Antineoplastic; Chemotherapy
Etoposide	Anti-Inflammatory; Chemotherapy
Furosemide	Diuretic
Glipizide	Sulfonylurea; Anti-diabetic
Glyburide	Anti-diabetic
Hydrochlorothiazide	Diuretic
Hydrocodone	Opioid; Analgesic
Melphalan	Chemotherapy
Metformin	Anti-diabetes
Oxycodone	Opioid; Analgesic
Promethazine	Antihistamine
Propoxyphene	Analgesic
Teniposide	Antineoplastic; Chemotherapy
Theophylline	Methylxanthines; Respiratory tract
Thiabendazole	Fungicide; Parasiticide
Triamterene	Diuretic
Zidovudine	Antiretroviral

Table 36. PPCP Other compounds tested (3).

Chemical Name	Application
Bisphenol A	Flame retardant; Synthetic
Diatrizoic acid	Contrast agent
Iopamidol	X-ray contrast media

9.2 Presence, Distribution, and Contamination Level of PPCPs in Mussel Tissue

9.2.1 PPCP Prescription Drugs (Antibiotic) in Mussel Tissue

NUMBER OF COMPOUNDS DETECTED:
9 / 49

NUMBER OF SITES WITH DETECTS:
10 / 10

MOST DETECTED COMPOUND:
Lomefloxacin

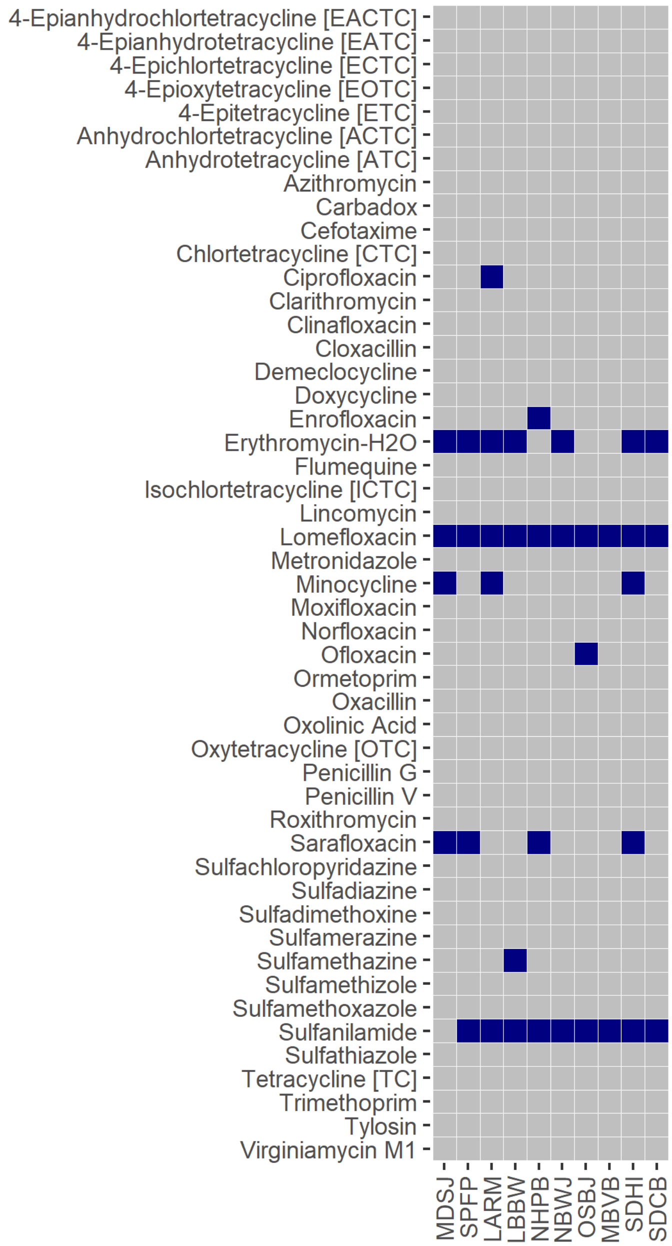


Figure 28. Distribution map showing presence ( ) and absence ( ) of PPCP Prescription Drugs (Antibiotic) compounds measured in mussel tissues in the Southern California Bight. Sites are listed geographically from north to south, following the coastline.

Table 37. Coastwide frequency of PPCP Prescription Drugs (Antibiotic) compound detection in mussel tissue when compound was detected at least once.

Compound	# Detects	# Sites Sampled	Frequency (%)
Lomefloxacin	10	10	100.0
Sulfanilamide	9	10	90.0
Erythromycin-H2O	7	10	70.0
Sarafloxacin	4	10	40.0
Minocycline	3	10	30.0
Ciprofloxacin	1	10	10.0
Enrofloxacin	1	10	10.0
Ofloxacin	1	10	10.0
Sulfamethazine	1	10	10.0

Table 38. Number of PPCP Prescription Drugs (Antibiotic) compound detects in mussel tissue at each site when at least one compound was detected.

Site	# Detects	# Compounds Analyzed	Frequency (%)
LARM	5	49	10.2
SDHI	5	49	10.2
LBBW	4	49	8.2
MDSJ	4	49	8.2
NHPB	4	49	8.2
SPFP	4	49	8.2
NBWJ	3	49	6.1
OSBJ	3	49	6.1
SDCB	3	49	6.1
MBVB	2	49	4.1

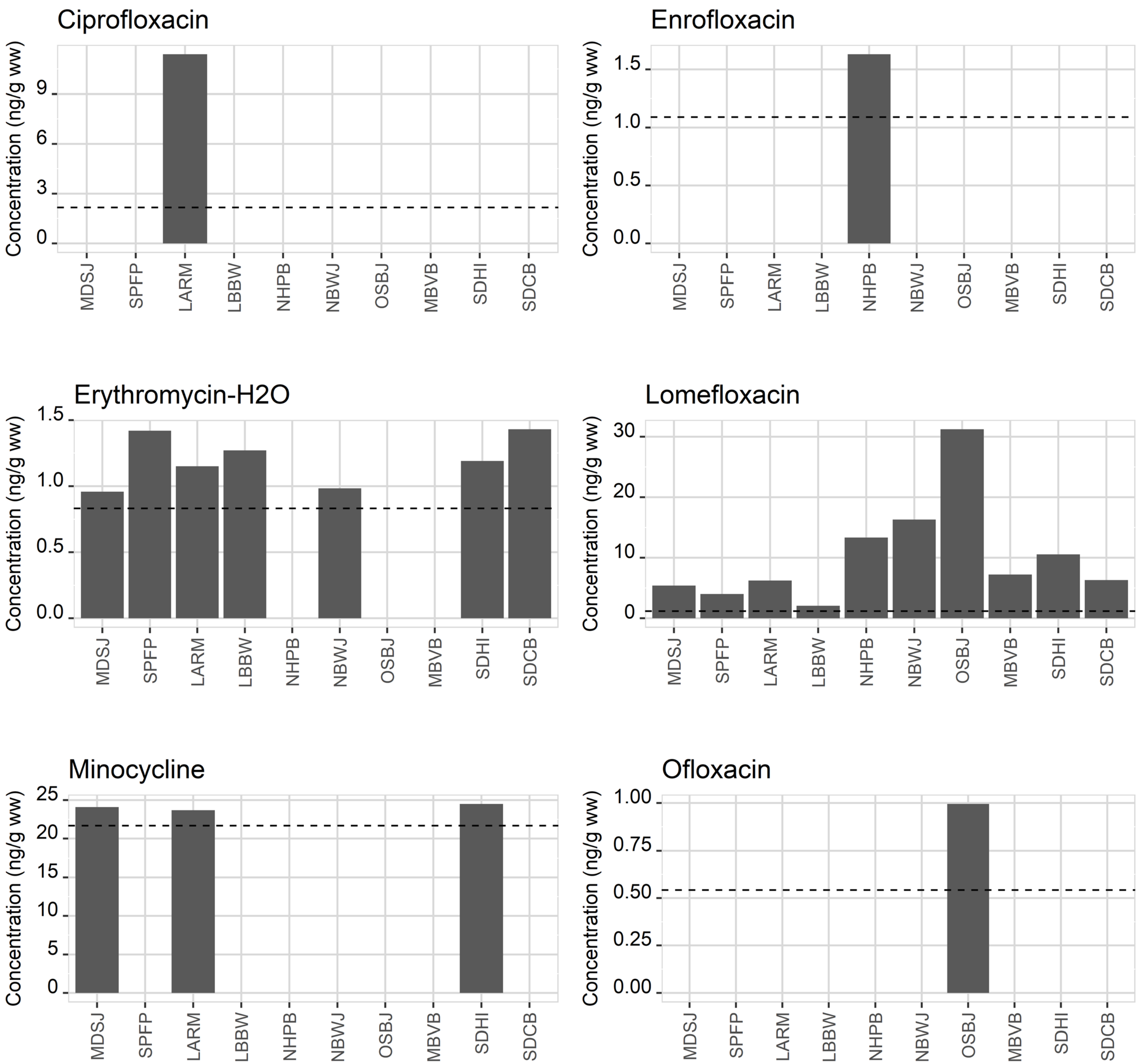
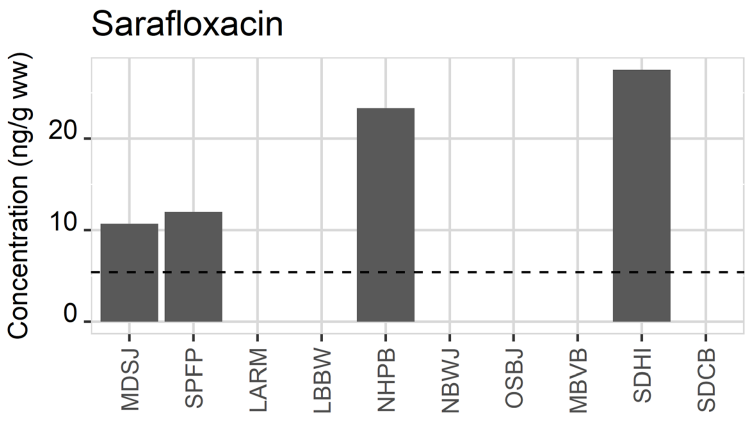
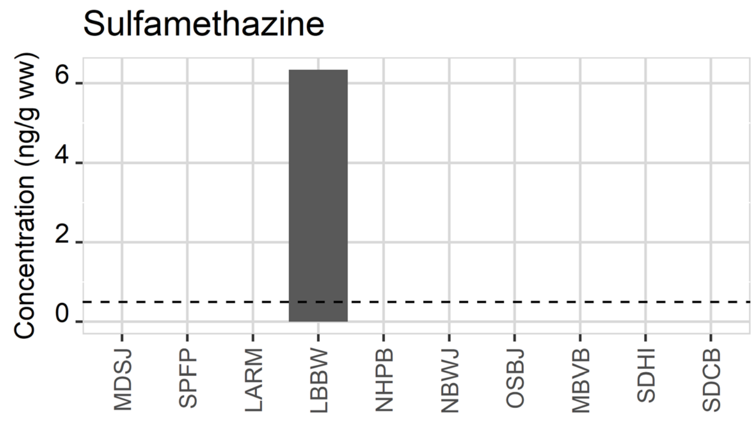


Figure 29. Bar graph showing magnitude of PPCP Prescription Drugs (Antibiotic) compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.





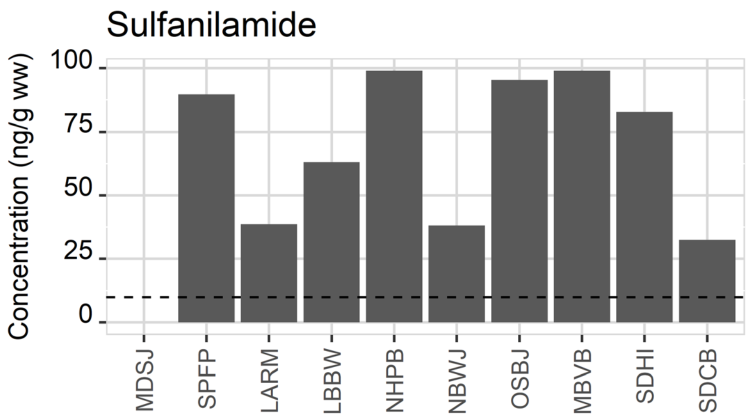


Figure 29 cont. Bar graph showing magnitude of PPCP Prescription Drugs (Antibiotic) compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.

9.2.2 PPCP Prescription Drugs (Cardiovascular) in Mussel Tissue

NUMBER OF COMPOUNDS DETECTED:
1 / 18

NUMBER OF SITES WITH DETECTS:
1 / 10

MOST DETECTED COMPOUND:
Diltiazem

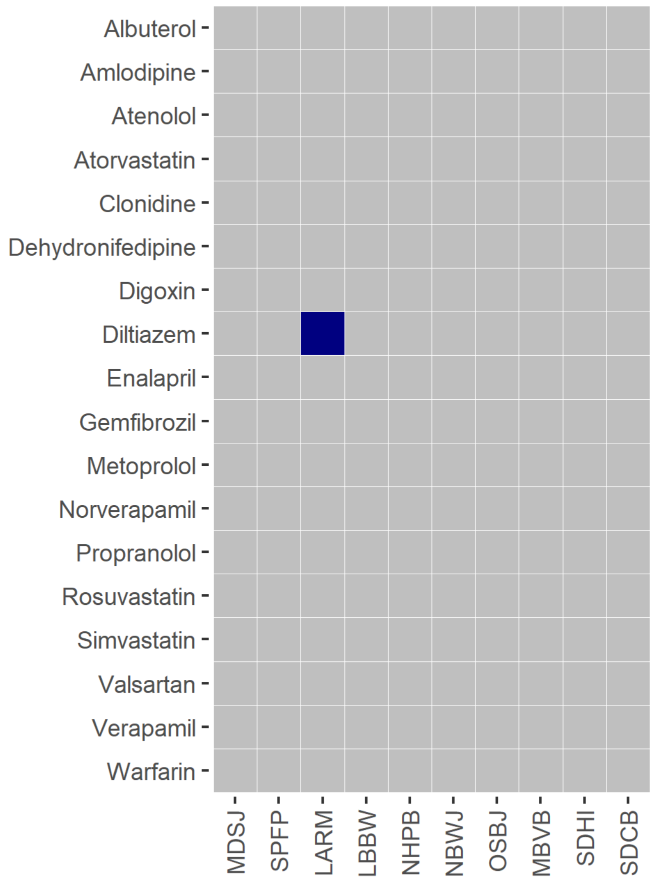


Figure 30. Distribution map showing presence ( ) and absence ( ) of PPCP Prescription Drugs (Cardiovascular) compounds measured in mussel tissues in the Southern California Bight. Sites are listed geographically from north to south, following the coastline.

Table 39. Coastwide frequency of PPCP Prescription Drugs (Cardiovascular) compound detection in mussel tissue when compound was detected at least once.

Compound	# Detects	# Sites Sampled	Frequency (%)
Diltiazem	1	10	10.0

Table 40. Number of PPCP Prescription Drugs (Cardiovascular) compound detects in mussel tissue at each site when at least one compound was detected.

Site	# Detects	# Compounds Analyzed	Frequency (%)
LARM	1	18	5.6

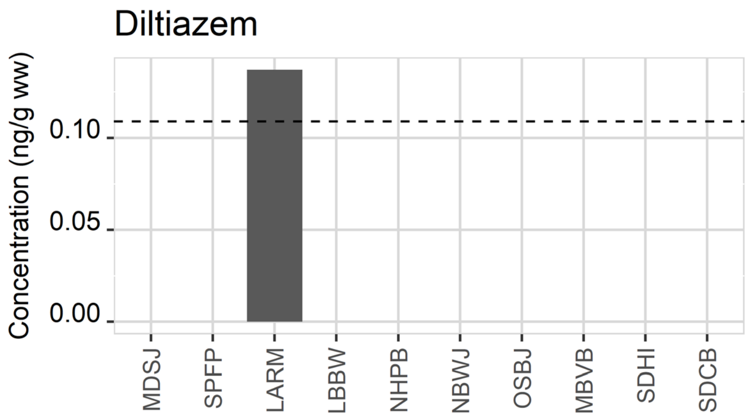


Figure 31. Bar graph showing magnitude of PPCP Prescription Drugs (Cardiovascular) compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.

9.2.3 PPCP Prescription Drugs (Psychiatric) in Mussel Tissue

NUMBER OF COMPOUNDS DETECTED:
4 / 13

NUMBER OF SITES WITH DETECTS:
6 / 10

MOST DETECTED COMPOUND:
Sertraline

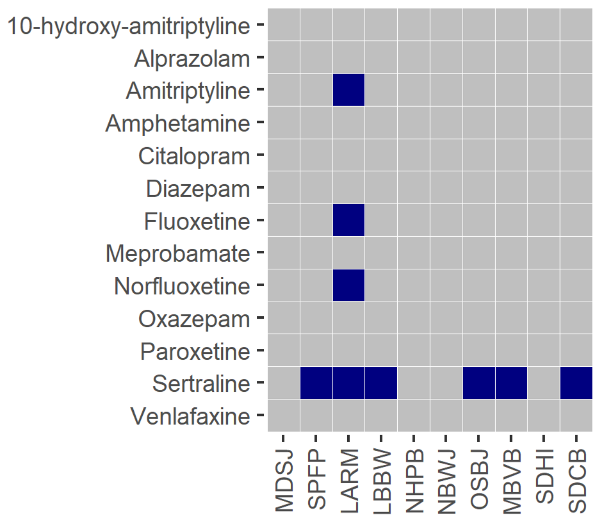


Figure 32. Distribution map showing presence ( ) and absence ( ) of PPCP Prescription Drugs (Psychiatric) compounds measured in mussel tissues in the Southern California Bight. Sites are listed geographically from north to south, following the coastline.

Table 41. Coastwide frequency of PPCP Prescription Drugs (Psychiatric) compound detection in mussel tissue when compound was detected at least once.

Compound	# Detects	# Sites Sampled	Frequency (%)
Sertraline	6	10	60.0
Amitriptyline	1	10	10.0
Fluoxetine	1	10	10.0
Norfluoxetine	1	10	10.0

Table 42. Number of PPCP Prescription Drugs (Psychiatric) compound detects in mussel tissue at each site when at least one compound was detected.

Site	# Detects	# Compounds Analyzed	Frequency (%)
LARM	4	13	30.8
LBBW	1	13	7.7
SPFP	1	13	7.7
OSBJ	1	13	7.7
MBVB	1	13	7.7
SDCB	1	13	7.7

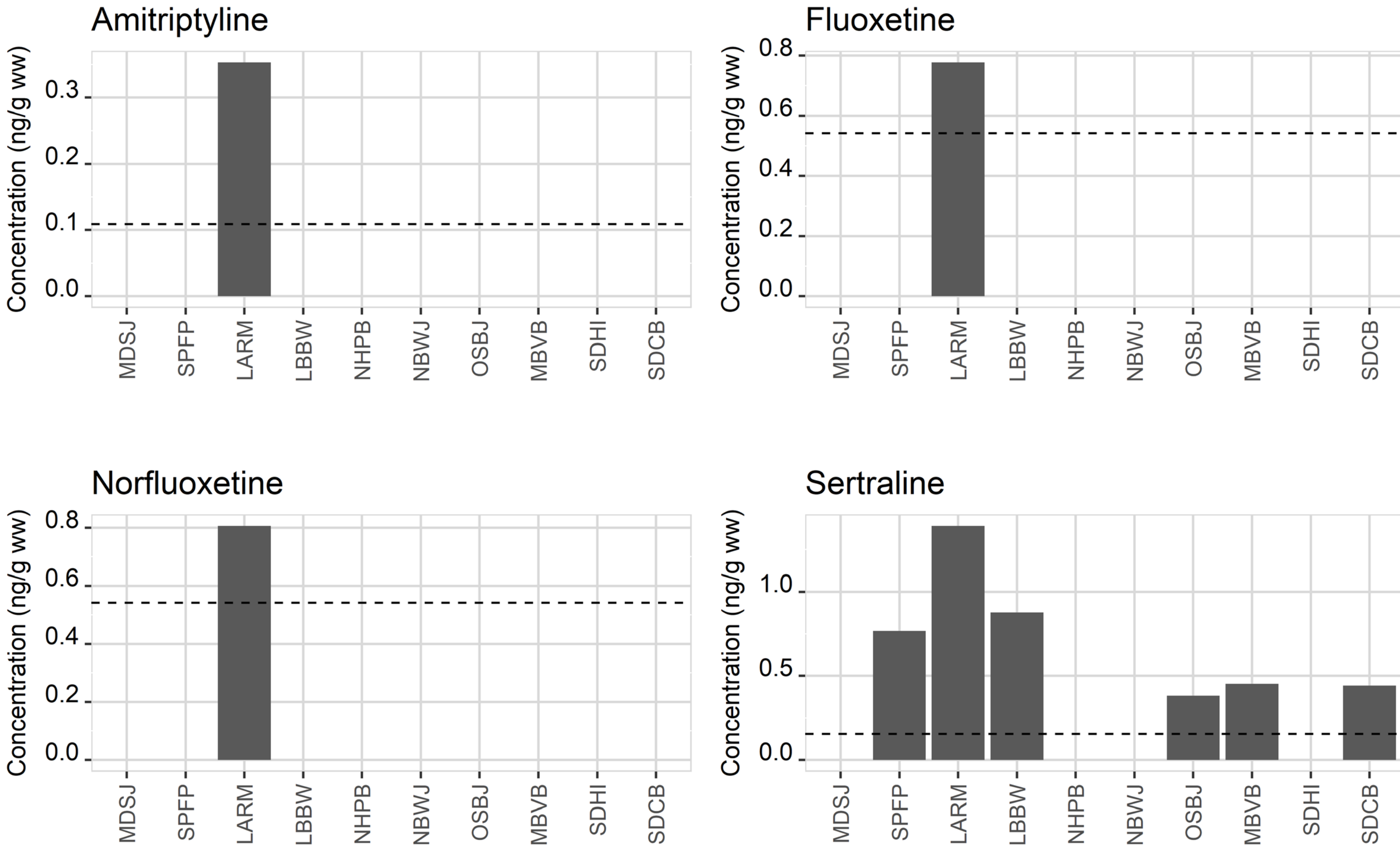


Figure 33. Bar graph showing magnitude of PPCP Prescription Drugs (Psychiatric) compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.

9.2.4 PPCP Prescription Drugs (Hormone) in Mussel Tissue

NUMBER OF COMPOUNDS DETECTED:
0 / 4

NUMBER OF SITES WITH DETECTS:
0 / 10

MOST DETECTED COMPOUND:
N/A

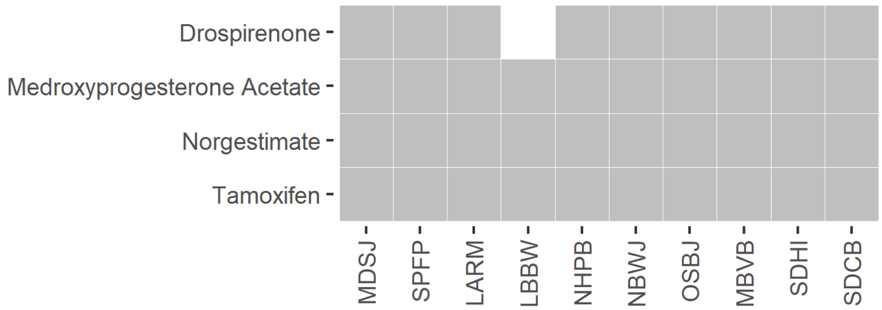


Figure 34. Distribution map showing presence ( ) and absence ( ) of PPCP Prescription Drugs (Hormone) compounds measured in mussel tissue in the Southern California Bight. Sites are listed geographically from north to south, following the coastline. ( ) means excluded from this report.

NOTE: Drospirenone at site LBBW was marked as "Non-Quantifiable" from laboratory analysis and so was excluded from this report.

9.2.5 PPCP Prescription Drugs (Steroid) in Mussel Tissue

NUMBER OF COMPOUNDS DETECTED:
1 / 10

NUMBER OF SITES WITH DETECTS:
1 / 10

MOST DETECTED COMPOUND:
Fluocinonide

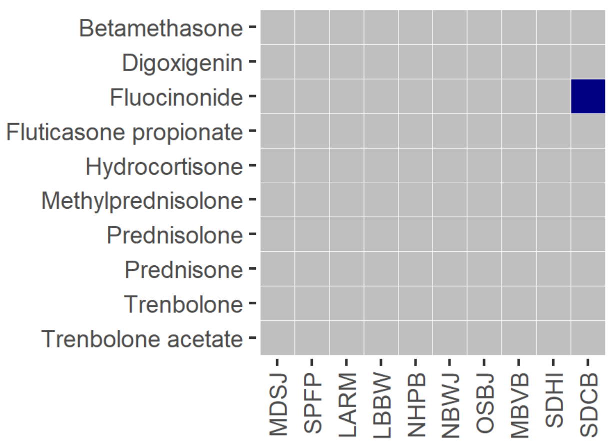


Figure 35. Distribution map showing presence ( ) and absence ( ) of PPCP Prescription Drugs (Steroid) compounds measured in mussel tissues in the Southern California Bight. Sites are listed geographically from north to south, following the coastline.

Table 43. Coastwide frequency of PPCP Prescription Drugs (Steroid) compound detection in mussel tissue when compound was detected at least once.

Compound	# Detects	# Sites Sampled	Frequency (%)
Fluocinonide	1	10	10.0

Table 44. Number of PPCP Prescription Drugs (Steroid) compound detects in mussel tissue at each site when at least one compound was detected.

Site	# Detects	# Compounds Analyzed	Frequency (%)
SDCB	1	10	10.0

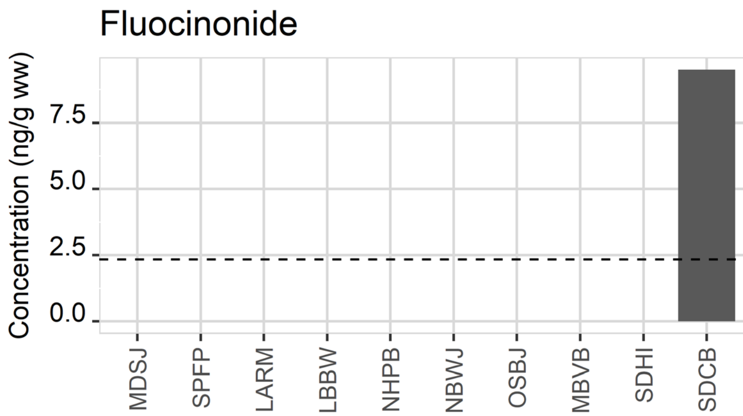


Figure 36. Bar graph showing magnitude of PPCP Prescription Drugs (Steroid) compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.

9.2.6 PPCP Recreational and Personal Care Drugs & Products in Mussel Tissue

NUMBER OF COMPOUNDS DETECTED:
4 / 17

NUMBER OF SITES WITH DETECTS:
2 / 10

MOST DETECTED COMPOUND:
Triclocarban

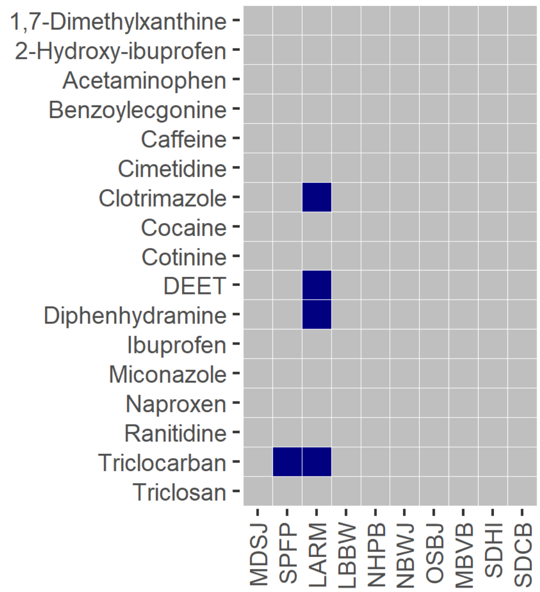


Figure 37. Distribution map showing presence ( ) and absence ( ) of PPCP Recreational and Personal Care Drugs & Products compounds measured in mussel tissues in the Southern California Bight. Sites are listed geographically from north to south, following the coastline.

Table 45. Coastwide frequency of PPCP Recreational and Personal Care Drugs & Products compound detection in mussel tissue when compound was detected at least once.

Compound	# Detects	# Sites Sampled	Frequency (%)
Triclocarban	2	10	20.0
Clotrimazole	1	10	10.0
DEET	1	10	10.0
Diphenhydramine	1	10	10.0

Table 46. Number of PPCP Recreational and Personal Care Drugs & Products compound detects in mussel tissue at each site when at least one compound was detected.

Site	# Detects	# Compounds Analyzed	Frequency (%)
LARM	4	17	23.5
SPFP	1	17	5.9

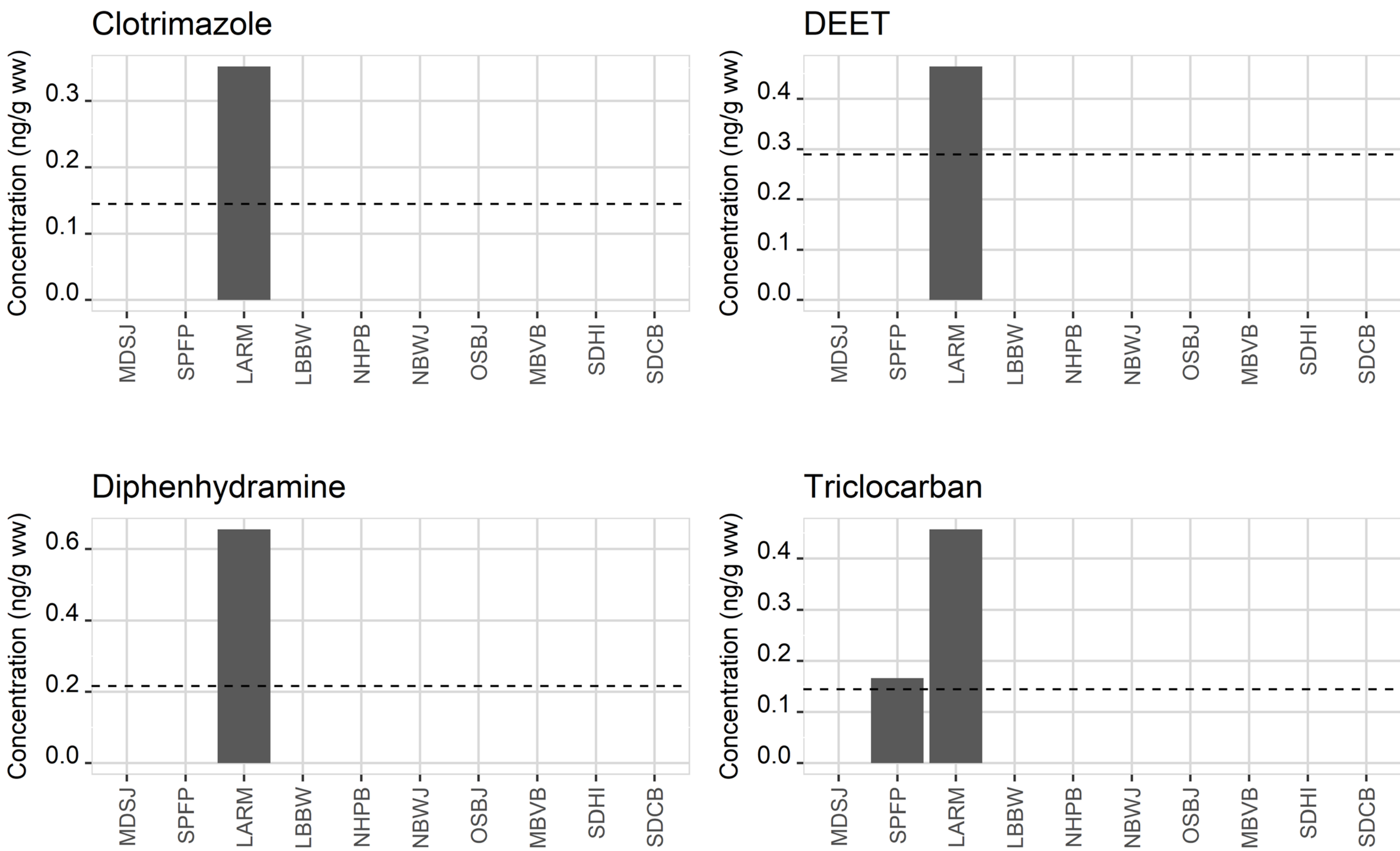


Figure 38. Bar graph showing magnitude of PPCP Recreational and Personal Care Drugs & Products compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.

9.2.7 PPCP Prescription Drugs (Misc.) in Mussel Tissue

NUMBER OF COMPOUNDS DETECTED:
3 / 27

NUMBER OF SITES WITH DETECTS:
4 / 10

MOST DETECTED COMPOUND:
Etoposide, Metformin

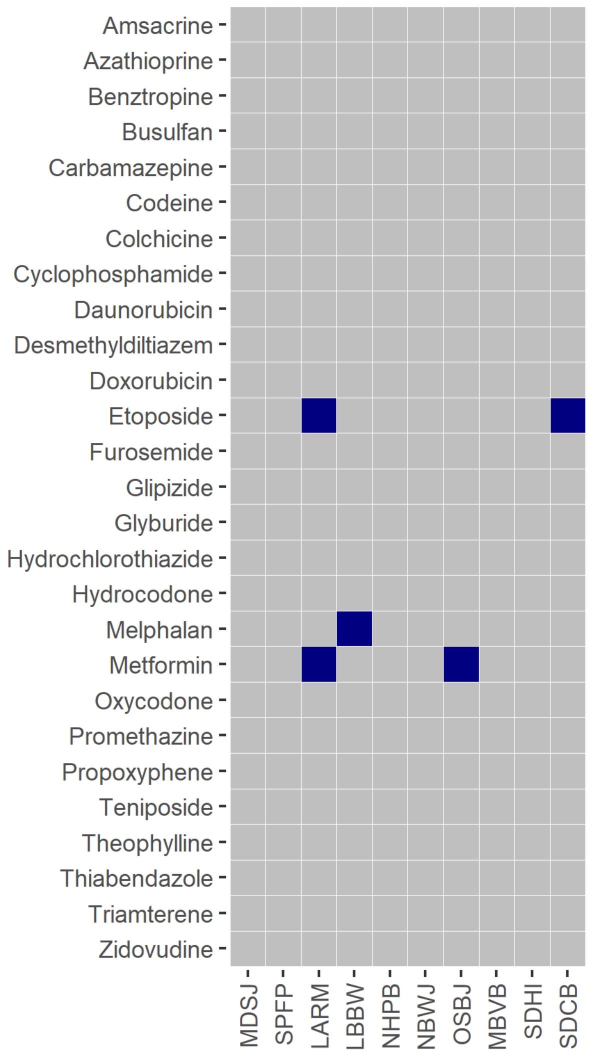


Figure 39. Distribution map showing presence ( ) and absence ( ) of PPCP Prescription Drugs (Misc.) compounds measured in mussel tissues in the Southern California Bight. Sites are listed geographically from north to south, following the coastline.

Table 47. Coastwide frequency of PPCP Prescription Drugs (Misc.) compound detection in mussel tissue when compound was detected at least once.

Compound	# Detects	# Sites Sampled	Frequency (%)
Etoposide	2	10	20.0
Metformin	2	10	20.0
Melphalan	1	10	10.0

Table 48. Number of PPCP Prescription Drugs (Misc.) compound detects in mussel tissue at each site when at least one compound was detected.

Site	# Detects	# Compounds Analyzed	Frequency (%)
LARM	2	27	7.4
LBBW	1	27	3.7
OSBJ	1	27	3.7
SDCB	1	27	3.7

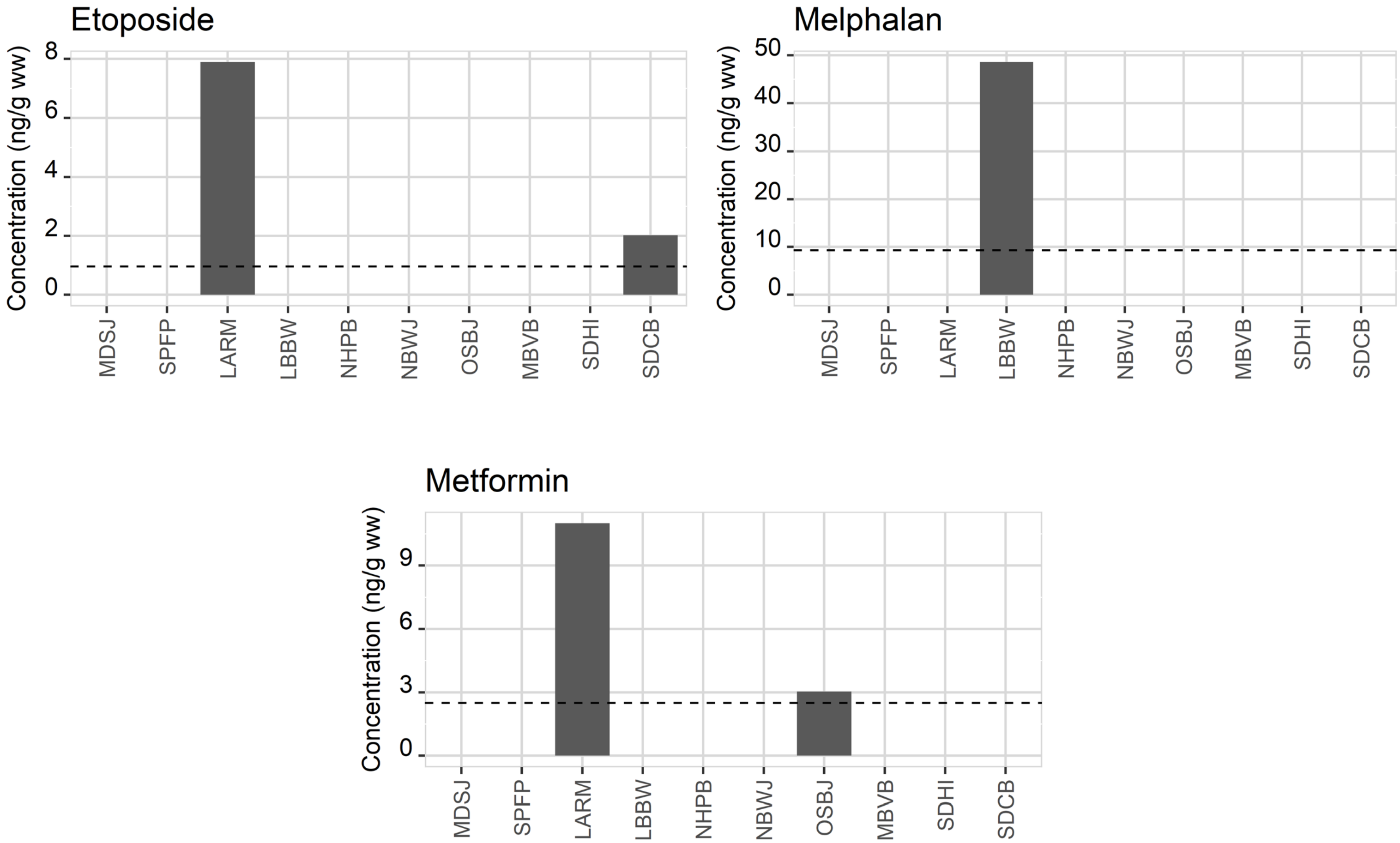


Figure 40. Bar graph showing magnitude of PPCP Prescription Drugs (Misc.) compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.

9.2.8 PPCP Other in Mussel Tissue

NUMBER OF COMPOUNDS DETECTED:
2 / 3

NUMBER OF SITES WITH DETECTS:
10 / 10

MOST DETECTED COMPOUND:
Iopamidol

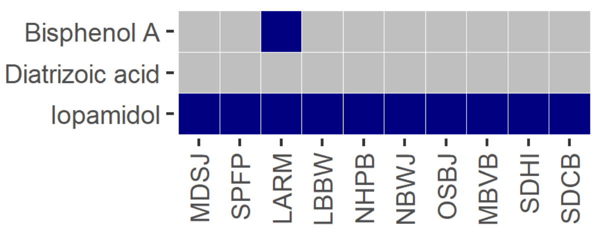


Figure 41. Distribution map showing presence ( ) and absence ( ) of PPCP Other compounds measured in mussel tissues in the Southern California Bight. Sites are listed geographically from north to south, following the coastline.

Table 49. Coastwide frequency of PPCP Other compound detection in mussel tissue when compound was detected at least once.

Compound	# Detects	# Sites Sampled	Frequency (%)
Iopamidol	10	10	100.0
Bisphenol A	1	10	10.0

Table 50. Number of PPCP Other compound detects in mussel tissue at each site when at least one compound was detected.

Site	# Detects	# Compounds Analyzed	Frequency (%)
LARM	2	3	66.3
MDSJ	1	3	33.3
LBBW	1	3	33.3
SPFP	1	3	33.3
NHPB	1	3	33.3
NBWJ	1	3	33.3
OSBJ	1	3	33.3
MBVB	1	3	33.3
SDHI	1	3	33.3
SDCB	1	3	33.3

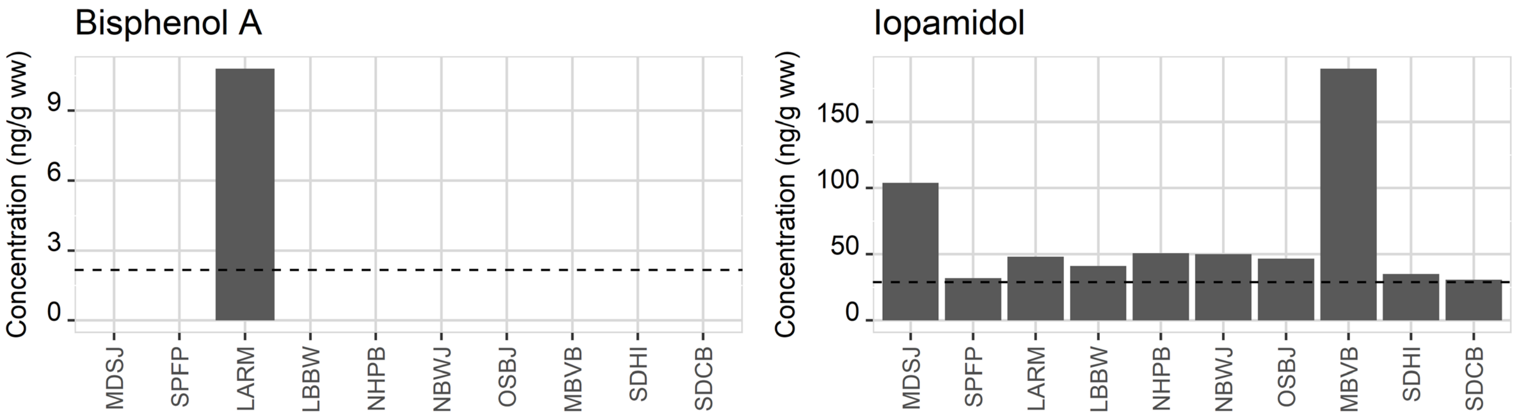


Figure 42. Bar graph showing magnitude of PPCP Other compounds detected in mussel tissue in the Southern California Bight. Dotted line represents the minimum weight corrected detection limit. Sites are listed geographically from north to south, following the coastline.

9.3 PPCPs Summary

Mussel Tissue

- PPCPs were analyzed at 10 out of 34 tissue sites
- 24/141 PPCP compounds were detected at least once
- Iopamidol and Lomefloxacin were the most commonly detected PPCP compounds with frequencies of 100.0%
- Minimum concentration detected was 0.14 ng/g ww of Diltiazem at site LARM
- Maximum concentration detected was 190.00 ng/g ww of Iopamidol at site MBVB
- Overall, PPCPs were detected 69/1409 possible times (141 compounds x 10 sites) for an overall 4.9% frequency of detection in the Southern California Bight
  - PPCP Prescription Drugs (Antibiotic) were detected 37/490 possible times (49 compounds x 10 sites) for an overall 7.5% frequency of detection in the Southern California Bight
  - PPCP Prescription Drugs (Cardiovascular) were detected 1/180 possible times (18 compounds x 10 sites) for an overall 0.5% frequency of detection in the Southern California Bight
  - PPCP Prescription Drugs (Psychiatric) were detected 9/130 possible times (13 compounds x 10 sites) for an overall 6.9% frequency of detection in the Southern California Bight
  - PPCP Prescription Drugs (Hormone) were detected 0/39 possible times (4 compounds x 10 sites) for an overall 0.0% frequency of detection in the Southern California Bight
    - Drospirenone at site LBBW was marked as "Non-Quantifiable" from laboratory analysis and so was excluded from this report.
  - PPCP Prescription Drugs (Steroid) were detected 1/100 possible times (10 compounds x 10 sites) for an overall 1.0% frequency of detection in the Southern California Bight
  - PPCP Recreational and Personal Care Drugs & Products were detected 5/170 possible times (17 compounds x 10 sites) for an overall 2.9% frequency of detection in the Southern California Bight
  - PPCP Prescription Drugs (Misc.) were detected 5/270 possible times (27 compounds x 10 sites) for an overall 1.9% frequency of detection in the Southern California Bight
  - PPCP Other were detected 11/30 possible times (3 compounds x 10 sites) for an overall 36.7% frequency of detection in the Southern California Bight

General Observations

- PPCPs in mussel tissue were ubiquitous in the Southern California Bight

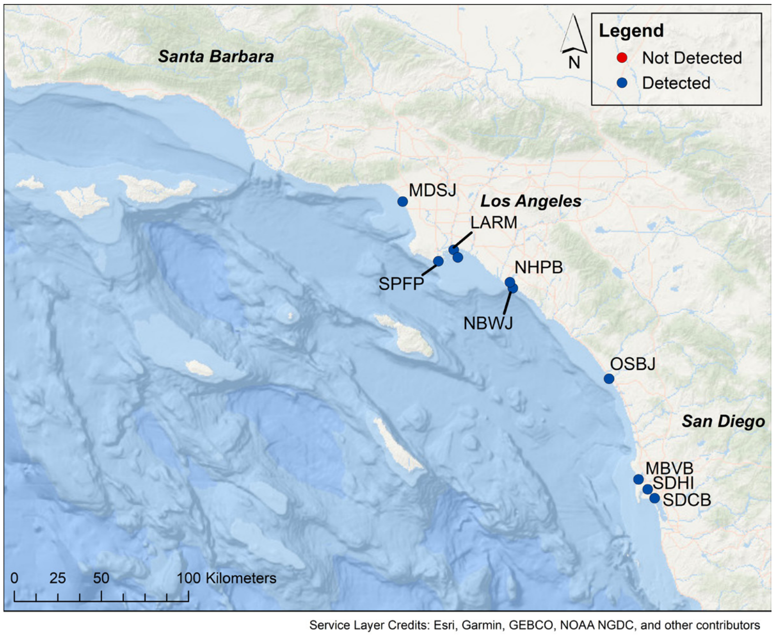


Figure 43. Map of Mussel Watch sites in the Southern California Bight highlighting locations of sites with PPCP compounds detected in mussel tissue.

10.0 SUMMARY

Mussels are good indicators of water quality, hence they have been used worldwide as sentinel species for chemical pollution in aquatic systems. In this study, mussel tissue samples (*Mytilus* species) were assessed for alkylphenol compounds (APs), alternative flame retardants (AFRs), polybrominated flame retardants (BFRs (PBDEs and PBBs)), current-use pesticides (CUPs), per- and polyfluoroalkyl substances (PFASs), and pharmaceutical and personal care products (PPCPs). The mussel samples were collected at historic MWP monitoring sites located within the Southern California Bight. Sample collection was conducted by SCWRPP and CINMS following standard protocols (Apeti et al., 2012). Mussel tissue and sediment samples from a combined 35 monitoring sites were analyzed for a total of 142 - 281 individual CEC compounds, depending on the sample matrix and site location. Separate result summaries for each CEC chemical class can be found in the Summary subsection of each CEC chemical class section within this document. This summary attempts to integrate all CEC contamination results into one analysis to assess overall contamination of sites in the Southern California Bight (Figure 44). Overall site contamination analysis was done using a multivariate cluster analysis for sums of contaminant concentrations in both mussel tissue and sediment samples. For each contaminant class, sites were clustered into five groups with statistically different degrees of overall contamination within this study.

The first observation of note, is that two mussel tissue sites (SANM and SCBR) had no detects of any CEC in any chemical class, although SANM was only analyzed for BFRs (Table A2, Table A3). Both of these sites are adjacent to the Channel Islands, locations with comparatively less human development than other sites assessed in this study (Figure 44). This distance from human presence and resulting inputs could explain the absence of detectable CEC contamination. Generally, the results indicate that, respective to sites analyzed in this study, low and medium contamination occurs across the Southern California Bight and high and very high contamination occurs primarily around more densely populated and developed areas (Figure 44, Table A2, Table A3). Most notably, one tissue site (LARM) and two sediment sites (SDHI and MDSJ) categorized as having “very high” contamination relative to the other sites analyzed are located near Los Angeles, CA and San Diego, CA which are densely populated areas (Table A2, Table A3).

Overall, the results indicate that CECs are present to varying degrees in the Southern California Bight and they are being accumulated at various concentrations in mussels and sediment. Mussel tissue or sediment samples from 33 out of 35 sites exhibited the presence of at least one CEC compound, highlighting the ubiquity of these contaminants in this region (Table 51, Table 52). In mussel tissue, APs had the highest detection frequency (16.7%), followed by PFASs (5.9%) (Table 53). In sediments, APs had the highest detection frequency (42.5%), followed by PBDEs (13.3%) (Table 54). It is important

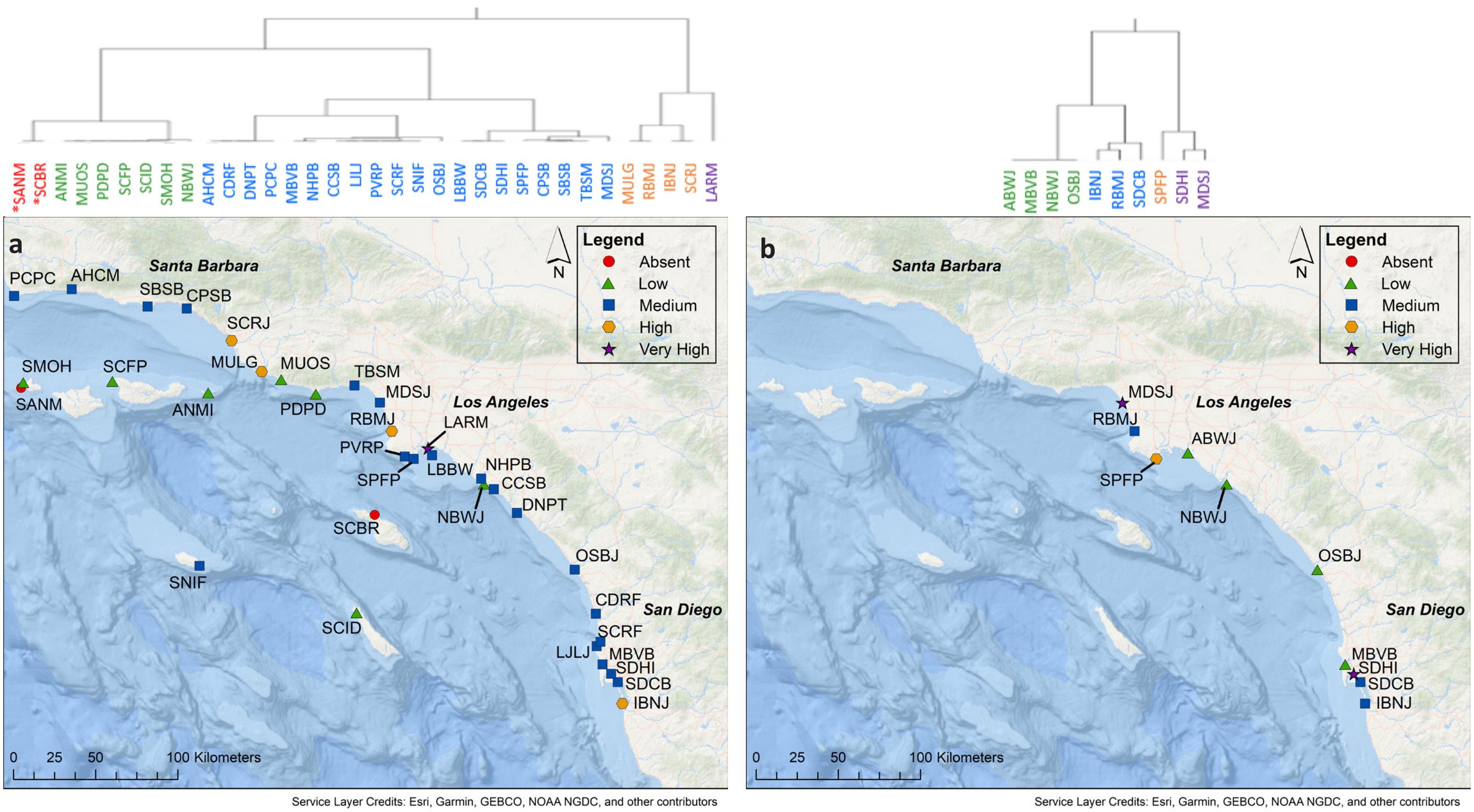


Figure 44. Map of Mussel Watch sites in the Southern California Bight highlighting locations with Absent, Low, Medium, High, and Very High degrees of contamination respective to one another in this study in (a) mussel tissue and (b) sediment. Cluster analysis results are also depicted above each corresponding map with the same color scheme as labeled in the map legends.

Table 51. Summary of coast-wide compound detection frequency in mussel tissue at each site.

Site	Total Compounds Detected	Total Compounds Analyzed	Total Detection Frequency	AP Total	AFR Total	PBB Total	PBDE Total	CUP Total	PFAS Total	PPCP Total
AHCM	1	140	0.7	1	0	0	0	0	0	--
ANMI	1	140	0.7	1	0	0	0	0	0	--
CCSB	7	140	5.0	0	0	0	3	0	4	--
CDRF	4	140	2.9	0	0	0	3	0	1	--
CPSB	4	140	2.9	1	0	0	2	0	1	--
DNPT	5	140	3.6	0	0	0	0	0	5	--
IBNJ	12	140	8.6	1	0	0	10	0	1	--
LARM	35	281	12.5	2	1	0	10	0	4	18
LBBW	16	280	5.7	0	0	0	6	0	3	7
LJLJ	3	140	2.1	0	0	0	0	0	3	--
MBVB	9	281	3.2	0	0	0	3	0	2	4
MDSJ	18	281	6.4	2	1	0	6	0	4	5
MULG	6	140	4.3	0	0	0	2	1	3	--
MUOS	1	140	0.7	1	0	0	0	0	0	--
NBWJ	5	281	1.8	0	0	0	0	0	1	4
NHPB	15	281	5.3	0	0	0	6	0	4	5
OSBJ	9	281	3.2	0	0	0	2	0	1	6
PCPC	1	140	0.7	0	0	0	0	0	1	--
PDPD	1	140	0.7	1	0	0	0	0	0	--
PVRP	2	140	1.4	1	0	0	0	0	1	--
RBMJ	7	140	5.0	2	0	0	2	0	3	--
SANM	0	70	0.0	--	--	0	0	--	--	--
SBSB	6	140	4.3	0	0	0	2	0	4	--
SCBR	0	140	0.0	0	0	0	0	0	0	--
SCFP	1	140	0.7	1	0	0	0	0	0	--
SCID	1	140	0.7	1	0	0	0	0	0	--
SCRF	3	140	2.1	1	0	0	0	0	2	--
SCRJ	4	140	2.9	1	0	0	0	1	2	--
SDCB	22	281	7.8	0	0	0	11	0	4	7
SDHI	18	281	6.4	2	0	0	5	0	5	6
SMOH	1	140	0.7	0	0	0	0	0	1	--
SNIF	2	140	1.4	1	0	0	0	0	1	--
SPFP	12	281	4.3	0	0	0	3	0	2	7
TBSM	3	140	2.1	2	0	0	0	0	1	--

to note that the presence, magnitude, and bioaccumulation of CECs in organisms such as mussels are typically compound dependent, with a small subset of contaminants representing the majority of detections within each chemical class.

While information regarding the context, toxicity, and overall impacts of CECs is still largely limited, results of this study in the Southern California Bight were compared to two similar studies conducted in the Gulf of Maine in 2015/2016 (Apeti et al., 2021) and along the California coast in 2009/2010 (Dodder et al. 2014). A total of 18 CECs were detected in both the Gulf of Maine study (Apeti et. al., 2021) and this Southern California Bight study (Table A4). Of those 18 compounds, the average contaminant concentrations were generally comparable, with the largest difference in average concentration only 8.0 ng/g ww (NP1EO) (Table A4). These comparisons provide context that the concentrations found in the Southern California Bight in this study are mostly consistent with existing data. More broadly, comparisons of detection frequency of each chemical class between the two studies showed similar contamination frequencies for all classes (Table A5).

Additionally, a total of 23 CECs were detected in both this Southern California Bight study and the west coast 2009-2010 study (Dodder et al. 2014) (Table A6). Of those 23 compounds, average contaminant concentrations showed average differences of less than 5.6 ng/g ww for all but four compounds (Table A6). There were large decreases in average concentrations of 4n-OP (difference of 468.4 n/g ww), NP1EO (73.9 ng/g ww), Lomefloxacin (18.7 ng/g ww), and Sulfamethazine (17.7 ng/g ww) (Table A6). The differences in concentrations found should be interpreted with consideration of methodology and inter-laboratory comparisons for context. Furthermore, in 2009 when the concentrations of 4n-OP and NP1EO were much higher, the average was skewed by high outliers, as evidenced by the median reported values being much less than the means (Dodder et al. 2014). These comparisons provide context that the concentrations found in the Southern California Bight in this study are consistent with concentrations detected in 2009/2010, with possible decreased contamination of 4n-OP, NP1EO, Lomefloxacin, and Sulfamethazine.

The influence of both anthropogenic and environmental factors makes it difficult to accurately predict the presence and concentration of CEC compounds in the environment. However, as this study shows, they are present and bioaccumulating to various degrees in coastal bivalves and sediment. This study provides needed data and information for the National MWP and provides contamination data required by coastal resource managers as they develop long-term policies to protect the services provided by the coastal environment within this region.

Table 52. Summary of coast-wide compound detection frequency in sediment at each site.

Site	Total Compounds Detected	Total Compounds Analyzed	Total Detection Frequency	AP Total	AFR Total	PBB Total	PBDE Total	CUP Total	PFAS Total
ABWJ	3	142	2.1	1	0	0	2	0	0
IBNJ	4	142	2.8	2	0	0	2	0	0
MBVB	5	142	3.5	2	0	0	3	0	0
MDSJ	10	142	7.0	1	1	0	4	1	3
NBWJ	3	142	2.1	2	0	0	1	0	0
OSBJ	2	142	1.4	2	0	0	0	0	0
RBMJ	3	142	2.1	2	0	0	1	0	0
SDCB	6	142	4.2	1	0	0	4	1	0
SDHI	9	142	6.3	2	1	0	4	0	2
SPFP	17	142	12.0	2	2	0	11	0	2

Table 53. Summary of coast-wide compound detection frequency in mussel tissue for each CEC compound class.

Compound Class	Total Detected	Total Possible Detects	Total Detection Frequency
AP	22	132	16.7
HBCD	2	99	2.0
PBB	0	646	0.0
PBDE	76	1734	4.4
CUP	2	990	0.2
PFAS	64	1089	5.9
PPCP	69	1409	4.9

Table 54. Summary of coast-wide compound detection frequency in sediment for each CEC compound class.

Compound Class	Total Detected	Total Possible Detects	Total Detection Frequency
AP	17	40	42.5
HBCD	4	30	13.3
PBB	0	190	0.0
PBDE	32	510	6.3
CUP	2	320	0.6
PFAS	7	330	2.1

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APPENDICES

Table A1. Percent dry values for tissue samples and % TOC values for sediment samples at each site collected in the Southern California Bight in 2018.

Site	% Dry of Tissue Samples*	% TOC of Sediment Samples**
ABWJ		0.08
AHCM	14.38	
ANMI	18.09	
CCSB	13.93	
CDRF	27.41	
CPSB	13.57	
DNPT	13.43	
IBNJ	15.59	0.02
LARM	16.67	
LBBW	16.99	
LJLJ	13.25	
MBVB	13.27	0.30
MDSJ	13.48	0.22
MULG	12.68	
MUOS	13.82	
NBWJ	11.98	0.04
NHPB	13.97	
OSBJ	12.57	0.02
PCPC	14.05	
PDPD	11.25	
PVRP	13.84	
RBMJ	13.17	0.01
SANM	17.09	
SBSB	14.01	
SCBR	14.87	
SCFP	16.67	
SCID	12.68	
SCRF	13.63	
SCRJ	28.45	
SDCB	15.18	0.21
SDHI	16.53	0.24
SMOH	15.00	
SNIF	15.55	
SPFP	13.71	1.52
TBSM	14.38	

** conc. (ng/g ww) = conc. (ng/g dw) x (% dry / 100)*

*** conc. TOC normalized (ng/g org.C) = conc. (ng/g dw) / (% TOC/100)*

Table A2. Breakdown of cluster analysis for mussel tissue in the Southern California Bight. The first section of the table is the cluster value assigned for each chemical class. The second section of the table is the calculations conducted to normalize the chemical class cluster sums by number of chemical classes assessed at each site. The final column is the overall chemical contamination cluster rank assigned to each site.

Site	AP Cluster	AFR Cluster	CUP Cluster	PBDE Cluster	PBB Cluster	PFAS Cluster	PPCP Other Cluster	PPCP Rx Antibiotic Cluster	PPCP Rx Cardio Cluster	PPCP Rx Misc. Cluster	PPCP Rx Psychiatric Cluster	PPCP Rx Steroid Cluster	PPCP Rec & PC Cluster	Cluster Sum	# Chemical Classes Analyzed	Normalized Cluster Value	Overall Cluster Rank
AHCM	2	0	0	0	0	0	--	--	--	--	--	--	--	2	5	13.3	2
ANMI	1	0	0	0	0	0	--	--	--	--	--	--	--	1	5	6.7	1
CCSB	0	0	0	1	0	2	--	--	--	--	--	--	--	3	5	20.0	2
CDRF	0	0	0	1	0	1	--	--	--	--	--	--	--	2	5	13.3	2
CPSB	1	0	0	1	0	2	--	--	--	--	--	--	--	4	5	26.7	2
DNPT	0	0	0	0	0	2	--	--	--	--	--	--	--	2	5	13.3	2
IBNJ	2	0	0	3	0	1	--	--	--	--	--	--	--	6	5	40.0	3
LARM	3	3	0	2	0	3	1	2	3	2	3	0	3	25	14	59.5	4
LBBW	0	0	0	1	0	1	1	2	0	3	2	0	0	10	14	23.8	2
LJLJ	0	0	0	0	0	3	--	--	--	--	--	--	--	3	5	20.0	2
MBVB	0	0	0	1	0	1	3	2	0	0	1	0	0	8	14	19.0	2
MDSJ	2	3	0	1	0	3	2	1	0	0	0	0	0	12	14	28.6	2
MULG	0	0	3	1	0	1	--	--	--	--	--	--	--	5	5	33.3	3
MUOS	1	0	0	0	0	0	--	--	--	--	--	--	--	1	5	6.7	1
NBWJ	0	0	0	0	0	1	1	1	0	0	0	0	0	3	14	7.1	1
NHPB	0	0	0	1	0	3	1	3	0	0	0	0	0	8	14	19.0	2
OSBJ	0	0	0	1	0	2	1	3	0	1	1	0	0	9	14	21.4	2
PCPC	0	0	0	0	0	2	--	--	--	--	--	--	--	2	5	13.3	2
PDPD	1	0	0	0	0	0	--	--	--	--	--	--	--	1	5	6.7	1
PVRP	1	0	0	0	0	2	--	--	--	--	--	--	--	3	5	20.0	2
RBMJ	2	0	0	1	0	2	--	--	--	--	--	--	--	5	5	33.3	3
SANM	--	--	--	0	0	--	--	--	--	--	--	--	--	0	2	0.0	0
SBSB	0	0	0	1	0	3	--	--	--	--	--	--	--	4	5	26.7	2
SCBR	0	0	0	0	0	0	--	--	--	--	--	--	--	0	5	0.0	0
SCFP	1	0	0	0	0	0	--	--	--	--	--	--	--	1	5	6.7	1
SCID	1	0	0	0	0	0	--	--	--	--	--	--	--	1	5	6.7	1
SCRF	2	0	0	0	0	1	--	--	--	--	--	--	--	3	5	20.0	2
SCRJ	1	0	3	0	0	2	--	--	--	--	--	--	--	6	5	40.0	3
SDCB	0	0	0	1	0	2	1	1	0	1	1	3	0	10	14	23.8	2
SDHI	2	0	0	1	0	3	1	3	0	0	0	0	0	10	14	23.8	2
SMOH	0	0	0	0	0	1	--	--	--	--	--	--	--	1	5	6.7	1
SNIF	1	0	0	0	0	2	--	--	--	--	--	--	--	3	5	20.0	2
SPFP	0	0	0	1	0	2	1	2	0	0	2	0	3	11	14	26.2	2
TBSM	2	0	0	0	0	2	--	--	--	--	--	--	--	4	5	26.7	2

Table A3. Breakdown of cluster analysis for sediments in the Southern California Bight. The first section of the table is the cluster value assigned for each chemical class. The second section of the table is the calculations conducted to normalize the chemical class cluster sums by number of chemical classes assessed at each site. The final column is the overall chemical contamination cluster rank assigned to each site.

Site	AP Cluster	AFR Cluster	CUP Cluster	PBDE Cluster	PBB Cluster	PFAS Cluster		Cluster Sum	# Chemical Classes Analyzed	Normalized Cluster Value		Overall Cluster Rank
ABWJ	1	0	0	1	0	0		2	5	13.3		1
IBNJ	2	0	0	2	0	0		4	5	26.7		2
MBVB	1	0	0	1	0	0		2	5	13.3		1
MDSJ	1	3	3	1	0	3		11	5	73.3		4
NBWJ	1	0	0	1	0	0		2	5	13.3		1
OSBJ	2	0	0	0	0	0		2	5	13.3		1
RBMJ	3	0	0	2	0	0		5	5	33.3		2
SDCB	1	0	3	2	0	0		6	5	40.0		2
SDHI	1	3	0	3	0	3		10	5	66.7		4
SPFP	1	3	0	1	0	3		8	5	53.3		3

Table A4. Compound average concentration (ng/g ww) comparison for compounds analyzed and detected in both this 2018 Southern California Bight study and the 2015/2016 Gulf of Maine MWP study.

Chemical Class	Compound	Gulf of Maine Average	Southern California Bight Average	Difference in Average
AP	4n-OP	1.4	1.6	-0.1
AP	NP1EO	9.2	17.1	-8.0
BFR	PBDE-100	0.2	0.1	0.1
BFR	PBDE-119	0.1	0.0	0.1
BFR	PBDE-47	0.2	0.4	-0.2
BFR	PBDE-66	0.1	0.0	0.0
BFR	PBDE-71_49	0.2	0.1	0.1
BFR	PBDE-77	0.2	0.0	0.2
BFR	PBDE-99	0.1	0.2	-0.1
PFAS	PFOS	0.6	0.0	0.6
PFAS	PFOSA	1.4	0.2	1.2
PPCP Prescription Drugs (Psychiatric)	Amitriptyline	2.3	0.0	2.3
PPCP Prescription Drugs (Psychiatric)	Fluoxetine	4.9	0.1	4.8
PPCP Prescription Drugs (Psychiatric)	Sertraline	4.4	0.4	4.0
PPCP Recreational and Personal Care Drugs & Products	DEET	5.4	0.0	5.4
PPCP Recreational and Personal Care Drugs & Products	Diphenhydramine	1.2	0.1	1.1
PPCP Recreational and Personal Care Drugs & Products	Triclocarban	3.6	0.1	3.6

Table A5. Chemical class frequency of detection comparison between this 2018 Southern California Bight study and the 2015/2016 Gulf of Maine MWP study.

Chemical Class	Gulf of Maine			Southern California Bight			Difference in Average
	# Detects	# Analyzed	Frequency (%)	# Detects	# Analyzed	Frequency (%)	
AP	16	160	10.0	22	132	16.7	-6.7
AFR	7	342	2.0	2	99	2	0.0
PBB	0	779	0.0	0	646	0	0.0
PBDE	150	2091	7.2	76	1734	4.4	2.8
CUP	0	1308	0.0	2	990	0.2	-0.2
PFAS	18	480	3.8	64	1089	5.9	-2.1
PPCP	113	4838	2.3	69	1409	4.9	-2.6

Table A6. Compound average concentration (ng/g ww) comparison for compounds analyzed and detected in both this 2018 Southern California Bight study and the 2009 California study (Dodder et al., 2014).

Chemical Class	Compound	California Average	Southern California Bight Average	Difference in Average
AP	4n-OP	470.0	1.6	468.4
AP	NP1EO	91.0	17.1	73.9
AFR	HBCD, alpha	0.3	0.1	0.2
BFR	PBDE-100	1.3	0.6	0.7
BFR	PBDE-153	0.2	0.2	0.0
BFR	PBDE-154	0.1	0.2	-0.1
BFR	PBDE-17	0.2	0.3	-0.1
BFR	PBDE-28	0.2	0.2	0.0
BFR	PBDE-47	6.6	1.0	5.6
BFR	PBDE-66	0.4	0.1	0.3
BFR	PBDE-49/71	0.6	0.4	0.2
BFR	PBDE-99	3.4	0.5	2.9
CUP	Dacthal	2.7	0.2	2.5
PFAS	PFDoDA	1.8	0.7	1.1
PFAS	PFUnDA	0.2	0.2	0.0
PPCP Prescription Drugs (Antibiotic)	Enrofloxacin	1.3	1.6	-0.3
PPCP Prescription Drugs (Antibiotic)	Erythromycin-H2O	0.1	1.2	-1.1
PPCP Prescription Drugs (Antibiotic)	Lomefloxacin	29.0	10.3	18.7
PPCP Prescription Drugs (Antibiotic)	Ofloxacin	1.2	1.0	0.2
PPCP Prescription Drugs (Antibiotic)	Sulfamethazine	24.0	6.3	17.7
PPCP Prescription Drugs (Psychiatric)	Amitriptyline	0.4	0.4	0.0
PPCP Prescription Drugs (Psychiatric)	Sertraline	1.4	0.7	0.7
PPCP Recreational and Personal Care Drugs & Products	Diphenhydramine	0.9	0.7	0.2

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