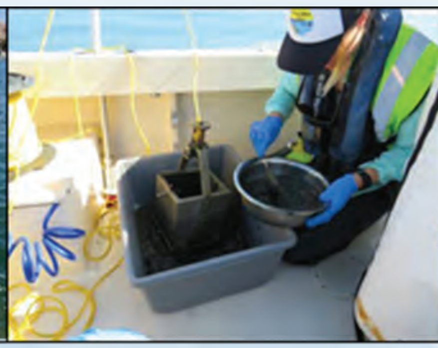
Occurrence and Bioaccumulation of Dissolved Organochlorines in San Diego Bay



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INTRODUCTION

San Diego Bay supports a diverse assemblage of fish species, which provides beneficial uses to both sport and sustenance fishermen; however, it is currently listed under the San Diego Regional Water Quality Control Board (SDRWQCB) Clean Water Act Section 303(d) list as impaired due to polychlorinated biphenyls (PCBs). The State of California Office of Environmental Health Hazard Assessment has issued a health advisory and guidelines for eating fish from San Diego Bay (OEHHA 2018), which recommends no consumption of some species due to tissue concentrations of PCBs and mercury. Previous efforts, including the 2013 Regional Harbor Monitoring Program (RHMP) Bioaccumulation Special Study effort (Amec Foster Wheeler 2017), the 2014 Shallow Water Habitat Study in San Diego Bay (Amec Foster Wheeler 2016), and an integrated food web bioaccumulation study (Bay et al. 2016) have quantified the levels of PCBs and other constituents of potential concern (COPCs) in fish and sediments from San Diego Bay. These studies have found PCB concentrations in some species of fish from the bay to exceed human consumption advisory levels (OEHHA 2008). Bioaccumulation in fish tissue is strongly influenced by contaminant concentrations in both sediment and water (U.S. Environmental Protection Agency [USEPA] 2000).

There are multiple sources of current and legacy inputs of PCBs and other organochlorine contaminants into San Diego Bay. These include stormwater runoff and industrial/military waste discharges (Chadwick et al. 1999). Current patterns of PCB contamination in Bay sediments are described by Douglas (2019). Much progress has been made in remediating contaminant hotspots in San Diego Bay and several locations have been identified for future cleanup activities. Planning of remediation actions often includes a goal of restoring sediment concentrations to ambient background concentrations in the bay, with the expectation that reduced sediment contaminant concentrations will result in proportionally reduced contaminant burdens in seafood.

Additional tools for evaluating the linkage between sediments and biota have recently been developed by the State Water Resources Control Board. The Water Board adopted an assessment framework for its sediment quality objective to protect human health (HHSQO) in 2018, which received EPA approval in 2019 (SWRCB 2018). This framework incorporates the use of bioaccumulation models to estimate the degree of linkage between site sediment and resident fish (Bay et al. 2017). This HHSQO assessment framework, and its associated bioaccumulation models, provides tools to plan and evaluate the success of sediment remediation efforts in San Diego Bay.

Bioaccumulation of PCBs and chlorinated pesticides in aquatic life occurs as a result of both dietary intake of contaminated prey and sediment (including incidental consumption of sediment associated with prey), and through the uptake from the water column by the gills/body surface. Water column concentrations can account for a large proportion of the body burden in species that reside in the water column and/or feed primarily on plankton. Most bioaccumulation models include water column exposure, but measurements of dissolved pesticides and PCBs can be limited or uncertain because site specific data are either not available or are limited by high detection limits. Use of bioaccumulation modeling for planning sediment remediation in San Diego Bay is also complicated by the movement of water throughout the bay. Tides, ship activity, and other factors affect movements of water and sediment and may alter the strength of the relationship between sediment and water column contamination within a site, which can limit the accuracy of the HHSQO assessment framework when applied on a discrete site-specific basis.

Recent studies in San Diego Bay have contributed to our understanding of PCB sources, fate, and bioaccumulation in the bay. A synthesis of historical and current chemical data evaluated the sources and movement of PCBs throughout the bay (Douglas 2019). This study concluded that historical deposits of PCBs in sediments are the predominant source of food web contamination in the bay and that extensive mixing of PCBs has occurred throughout the bay. The HHSQO bioaccumulation model was adapted and calibrated for use in investigating various PCB management scenarios in San Diego Bay (Toll 2019). The resulting model parametrized by Toll (2019) was effective in describing bioaccumulation relationships within San Diego Bay.

The objectives of this study were to investigate the contributions of sediment organochlorines (PCBs, DDTs, and chlordanes) to the water column in San Diego Bay and to evaluate the influence of these conditions on biota contamination and bioaccumulation model estimates. This study was a joint venture, conducted in partnership with the Port of San Diego, City of San Diego, Wood Environment and Infrastructure Solutions, Inc. (Wood), and Naval Information Warfare Center (NIWC, formally SPAWAR Systems Center). DDTs, dieldrin, and chlordanes were included in the study as sediment concentrations throughout the bay are low, and fish tissue sampling throughout the bay has reported low concentrations, with results typically meeting State of California Fish Contamination Goals (OEHHA 2008).

This report includes a summary of results from a fish contamination study conducted by our partners (Wood 2019) as well as preliminary PCB fate analyses by NIWC. These results are combined with chemical analyses of organochlorines in sediment, pore water and the water column to address the study objectives. Bioaccumulation modeling was used to investigate the relative influence of sediment and water contamination on food web contamination. Some of the analyses and comparisons are restricted to PCBs for the sake of brevity or because of lack of data for other contaminant groups. This report also contains recommendations to improve the use of bioaccumulation models for contaminated sediment assessment and management in San Diego Bay.

SAMPLING AND ANALYSIS

This study included two sampling events in 2018: March-June (Event 1, winter) and September-October (Event 2, summer). The use of two sampling events was intended to investigate the level of temporal variation in water column and biota contaminant concentrations. In this context, temporal variation refers simply to differences between the two sampling events, the study design and data are not sufficient to determine whether such changes are the result of seasonal factors or long-term processes such as natural remediation.

Ten stations were sampled throughout San Diego Bay, representing a range of contaminant levels (Figure 1 and Table 1). Both sampling events included collection of sediment and water column grab samples, fish and phytoplankton samples, and passive sampling for calculation of dissolved contaminants in the water column, pore water, and sediment-water interface. The water column grab samples (1 L) were collected at a subset of five stations. Sediment grab samples and water column passive samplers were collected at all ten stations. Passive samplers were deployed for approximately 30 days with water grabs collected upon deployment and retrieval, and sediment grabs collected on retrieval.

Biota samples were collected by Wood during each deployment event in areas near a subset of six stations (Figures 2-6). Three species of fish were targeted: spotted sand bass (*Paralabrax maculatofasciatus)*, shiner perch (*Cymatogaster aggregata)*, and topsmelt (*Atherinops affinis)*, using a combination of trawls, seine nets, and hook and line fishing. Plankton tows were also conducted at each site to obtain a sample of mixed zooplankton for chemical analysis. Details of the biota sampling and tissue chemical analyses are described in a separate report (Wood 2019).

All sediment and water samples were analyzed for chlordanes, dieldrin, DDTs, and PCBs. Dieldrin was not measured in biota, and so was not included in the bioaccumulation modeling. Total organic carbon (TOC), dissolved organic carbon (DOC), and lipid content were measured in sediment, water, and biota, respectively. PCB analyses for biota included the 63 congeners specified by the HHSQO framework (Table 2). A subset of 43 of these congeners was analyzed in the passive sampler and sediment grab samples. Total PCBs concentrations were calculated as the sum of the subset of congeners analyzed in tissue and sediment. The subset of congeners selected for summation represents the most prevalent congeners occurring in Southern California and is consistent with the congeners used in statewide and regional monitoring programs. However, use of a subset of congeners will result in an underestimate of the total PCB concentration compared to analysis of all 209 congeners. Analytical chemistry methods are described in Attachment 1.

Table 1. Station location coordinates within San Diego Bay and sample types collected.

Station ID	Latitude	Longitude	Water Grab	Sediment Grab	Passive Samplers *(Sediment and water column)*	Biota
SDBay-1	32.7245400	-117.2246600	x	x	x	x
SDBay-2	32.7174512	-117.2159143		x	x	
SDBay-3	32.7267390	-117.1761710	x	x	x	x
SDBay-4	32.7024000	-117.1617800		x	x	
SDBay-5	32.6929000	-117.1480000		x	x	
SDBay-6	32.6847938	-117.1600035		x	x	x
SDBay-7	32.6862720	-117.1338100	x	x	x	x
SDBay-8	32.6651840	-117.1498040	x	x	x	x
SDBay-9	32.6469360	-117.1182380		x	x	
SDBay-10	32.6258023	-117.1115252	x	x	x	x

Figure 1. Station locations in San Diego Bay. Figure courtesy of Wood Environment and Infrastructure Solutions, Inc.

Figure 2. Biota collection areas for Station 1. Green = bass, topsmelt, and zooplankton collection; yellow = perch collection. Figure courtesy of Windward Environmental, LLC.

Figure 3. Biota collection area for Station 3. Figure courtesy of Windward Environmental, LLC.

Figure 4. Biota collection areas for Stations 6 and 7. Blue = bass, and topsmelt collection; magenta & blue = zooplankton collection. Figure courtesy of Windward Environmental, LLC.

Figure 5. Biota collection area for Station 8. Figure courtesy of Windward Environmental, LLC.

Figure 6. Biota collection area for Station 10.

Table 2. Constituents analyzed in samples.

Sediment TOC	**PCBs**	**PCBs cont.**	**PCBs cont.**
	PCB 8	PCB 95*	PCB 157
Water DOC	PCB 11*	PCB 97*	PCB 158
	PCB 18	PCB 99	PCB 167
Tissue % lipid	PCB 27*	PCB 101	PCB 168
	PCB 28	PCB 105	PCB 169
Chlordanes	PCB 29*	PCB 110	PCB 170
cis-Chlordane	PCB 31*	PCB 114	PCB 174*
trans-Chlordane	PCB 33*	PCB 118	PCB 177
cis-Nonachlor	PCB 37	PCB 119	PCB 180
trans-Nonachlor	PCB 44	PCB 123	PCB 183
Oxychlordane	PCB 49	PCB 126	PCB 187
	PCB 52	PCB 128	PCB 189
Dieldrin	PCB 56*	PCB 132*	PCB 194
	PCB 60*	PCB 137*	PCB 195*
DDTs	PCB 64*	PCB 138	PCB 198*
op-DDD	PCB 66	PCB 141*	PCB 199*
op-DDE	PCB 70	PCB 146*	PCB 200
op-DDT	PCB 74	PCB 149	PCB 201
pp-DDD	PCB 77	PCB 151	PCB 203*
pp-DDE	PCB 81	PCB 153	PCB 206
pp-DDT	PCB 87	PCB 156	PCB 209

*Measured only in tissue samples.

Water Column Grab Sampling

A mid-column water sample was collected by Wood using a Van Dorn bottle at 5 stations (Table 1) during both sampling events. Water samples were collected twice during each event; near the start of the deployment of the passive sampling devices and at the time of passive sampling device recovery. Temperature, dissolved oxygen, salinity, and pH measurements were obtained using a handheld meter.

Passive Sampling of Water and Sediment

Passive samplers were used to calculate water concentrations of dissolved PCBs, DDTs, chlordane, and dieldrin. Passive sampling devices (PSDs) were used in this study to provide measurement of individual congener concentrations at low detection limits, as well as to obtain a time-weighted average concentration for the site. Analysis of chlorinated pesticide and PCB concentrations in associated sediment and water grab samples allows for direct comparison to the data derived from the PSDs to enable a more accurate assessment of partitioning among particulate and dissolved phases. Passive sampling devices were deployed at each station for both sampling events, each for approximately 28 days. SCCWRP water column PSDs and NIWC sediment-water interface PSDs were deployed during each sampling event.

The water column PSDs consisted of low-density polyethylene (LDPE) film with a thickness of 25 µm threaded onto copper wire loops in two pieces; one 91 cm x 10 cm, 2 g piece with no PRCs (performance reference compounds); and one 4.3 cm x 10 cm, 0.1 g surrogate sampler containing PRCs. PRCs were used to correct estimated concentrations for particularly hydrophobic target analytes (e.g., PCBs with 6 or more chlorines) which are not expected to reach equilibrium between the water column or sediment porewater and the LDPE material during an approximate 28-day exposure period. The PRCs included a suite of representative unlabeled PCB congeners that span a wide range of chlorination (and thus hydrophobicity) and that are rarely detected in the environment (Table 3); a C-13 labeled DDE was used as a PRC for the DDT compounds. The nominal pre-loading PRC concentration was 1000 ng PRC/g LDPE. Triplicate water column PSDs were set at mid-depth for each site.

The sediment-water interface PSDs consisted of the same LPDE film mounted in a stainless-steel sampling frame (53 cm x 20 cm, 2.4 g) with one replicate per site. The entire film was loaded with PRCs. Upon retrieval, the samplers were split into two subsamples: the sediment pore water portion (below sediment-interface) and the water portion (just above sediment-water interface). Sediment-water interface samples collected during Event 1were analyzed by SCCWRP for the same analytes measured in sediment (Table 2). The Event 2 sediment-water interface samples were analyzed by NIWC for a subset of 18 PCB congeners used in the NOAA Status and Trends Program; total PCBs for these samples were estimated by multiplying the sum of congeners by a factor of 2 (approach used by NOAA Status and Trends).

Passive sampling deployment times and sampling success varied as a result of site access limitations, equipment malfunction, and sampler loss. Additional detail regarding sampling activities for each event are provided in Attachments 2 and 3.

Diffusive flux of PCBs from the sediment was calculated for each station as:

Flux (g/cm/s) = (D_water)(PCB Gradient)/Benthic Boundary Layer thickness

D_water = 4E-6 cm^2/s

Gradient = (Pore water PCB - surface water PCB) ng/L

BBL thickness = 0.01 cm (100 µm)

Table 3. Performance reference compounds (PRCs) for LDPE film passive samplers.

Compound	No. Cl	log K_{ow}
PCB 30	3	5.4
PCB 50	4	5.6
PCB 98	5	6.1
PCB 155	6	6.6
PCB 184	7	6.9
PCB 204	8	7.3
13C p,p'- DDE	4-Cl	6.9

BIOACCUMULATION MODELING

The bioaccumulation models developed for the HHSQO assessment framework were used in this study. Details of model application are described in Bay et al. (2017). These models were adapted from the Arnot and Gobas (2004) food web model, modified by Gobas and Arnot (2010) for use in modeling PCBs in San Francisco Bay. The Arnot and Gobas model is structured to depict contaminant concentration in biota as the mass balance of key uptake and loss processes. The model structure accounts for uptake by diet and respiration; loss by egestion, metabolism, and respiratory elimination; and growth dilution:

Biota Concentration (C_{Biota}) =

(Respiratory Uptake*Water Concentration+ Dietary Uptake*Prey Concentration) /

(Elimination + Fecal Egestion + Growth + Metabolism)

Several modifications were made to the Gobas and Arnot model for the HHSQO framework. The first change was to expand the list of PCB congeners and add three classes of chlorinated pesticides: chlordanes, dieldrin, and DDTs. The second modification consisted of basing temperature and salinity corrected K_{OW} values for each congener on site-specific measurements. Third, an equilibrium partitioning approach was used to estimate dissolved contaminant concentrations in the water column in situations when measured values were not available. These estimations were based on the same model used to estimate contaminant concentrations in pore water; one-eighth of the calculated pore water value was used for the water column model input in cases where measured data were not available, or the measured concentration was higher than the estimate. Finally, the model's food web structure was modified to be more inclusive of the diverse types of sport fish in California bays and estuaries. This included the addition of several sport fish, including the California halibut, spotted sand bass, queenfish, common carp, topsmelt, and striped mullet. Additional prey items were also added, such as macrophytes and the decapod crab. Evaluation of the bioaccumulation model's performance when applied to southern California embayments is described in Bay et al. (2017).

The model uses a food web structure that is specific for each of nine fish indicators, representing different dietary types or habitats. For each indicator, calculations are performed on a congener-specific basis and later summed to provide total contaminant concentration (i.e., total PCBs, DDTs, and chlordanes).

The modeling parameters for this study included site-specific measurements of sediment and water column contaminants, sediment TOC, water DOC, fish tissue lipid, and water quality characteristics (temperature, salinity, dissolved oxygen). The average values recorded during Events 1 and 2 were used for model inputs. Using the model, an estimated tissue concentration was calculated for each congener/metabolite and then summed to obtain the total estimated tissue concentration of PCBs, DDTs, and chlordanes. Estimated tissue concentrations were compared to the average of biota composites collected during each sampling event. Separate model runs were conducted for each of the six stations for which biota were collected: SD1, 3, 6, 7, 8, and 10.

Estimated tissue concentrations were calculated for four types of biota: spotted sand bass, shiner perch, topsmelt, and zooplankton. Shiner perch and topsmelt could not be collected from some locations, limiting the number of comparisons for these species.

Exploratory model analyses

Three variations of bioaccumulation model application were used to investigate habitat and mechanistic factors potentially affecting bioaccumulation.

Influence of water column contamination

Contaminant uptake from water via respiration is one of two routes of contaminant exposure/accumulation in aquatic organisms. Variation in dissolved contaminant concentration therefore has a potentially large influence on bioaccumulation for all species, regardless of dietary guild.

The relative influence of water column chemical contamination was evaluated by varying the dissolved chemical concentrations used for model inputs. Three scenarios were evaluated: 1) use of measured dissolved concentrations as specified in the SQO assessment framework (baseline), 2) use of estimated, rather than measured, dissolved concentration, and 3) lack of dissolved contaminants in the water column (dissolved concentration set to zero). The predicted biota tissue concentrations from scenarios 2 and 3 were compared to results from unaltered (baseline) bioaccumulation model.

Bioaccumulation site scale

Bioaccumulation model performance is very sensitive to variation in water and sediment chemical concentrations. Sediment grab and water column chemistry data were available for only a single location for each of the six biota sampling stations. Some of these stations were located in marinas or commercial sites likely to have substantial spatial chemistry gradients among the biota's forage range that could bias the model results. The influence of spatial variation in sediment contamination was investigated by applying the baseline bioaccumulation model to predict tissue concentration for average sediment/dissolved chemistry data representing four spatial scales: station (sampling location, P_Station), biota collection area (P_Area), bay region (North, Central, or South; P_Region), and entire bay (P_Bay). These model predictions were conducted for PCB congener 118, previously established by Windward Environmental, LLC to be a good indicator of overall PCB contamination patterns in San Diego Bay (Toll 2019). The Windward analyses were based on a large database compiled from pre-existing San Diego Bay sediment data collected since 2008 and including new measurements conducted in 2017 and 18 (Douglas 2019).

Site-specific model calibration

Tissue predictions from the SQO bioaccumulation model were compared to those from the calibrated model developed by Windward that was used to evaluate bay sediment management scenarios (Toll 2019). PCB118 sediment data from the site-wide analysis was used for this comparison. The baseline SQO model and two variations of the SQO model that incorporated parameters in the Windward model were used in the comparison.

CHEMICAL ANALYSIS RESULTS AND DISCUSSION

Sediment

Sediment chemistry results for Events 1 and 2 are summarized in Figures 7-9 (courtesy of Wood) and Tables 4-7. Concentrations in the figures are presented as symbols representing five concentration range categories. Each range of values was derived by dividing the full range of concentrations measured during this study into five equal bins.

Overall, chemical concentrations were elevated to a greater degree at sites within marinas and commercial/industrial terminals (SD1, 3, 4, 5, and 7). PCBs and chlordanes were most prevalent in the bay, with detections at 10/10 and 9/10 stations, respectively. DDTs and dieldrin were detected in sediments at approximately half of the sites.

Total PCB concentrations across both events ranged from 0.84 ng/g dw (SD2 Event 2) to 690 ng/g dw (SD5 Event 2). Total chlordane concentrations ranged from non-detect (SD2 Event 2) to 14.2 ng/g dw (SD7 Event 1). Total DDT concentrations in the sediments ranged from non-detect (SD2, 6, 8, 9, and 10) to 17.4 ng/g dw at SD1 (Event 2). Little temporal variation in concentrations between sampling events was evident for most stations. The exception was PCBs at stations SD1 & 5, which had much higher concentrations for Event 2. The sample locations at both SD1 and 5 were collected approximately 50 to 60 meters apart between the two sampling events due to access issues at these sites. It is likely that the variability observed between sampling events at these sites was driven by small scale spatial variability as opposed to temporal differences.

Sediment TOC, an important bioaccumulation factor, was similar among most stations and between events (Tables 5 and 7). The exception was SD2, which had much lower TOC (0.2-0.3%) compared to other locations (0.4-1.9%).

Table 4. Summary of pesticide and PCB concentrations in sediment grab samples collected during Event 1 (May 2018) in San Diego Bay.

Chemical	SD-01	SD-02	SD-03	SD-04	SD-05	SD-06	SD-06 Duplicate	SD-07	SD-08	SD-09	SD-10
Sum Chlordanes (ng/g dw)	3.57	≤0.017	12.4	7.84	1.50	0.115	0.105	14.2	0.332	0.431	0.268
Dieldrin (ng/g dw)	0.330	<0.121	0.561	0.727	0.189	<0.121	<0.121	1.64	<0.121	<0.121	<0.121
Sum DDTs (ng/g dw)	10.4	<0.250	3.55	2.51	2.30	<0.250	<0.250	5.89	≤0.366	0.748	≤0.646
Sum PCBs (ng/g dw)	394	2.40	285	71.4	152	7.20	6.70	86.3	20.6	10.2	9.37

'<' symbol represents a non-detect with the value equal to the MDL **'≤' symbol represents a detection but at an estimated concentration lower than the MDL**

Table 5. Summary of sediment TOC and water DOC concentrations during Event 1 (March-June 2018) in San Diego Bay.

Chemical	SD-01	SD-02	SD-03	SD-04	SD-05	SD-06	SD-07	SD-08	SD-09	SD-10
Sediment TOC (%)	1.92	0.31	1.35	1.81	1.71	0.42 (0.41)*	1.95	0.92	1.13	1.56
Water DOC-Deployment (mg/L)	0.94	NC	1.04 (1.10)*	NC	NC	NC	1.17	1.27	NC	1.55
Water DOC-Retrieval (mg/L)	0.83 (0.82)*	NC	0.89	NC	NC	NC	0.79	0.95	NC	0.94

NC=Not collected ***Duplicate sample values in parentheses** **'<' symbol represents a non-detect with the value equal to the MDL**

'≤' symbol represents a detection but at an estimated concentration lower than the MDL

Table 6. Summary of pesticide and PCB concentrations in sediment grab samples collected during Event 2 (October 2018) in San Diego Bay.

Chemical	SD-01	SD-02	SD-03	SD-03 Duplicate	SD-04	SD-05	SD-06	SD-07	SD-08	SD-09	SD-10
Sum Chlordanes (ng/g dw)	5.89	≤0.017	9.47	8.42	3.30	1.36	0.208	10.9	0.241	0.275	0.245
Dieldrin (ng/g dw)	0.333	<0.164	0.308	0.343	0.211	0.427	<0.164	0.987	<0.164	<0.164	<0.164
Sum DDTs (ng/g dw)	17.4	<0.321	4.57	4.39	1.43	2.46	≤0.354	4.02	≤0.346	≤0.544	0.698
Sum PCBs (ng/g dw)	653	0.840	295	276	62.4	690	14.1	102	16.8	7.30	10.8

‘<’ symbol represents a non-detect with the value equal to the MDL **‘≤’ symbol represents a detection but at an estimated concentration lower than the MDL**

Table 7. Summary of sediment TOC and water DOC concentrations during Event 2 (Sept-Oct 2018) in San Diego Bay.

Chemical	SD-01	SD-02	SD-03	SD-04	SD-05	SD-06	SD-07	SD-08	SD-09	SD-10
Sediment TOC (%)	1.91	0.16	1.50 (1.49)*	1.03	1.69	0.70 (0.71)*	1.85	0.74	0.88	1.47
Water DOC-Deployment (mg/L)	1.17 (1.05)*	NC	1.30	NC	NC	NC	2.01	1.58	NC	1.43
Water DOC-Retrieval (mg/L)	0.83 (0.81)*	NC	0.88	NC	NC	NC	0.86	1.03	NC	1.14

NC=Not collected ***Duplicate sample values in parentheses** **‘<’ symbol represents a non-detect with the value equal to the MDL**

‘≤’ symbol represents a detection but at an estimated concentration lower than the MDL

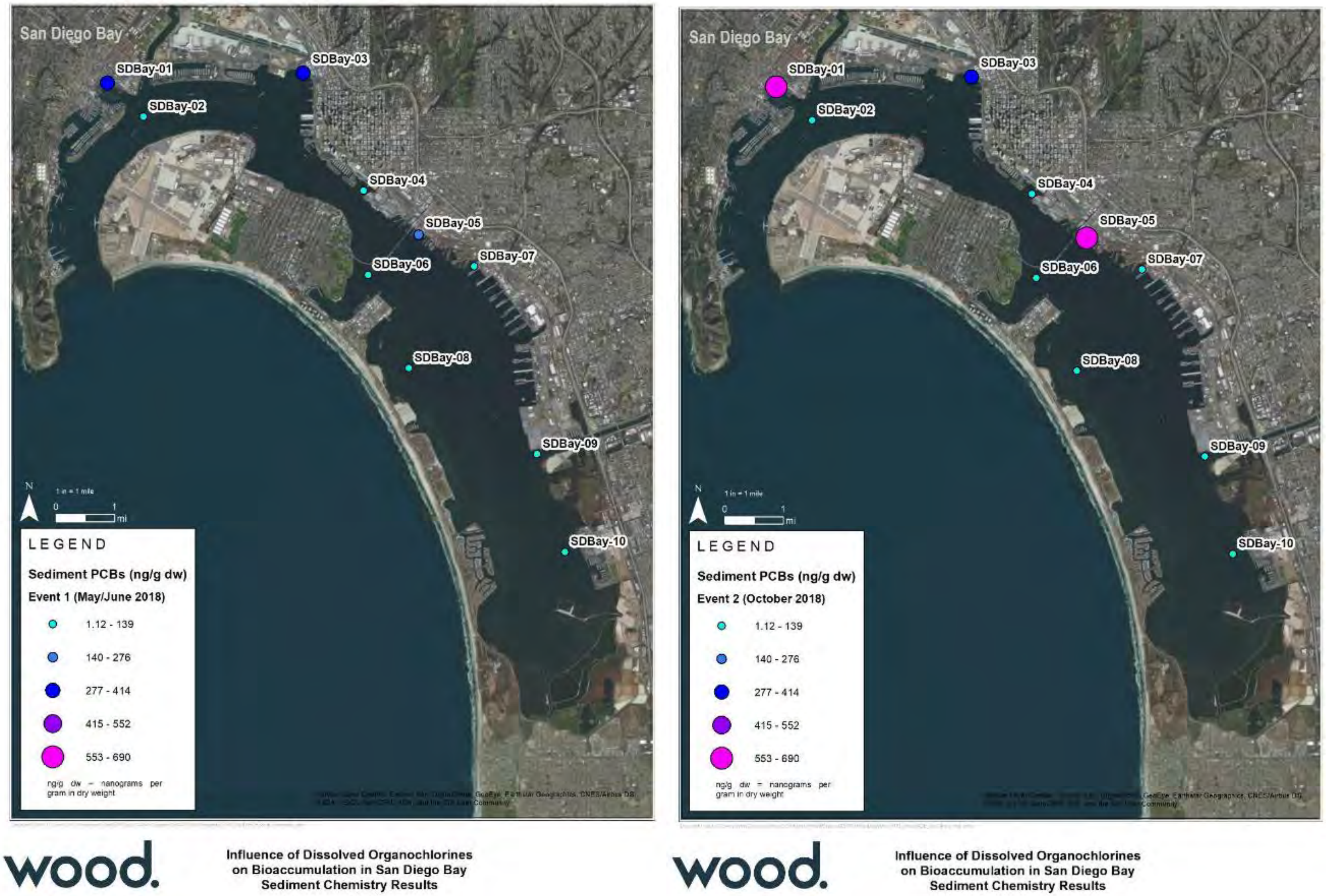
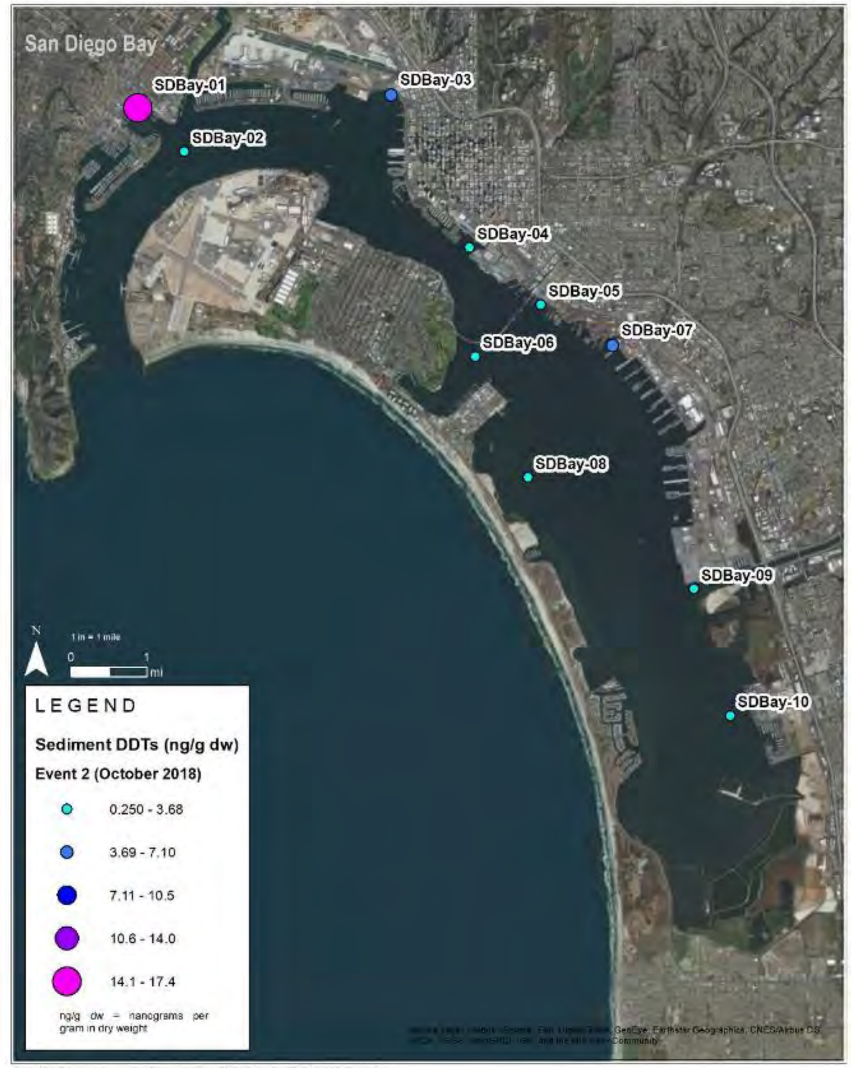


Figure 7. Sediment PCBs in Event 1 (left) and 2 (right). Figure courtesy of Wood Environment and Infrastructure Solutions, Inc.



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Influence of Dissolved Organochlorines on Bioaccumulation in San Diego Bay Sediment Chemistry Results

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Influence of Dissolved Organochlorines on Bioaccumulation in San Diego Bay Sediment Chemistry Results

Figure 8. Sediment DDTs in Event 1 (left) and 2 (right). Figure courtesy of Wood Environment and Infrastructure Solutions, Inc.

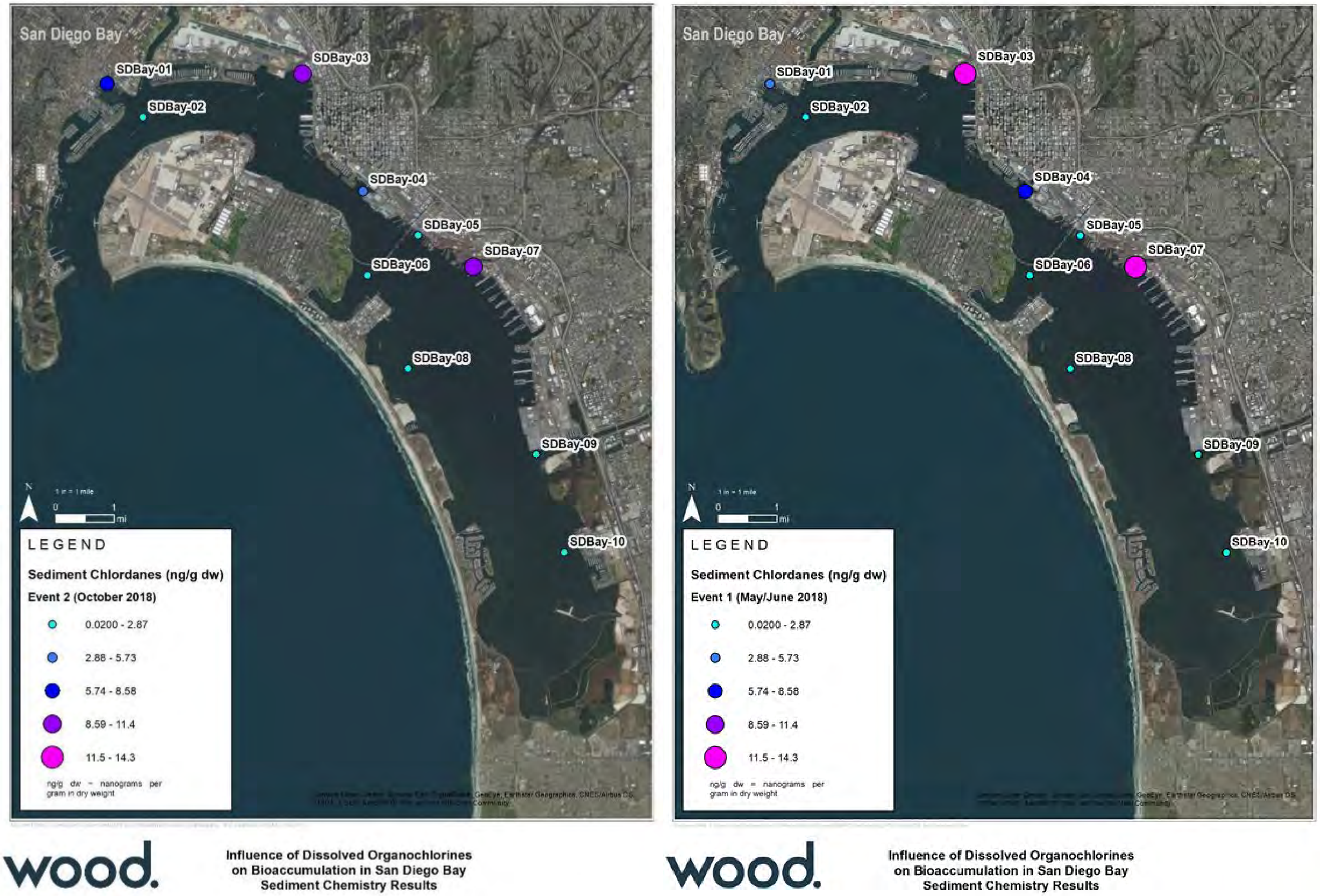

Figure 9. Sediment chlordanes in Event 1 (left) and 2 (right). Figure courtesy of Wood Environment and Infrastructure Solutions, Inc.

Water

The passive samplers detected dissolved PCBs, DDTs, and chlordanes in the water column at all stations during both events (Tables 8 and 10). PSD-derived concentrations in the water generally corresponded to contamination patterns in the sediment, with the highest dissolved values measured in passive samplers collected in areas with the highest sediment concentration. Water column concentrations of chlordane, dieldrin, and DDTs were less than the water quality objective for human health protection (California Toxics Rule for consumption of organisms [40CFR 131]). Dissolved PCB concentrations exceeded the water quality objective for human health protection at 4 stations during Event 1 and at 9 stations during Event 2.

Linear regression analysis indicated that dissolved PCBs in the water column were strongly associated with sediment concentration at the same site (Figure 10). The regression results indicated that variation in sediment PCBs accounted for 82-85% of variation in dissolved PCBs. However, the regression lines do not pass through zero indicating that other sources, such as particulates which were shown by Douglas (2019) to have measurable concentrations of PCBs, may have contributed to water column concentrations.

An apparent temporal influence on the sediment-water column contaminant relationship was present. Dissolved concentrations during Event 2 were approximately twice as high as those measured at similar sediment concentrations during Event 1 (Figure 10). The slope of the sediment-water regression was similar between events.

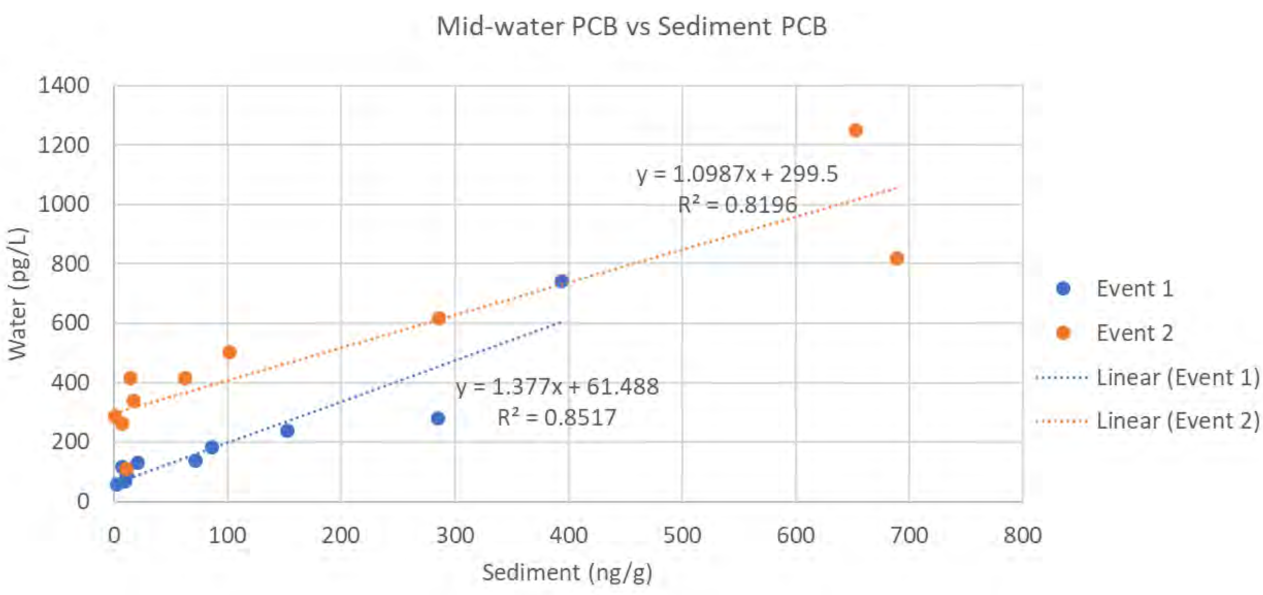

Figure 10. Relationship between dissolved PCBs in the water column (calculated from PSDs) and sediment. Figure and analysis courtesy of NIWC.

Table 8. Summary of mean (n=3) water column passive sampler contaminant concentrations during Event 1 (March-June 2018).

Chemical	WQO	SD-01	SD-02	SD-03	SD-04	SD-05	SD-06	SD-07	SD-08	SD-09	SD-10
Sum Chlordanes (pg/L)	590	9.66	2.66	16.2	8.86	8.23	4.95	17.7	4.96	7.25	5.25
Dieldrin (pg/L)	140	4.70	≤2.08	4.75	4.27	4.87	3.68	7.38	4.97	5.83	4.81
Sum DDTs (pg/L)	590	21.9	4.54	8.22	6.13	7.12	3.81	7.56	3.80	5.99	4.69
Sum PCBs (pg/L)	170	785	60.0	295	142	248	121	189	136	92.0	69.4

***Duplicate sample values in parentheses; '≤' symbol represents a detection but at an estimated concentration lower than the MDL; WQO is water quality objective for protection of human health for seafood consumption from California Toxics Rule.**

Table 9. Summary of sediment-water interface passive sampler contaminant concentrations during Event 1 (March-June 2018).

Chemical	Depth	WQO	SD-01	SD-03	SD-04	SD-05	SD-06	SD-07	SD-08	SD-09	SD-10
Sum Chlordanes (pg/L)	Above surface	590	9.56	45.0	17.4	16.0	1.16	36.5	13.1	13.8	6.91
	Below surface		19.5	206, 216*	120	48.6, 33.8*	66.0	120	10.3	16.1	7.40
Dieldrin (pg/L)	Above surface	140	<21.6	<22.8	<34.5	≤12.7	<9.47	≤14.3	<32.6	<39.1	<45.8
	Below surface		≤7.07	41.5, 48.1*	63.9	184, 57.9*	44.2	96.6	≤7.60	9.97	<7.15
Sum DDTs (pg/L)	Above surface	590	6.36	37.5	28.6	31.8	<1.11	25.8	30.1	<4.58	<5.36
	Below surface		13.9	72.1, 84.3*	79.2	94.3, 97.0*	217	53.4	27.7	66.2	50.5
Sum PCBs (pg/L)	Above surface	170	301	907	226	451	42.7	237	299	110	171
	Below surface		825	4671, 4653*	1126	3618, 2939*	1219	433	325	162	154

***Represents the lower portion of the sub-surface sampler; '<' symbol represents a non-detect with the value equal to the MDL; '≤' symbol represents a detection but at an estimated concentration lower than the MDL; WQO is water quality objective for protection of human health for seafood consumption from California Toxics Rule.**

Table 10. Summary of mean (n=3) water column passive sampler contaminant concentrations during Event 2 (Sept-Oct 2018).

Chemical	WQO	SD-01	SD-02	SD-03	SD-04	SD-05	SD-06	SD-07	SD-08	SD-09	SD-10
Sum Chlordanes (pg/L)	590	27.1	11.6	28.6	22.1	25.5	14.3	26.2	11.4	15.0	4.62
Dieldrin (pg/L)	140	6.59	5.38	6.39	7.23	8.14	5.04	7.06	5.44	5.84	≤4.06
Sum DDTs (pg/L)	590	81.4	22.3	25.9	24.5	37.3	23.8	28.9	17.0	29.6	11.5
Sum PCBs (pg/L)	170	1250	289	616	416	818	416	503	338	263	111

***Duplicate sample values in parentheses; '≤' symbol represents a detection but at an estimated concentration lower than the MDL; WQO is water quality objective for protection of human health for seafood consumption from California Toxics Rule.**

Table 11. Summary of sediment-water interface passive sampler contaminant concentrations during Event 2 (Sept-Oct 2018). No samples collected for stations SD-02 and SD-09.

Chemical	Depth	WQO	SD-01	SD-03	SD-04	SD-05	SD-06	SD-07	SD-08	SD-10
Sum PCBs (pg/L)	Above surface	170	na	na	578	996	1270	868	810	528
	Below surface		na	na	2430	11700	221	1350	1160	738

***Represents the lower portion of the sub-surface sampler; na: data excluded as outlier; WQO is water quality objective for protection of human health for seafood consumption from California Toxics Rule.**

Calculated dissolved PCB, DDT, and chlordane concentrations for pore water and the sediment-water interface samples were generally greater than those for the overlying water column (Tables 9 and 11, Figure 11). Concentrations of dissolved DDTs, chlordane, and dieldrin above the sediment-water interface were less than the water quality objective for human health protection (California Toxics Rule for consumption of organisms [40CFR 131]). PCB concentrations above the sediment-water interface were higher than the water quality objective at 7 stations during Event 1 and 6 stations during Event 2.

Within a station, dissolved concentrations usually showed a trend of being highest in pore water and lowest in the water column. This trend is indicative of a net flux of contamination out of the sediment and into the water column.

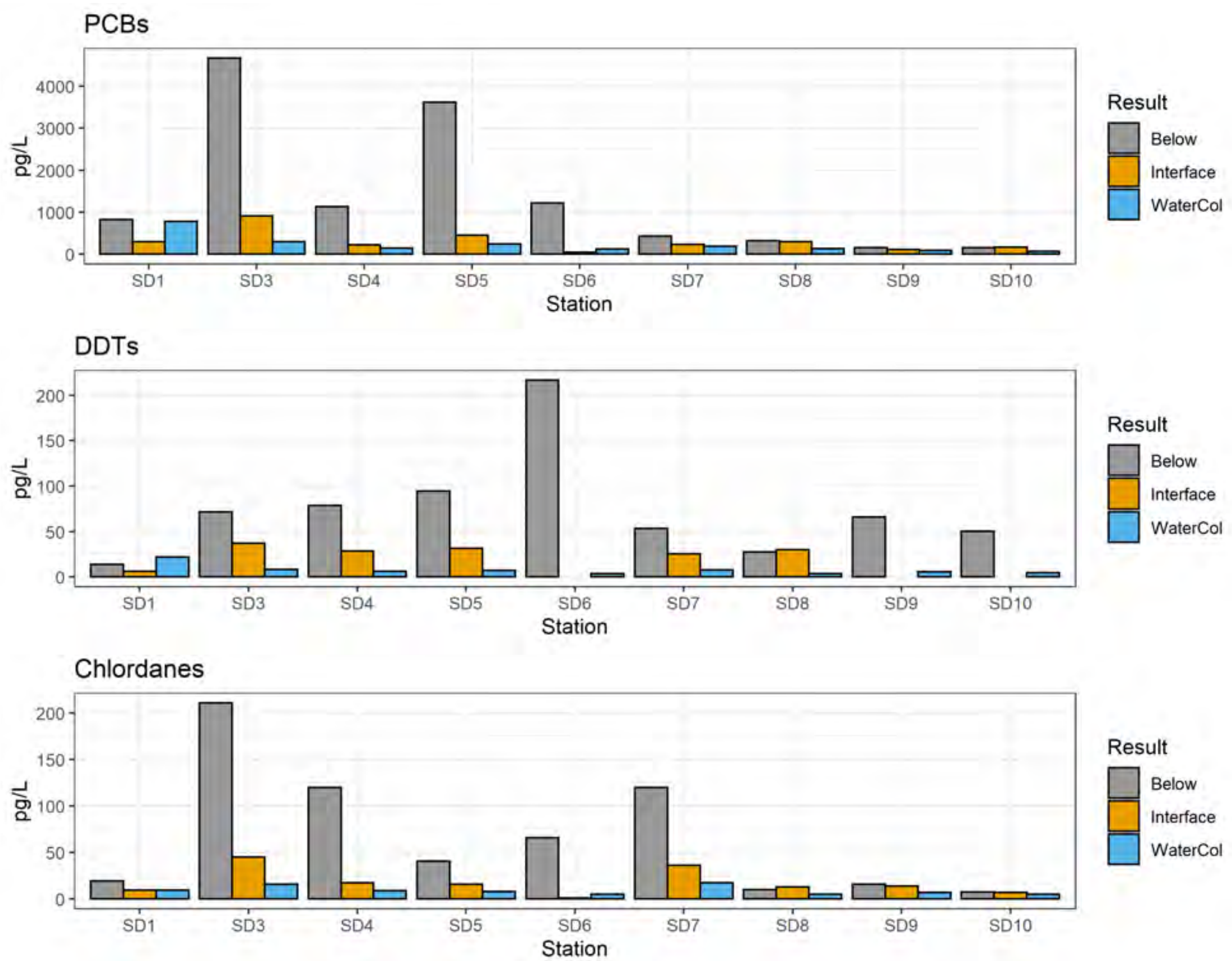

Figure 11. Dissolved contaminants (using passive samplers) in pore water, sediment-water interface, and water column samples for Event 1.

PCB diffusive flux was strongly dependent on sediment concentration, with the highest flux at stations having the highest sediment PCB concentration (Figure 12). Regression analysis showed that variation in sediment concentration accounted for 95% of variation in flux. PCB flux magnitude was similar between sampling events and ranged from 8.10 x 10^{-17} to 4.28 x 10^{-15} g/cm/s. PCB flux from sediment provides a supporting mechanism to account for the strong association between sediment and water column PCB concentrations.

A PCB mass balance model based on the sediment, water column, and porewater PCB data from this study coupled with a hydrodynamic and fate/transport model was developed by NIWC (Carilli et al. 2019). Initial model runs suggest that diffusive flux of PCBs from legacy contamination of the sediment is sufficient to account for present-day concentrations of PCBs in the water column.

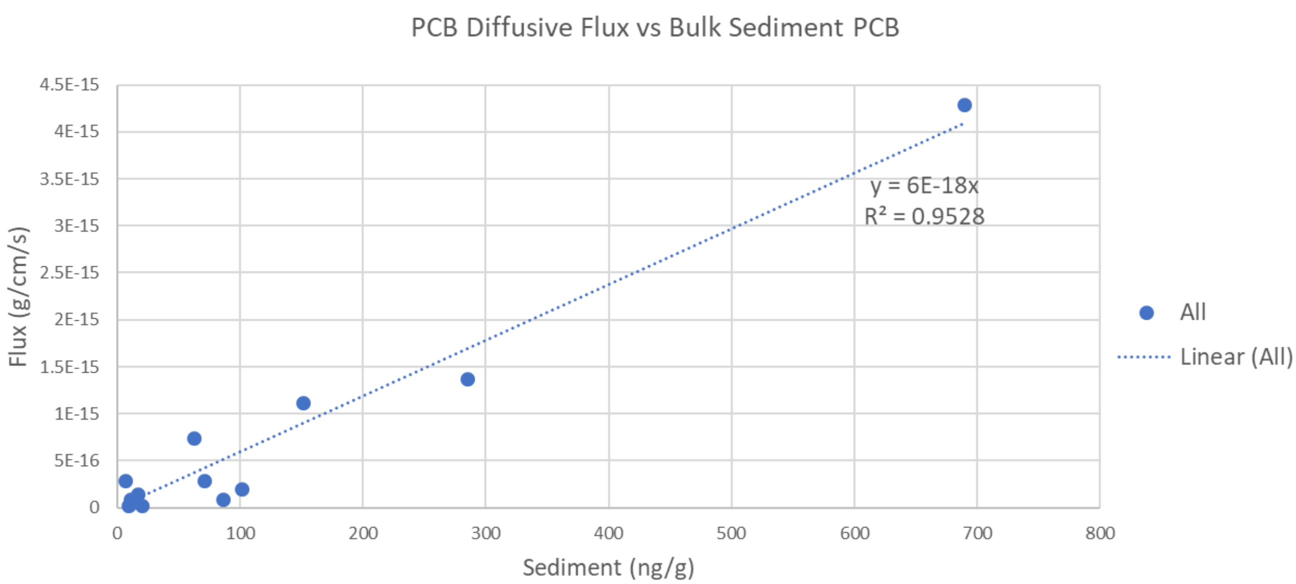

Figure 12. Diffusive flux of PCBs from sediments during both sampling events.

Different methodologies were used to quantify water column organochlorine concentrations in this study, compared to the PCB source and bioaccumulation studies conducted by Douglas (2019) and Toll (2019). Passive samplers were used in the current study, while high-volume grab water samples, combined with high-resolution gas chromatography/high-resolution mass spectrometry (HRCG/HRMS) was used by Douglas and Toll. Each method is capable of providing reliable quantitative concentration results at the low detection levels needed for bioaccumulation modeling. Each method has specific attributes desirable for their respective study designs. The high-volume sampling method provides a direct measurement of both dissolved (plus colloidal) and particulate fractions, which is useful for parameterizing the bioaccumulation model applied by Toll (2019). The passive sampling method used in the present study does not involve filtration and measures the truly dissolved contaminant fraction that is sorbed onto the PSD over an extended time period to provide a time-integrated concentration representative of average exposure conditions.

Both the passive sampler and high-volume grab methods are technically sophisticated and require robust quality assurance methods to ensure accurate data. Data from both types of sampling/analysis methods are highly relevant for bioaccumulation studies, but they are not directly comparable between studies due to differences in sampling interval (grab vs. 28-day deployment) and number of congeners analyzed (209 vs. 43).

Biota

Plankton and spotted sand bass were collected from each site during both events. Shiner perch were not available from sites SD3 and 7 for either event, or from SD10 for Event 2. Topsmelt were not available from sites SD8 and 10 in Event 1. Composites of 3-5 fish were analyzed for each station. Additional composites and individual fish were collected and analyzed for some sites, depending upon fish availability. The number and types of samples are documented in Wood (2019). Biota chemistry results for Events 1 and 2 based on pooled data for all samples and locations are summarized in Figures 13-16 (courtesy of Wood). Subsequent comparisons and analyses (i.e., Figures 17-33) utilize data representative of only composite samples.

General trends among species for San Diego Bay are shown in box plots based on pooled data (Figure 13). Among species, the highest tissue concentrations were measured for PCBs (12.8 – 176 ng/g), with both the highest and lowest values present in zooplankton. DDTs were present at concentrations ranging from 1.01 ng/g (zooplankton) to 16.6 ng/g (shiner perch). All DDT concentrations were below the OEHHA FCG (fish contaminant goal) of 21 ng/g. Chlordanes were present at lower concentrations compared to other organochlorines; with most samples below the chlordane FCG of 5.6 ng/g and all samples below the OEHHA chlordane ATL (advisory tissue level) of 190 ng/g, based on consuming three meals of fish per week. Chlordane concentrations were nondetect (<0.25 ng/g) in several samples of zooplankton, spotted sand bass or topsmelt, and ranged to 15.2 ng/g in zooplankton.

The pooled sample data in Figure 13 are also presented normalized to lipid to facilitate comparisons among species. Median concentrations of PCBs, DDTs, and chlordanes were similar among species. Much variability among samples is evident, likely due to site-specific or species-specific factors. Significant differences in total PCBs were present among species, with the greatest concentrations in spotted sand bass and topsmelt (ANOVA, Wood 2019). No significant differences in the pooled data among species were present for DDTs and chlordanes.

Spatial plots of the tissue data (Figures 14-16) showed that variation in tissue contamination generally corresponded with that of sediment, with higher concentrations present in samples from sites with the highest sediment contaminant concentrations. Spotted sand bass and shiner perch collected during Event 2 generally had higher tissue PCB concentrations. There were no apparent sampling event differences for PCB concentrations in plankton, while, topsmelt exhibited lower tissue concentrations during Event 2 (Wood 2019).

Total DDT tissue concentrations tended to be greater during Event 2 for all species. For all species, total chlordanes did not show any significant differences between sampling events.

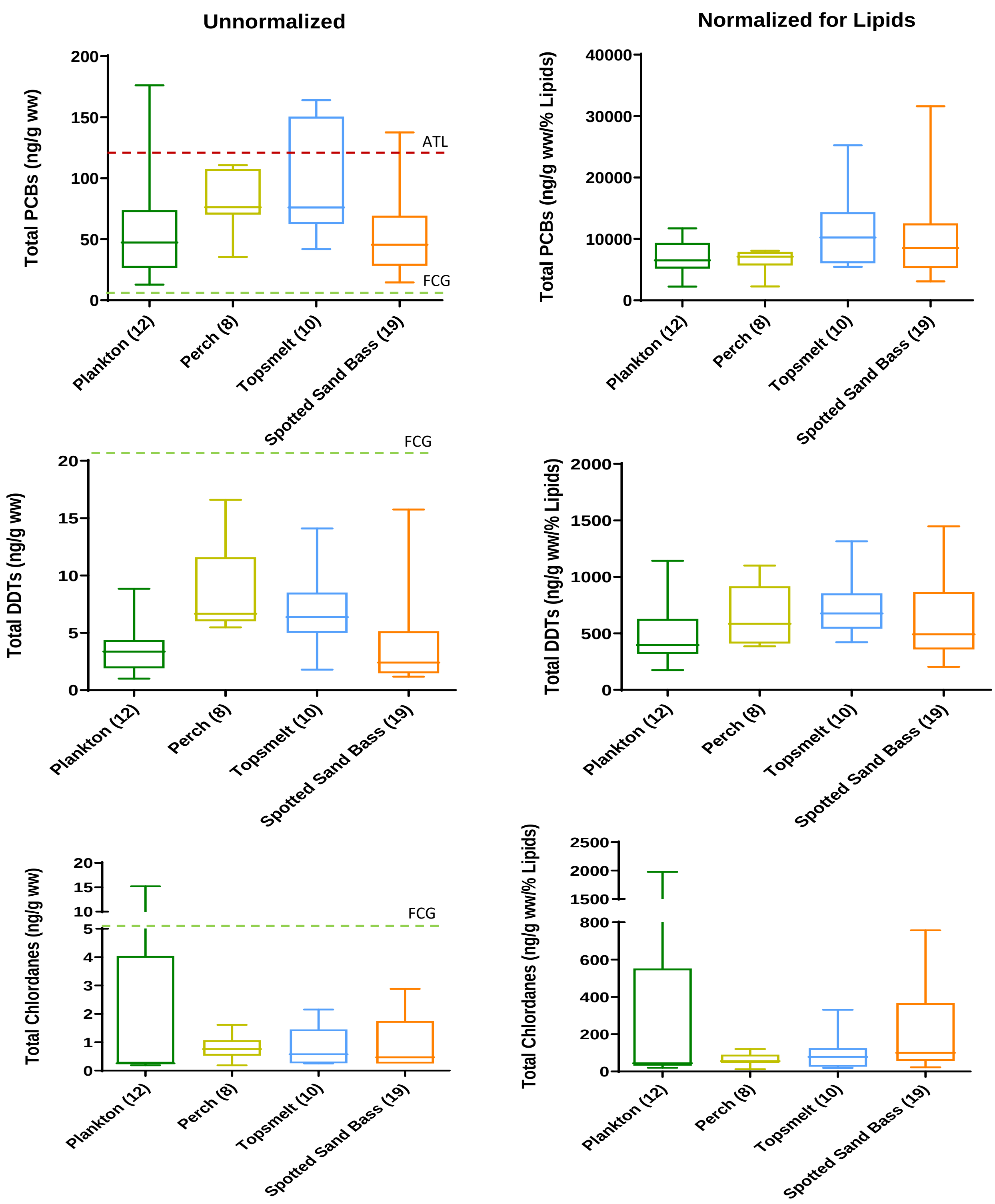

Figure 13. Total contaminant tissue concentrations across species (all samples, locations and sampling events combined). Fillet tissue was analyzed for sand bass; whole body was analyzed for other species. Box plots include the median value, quartiles, and range of data (number of samples denoted in parentheses). OEHHA Fish Contaminant Goal (FCG) and no consumption Advisory Tissue Level shown by dashed lines. Figure courtesy of Wood Environment and Infrastructure Solutions, Inc.

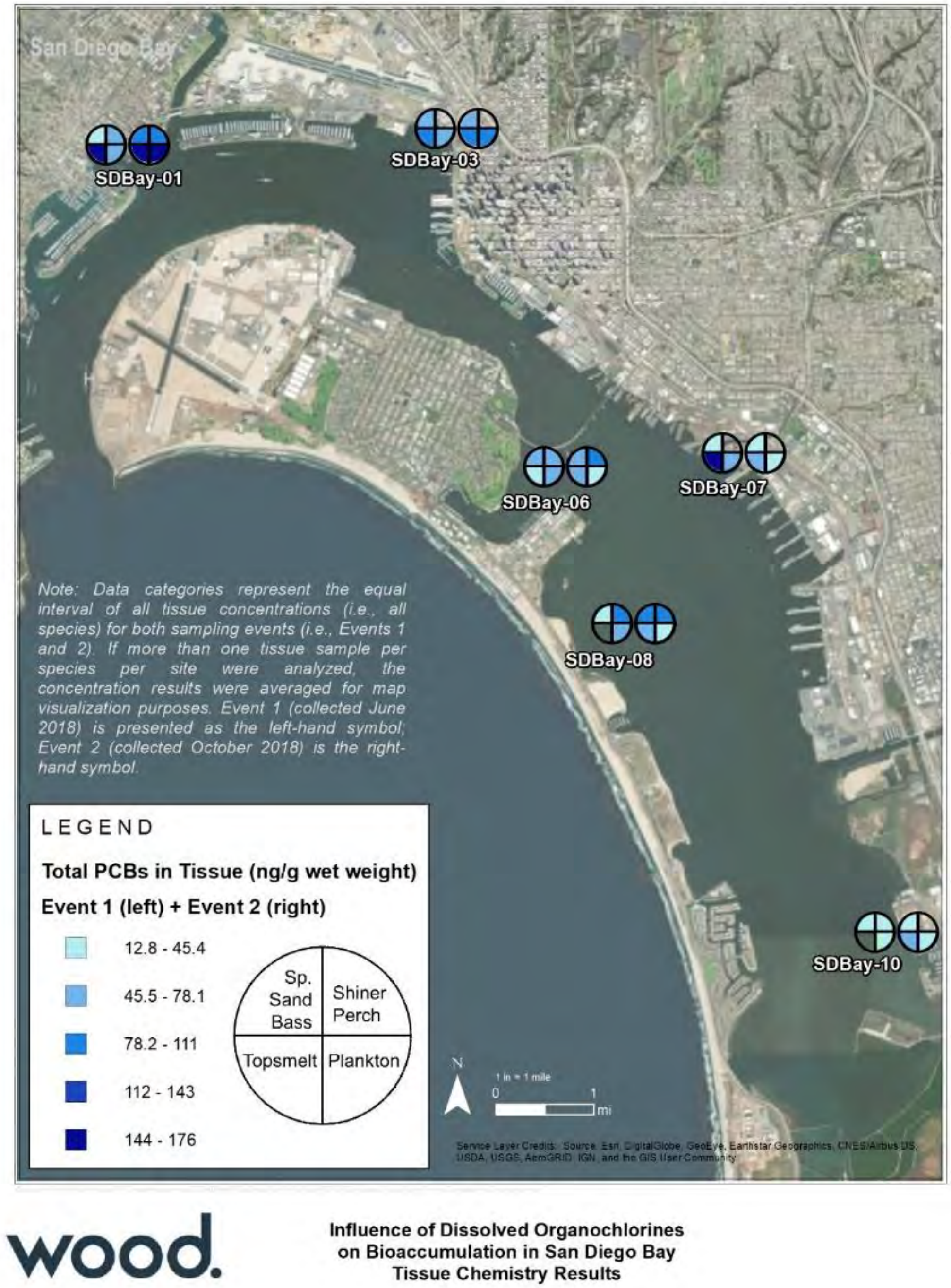

Figure 14. Summary of tissue chemistry results for PCBs. Figure courtesy of Wood Environment and Infrastructure Solutions, Inc.

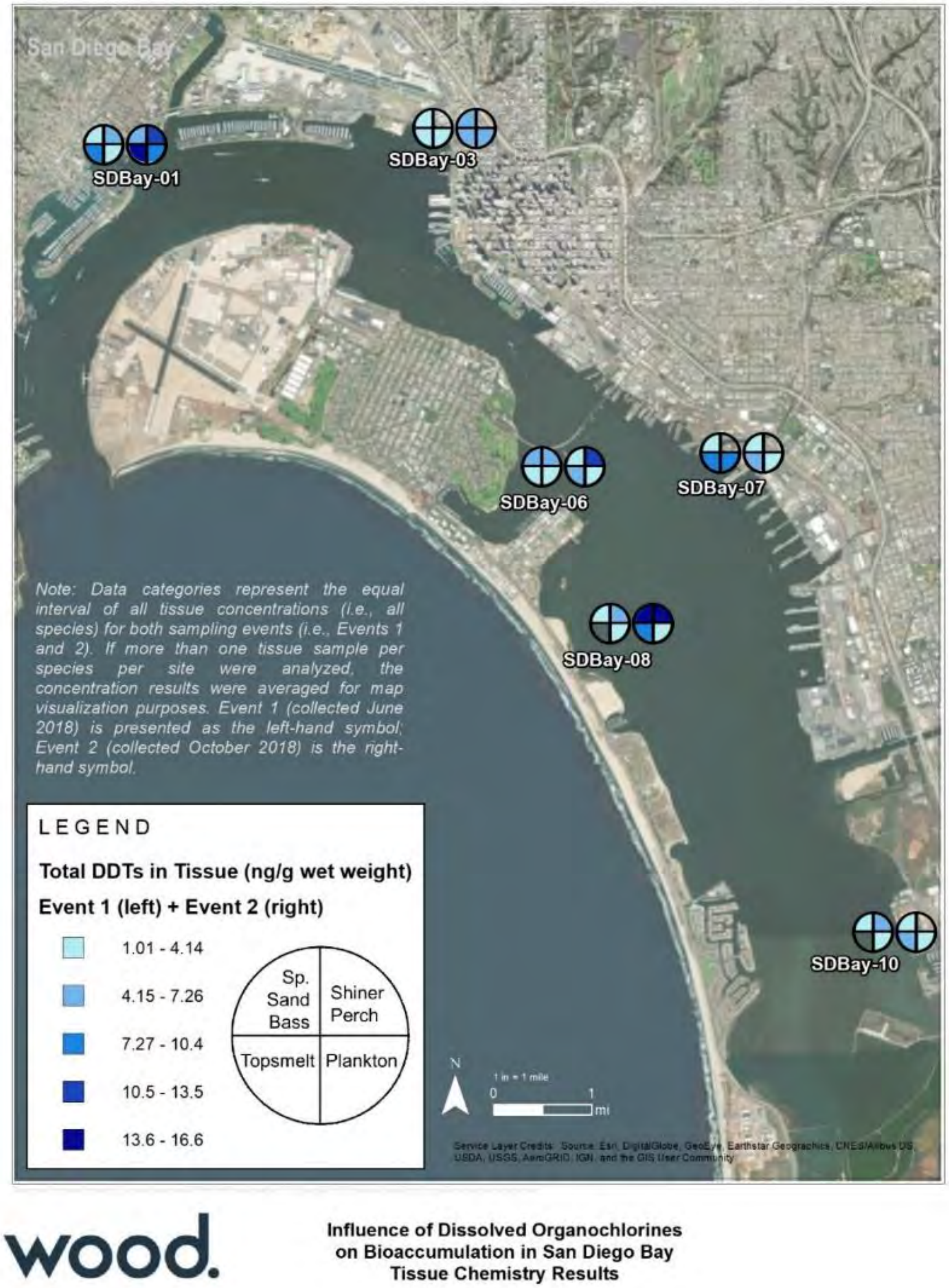

Figure 15. Summary of tissue chemistry results for DDTs. Figure courtesy of Wood Environment and Infrastructure Solutions, Inc.

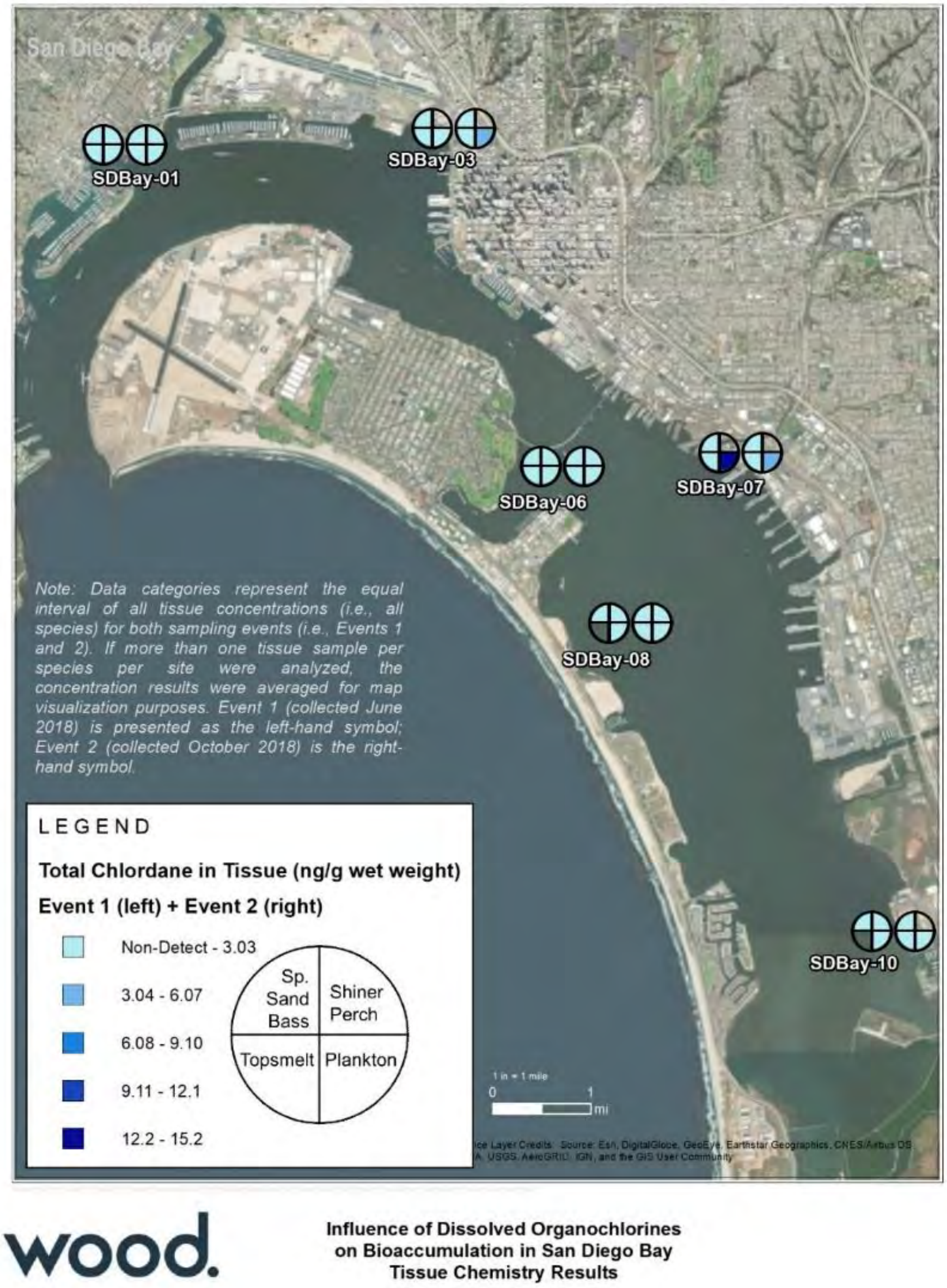

Figure 16. Summary of tissue chemistry results for chlordanes. Figure courtesy of Wood Environment and Infrastructure Solutions, Inc.

Regression analysis was used to document relationships between tissue contamination and sediment PCB concentration (Figure 17). Relationships between tissue, event, and sediment were variable for each species. Spotted sand bass and topsmelt were the only species to have a significant relationship between sediment and tissue for both Events 1 and 2. Variation in sediment concentration appeared to account for 71% of spotted sand bass tissue contaminant variation for Event 1, and account for 45% of the variation for Event 2. Sediment:tissue relationships for topsmelt were more consistent, with a similar regression slope for Events 1 and 2.

The strongest sediment:tissue relationship was indicated for zooplankton in Event 2, which had the highest regression slope and explained 99% of tissue variation (Figure 17). No relationship between sediment and tissue contamination was apparent for zooplankton in Event 1, or for shiner perch for either event. Relatively small and inverse changes in shiner perch PCB concentration were observed over the range of sediment contamination in the samples. For example, shiner perch tissue concentrations declined by approximately 30 ng/g ww over an increase in sediment PCBs of more than 600 ng/g dw.

The inconsistency in the sediment:tissue regressions between events may suggest that a temporal factor is influencing bioaccumulation in these species. Potential factors might include: the measured sediment contaminant concentrations are not representative of the fish exposure area, less feeding activity (and therefore bioaccumulation) in colder water present during the months preceding Event 1, greater fish movement (less site fidelity) in Event 1, or stronger sediment flux of PCBs during Event 2 (see Figure 10).

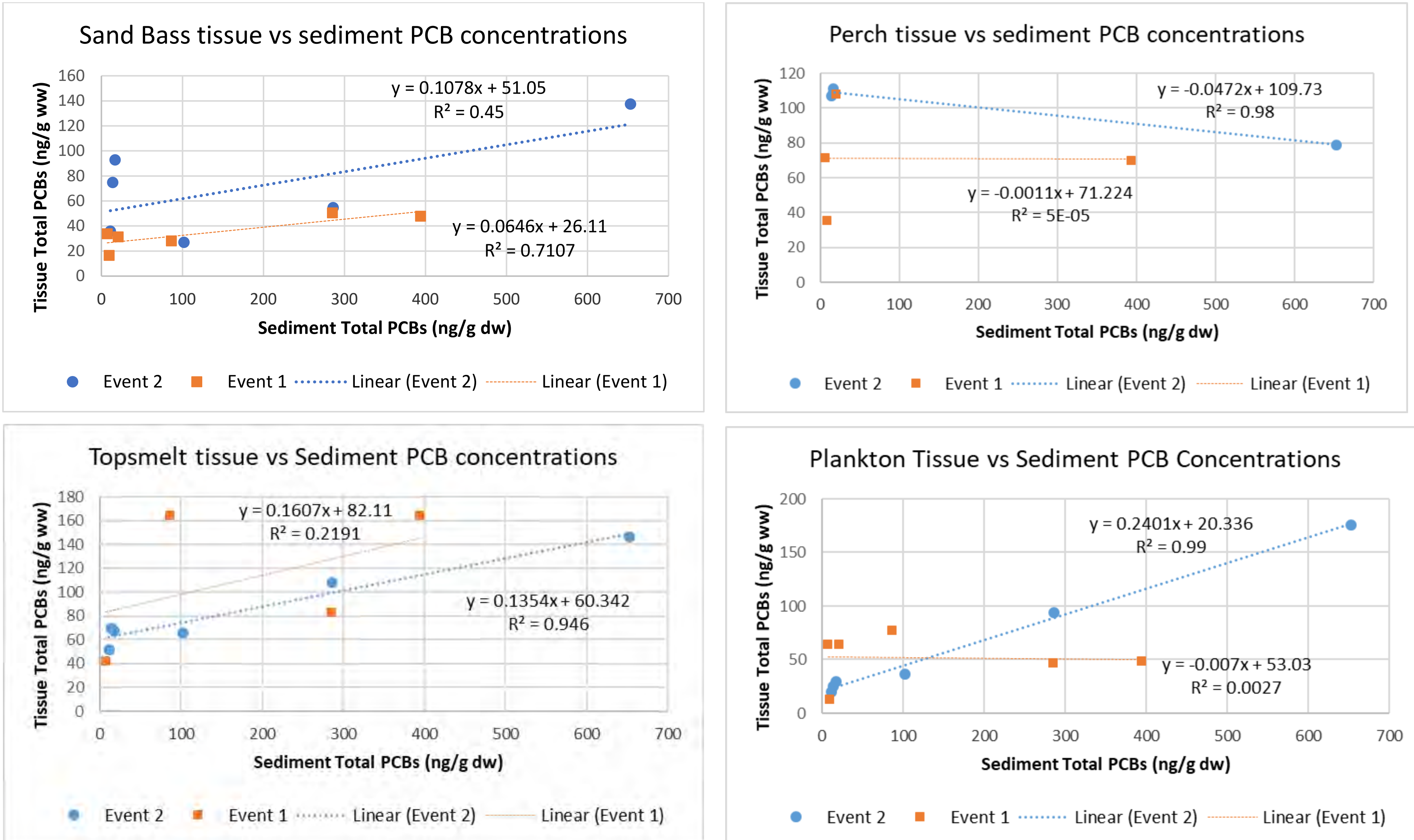

Figure 17. Relationships between tissue PCBs and sediment. Figure and analyses courtesy of NIWC.

BIOACCUMULATION RESULTS AND DISCUSSION

Station chemistry comparison

Estimated biota concentrations from the baseline SQO bioaccumulation model runs are presented by contaminant group in Figures 18-20. The estimated tissue concentrations are based on average sediment and dissolved contamination data measured at each station for Events 1 and 2. The model results for each species take into account differences in dietary habits (i.e., dietary guild): spotted sand bass = benthic diet with piscivory; shiner perch = benthic and pelagic without piscivory; topsmelt = benthic and pelagic with herbivory, zooplankton = consumes exclusively phytoplankton. Site-specific values for tissue lipid, sediment TOC, dissolved organic carbon (DOC), temperature, salinity, and DO content were used, based on sample analyses for this study (Wood 2019).

Each figure shows the predicted tissue concentration from the bioaccumulation model paired with the corresponding average field biota measurement (composite samples only). Measured sediment and dissolved water concentrations are included in each figure for reference.

Estimated biota concentrations from the models showed a close correspondence to measured sediment and water concentrations, with the highest values for stations with the highest sediment contaminant concentrations: SD1, 3, and 7. This result is expected, as the measured sediment and water data are the primary factors determining the model results.

Model estimated concentrations for all contaminant types frequently exceeded those observed at the site for most samples. For example, modeled PCB concentrations in spotted sand bass exceeded observed values by an average factor of 42 (calculated as model conc./field conc.), ranging from 72 for SD1 to a factor of 14 for SD10 (Figure 18, Table 12). The degree of model overestimation was lower for shiner perch and topsmelt. Model PCB values for shiner perch were 24 to 3.7 times higher than observed (average = 8.8). PCB estimates for topsmelt ranged from 6.0 to 1.2 times the observed values (average = 3.3). Modeled and observed PCB values for zooplankton were most like one another, with the estimates ranging from 1.9 to 1.1 times the observed value (average = 1.4).

Similar relationships between model and observed values were evident for DDTs and chlordanes among species (Figures 19 and 20). The magnitude of model overestimation for these contaminants was like that observed for PCBs (Table 12). For example, average model overestimation for topsmelt was 3.3, 3.4 and 3.4 for PCBs, DDTs and chlordanes, respectively.

Trends in model overestimation among species appeared to correspond with the proportion of benthic organisms in their diet. This is likely because the exposure concentration estimated from the single sediment grab sample per event is not representative of the sediment and particulates to which benthic organism tissue concentrations are most directly linked. The highest mean overestimation was observed for spotted sand bass and shiner perch, species whose diet was composed of 64% and 75% of benthic species, respectively. Topsmelt and zooplankton were classified by the SQO model as having a diet composed of 47% and 0% benthos, respectively. The degree of model overestimation for spotted sand bass and shiner perch also appeared to be related to sediment and/or water concentration. The highest overestimation factors PCBs and DDTs for these species were obtained from bioaccumulation model analyses using contamination data from SD1, which had the highest (and probably the most spatially variable) sediment and water concentrations in this study.

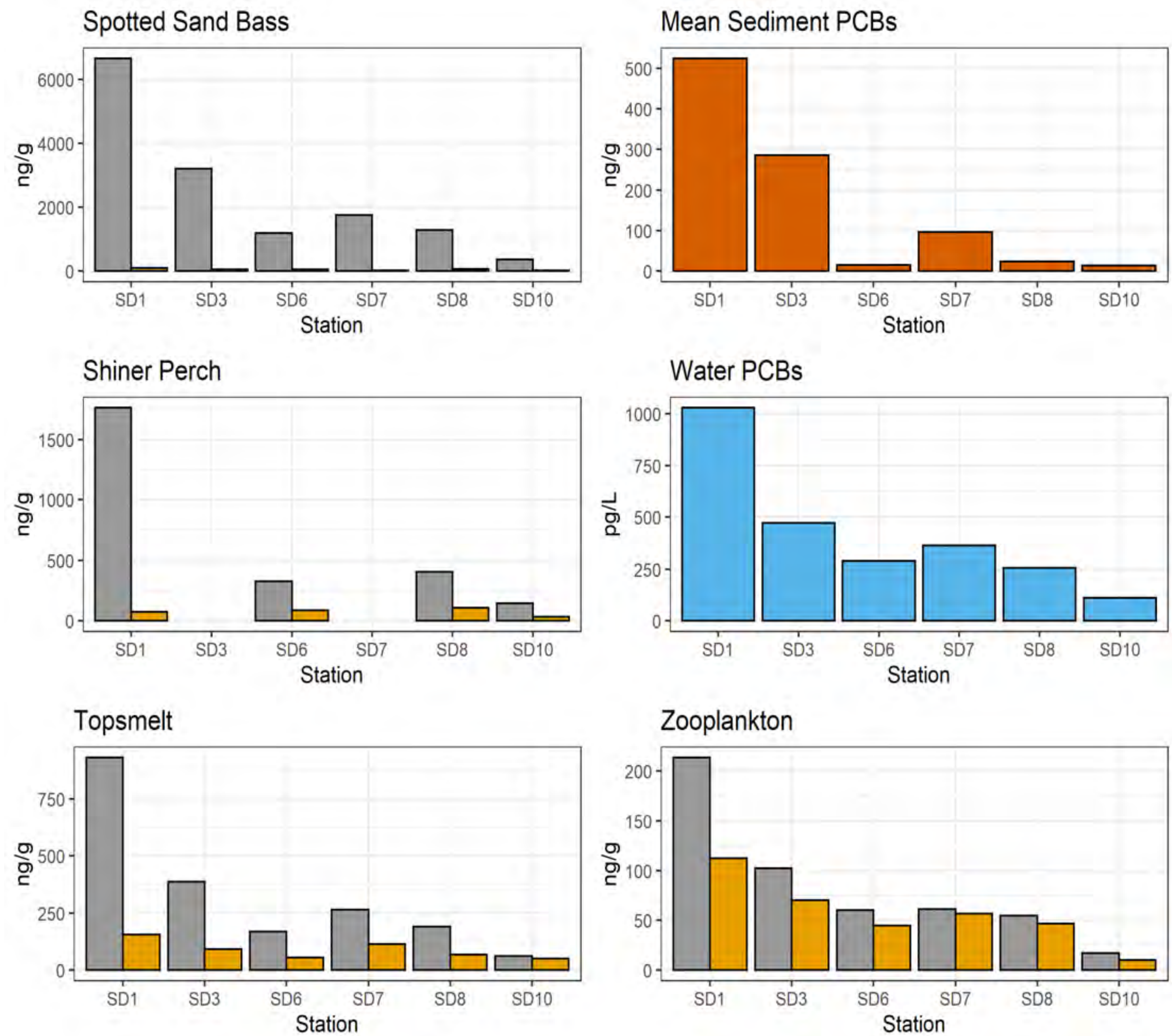

Figure 18. Bioaccumulation model comparisons for PCBs. Gray bars represent model estimates; gold bars show average composite concentrations for field-collected biota. Modeling based on average measured sediment and water concentrations for Events 1 and 2).

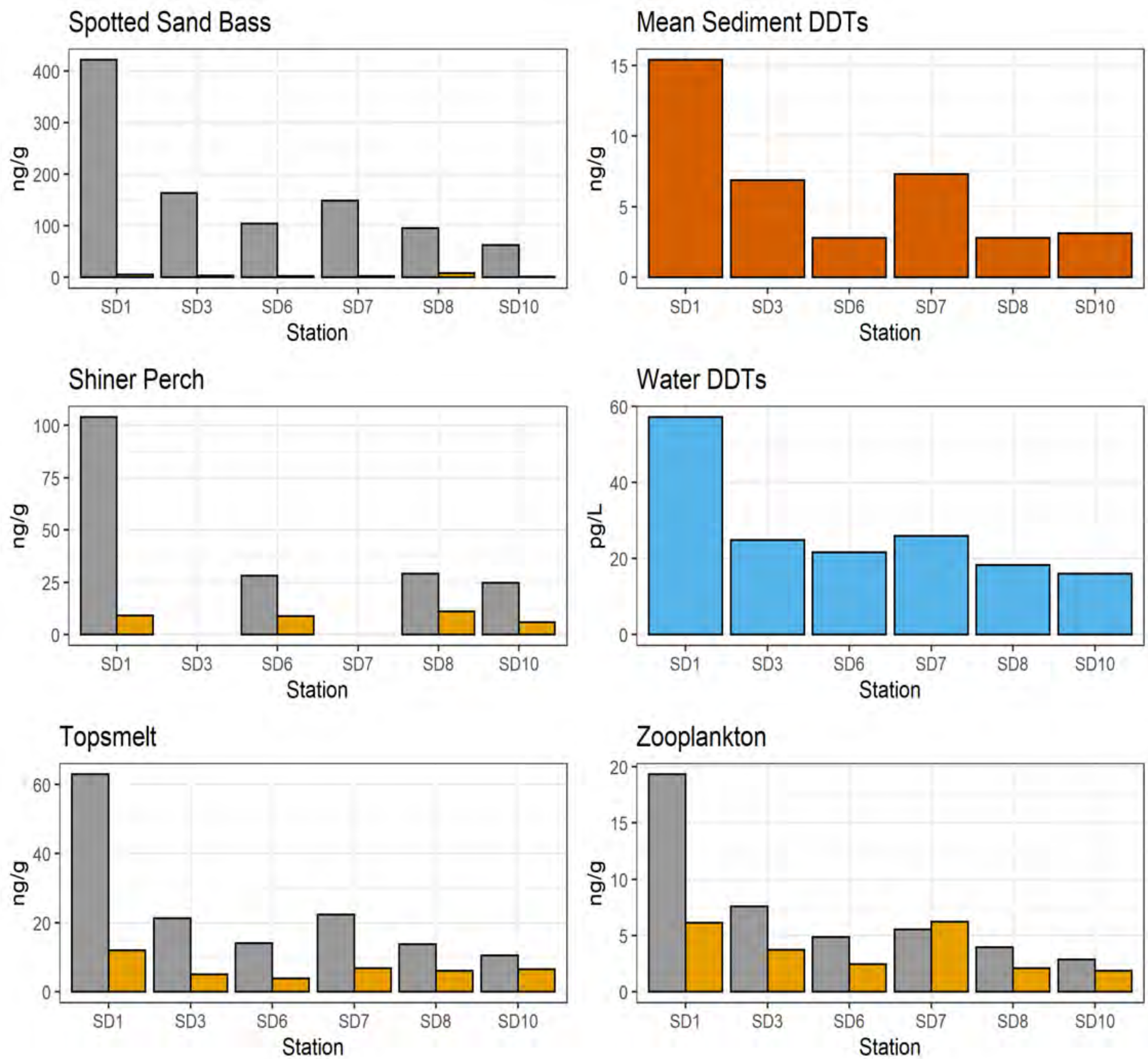

Figure 19. Bioaccumulation model comparisons for DDTs. Gray bars represent model estimates; gold bars show average composite concentrations for field-collected biota. Modeling based on average measured sediment and water concentrations for Events 1 and 2).

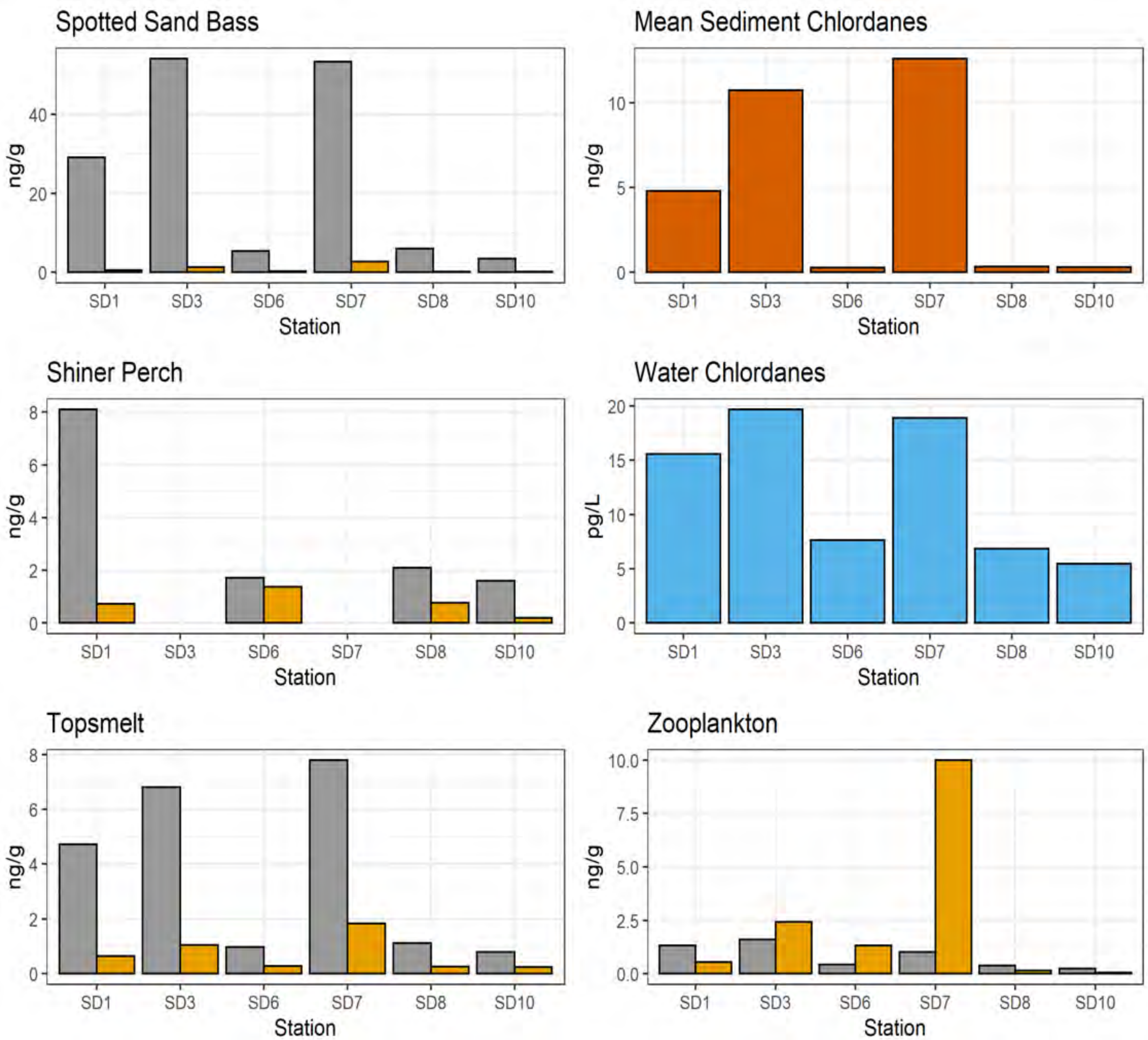

Figure 20. Bioaccumulation model comparisons for chlordanes. Gray bars represent model estimates; gold bars show average composite concentrations for field-collected biota. Modeling based on average measured sediment and water concentrations for Events 1 and 2).

Table 12. Observed and model tissue contaminant concentrations for station mean sediment concentration. M/O is the ratio of the model estimate to the observed tissue concentration.

	Spotted Sand Bass			Shiner Perch			Topsmelt			Zooplankton		
Station	Obs	Model	M/O	Obs	Model	M/O	Obs	Model	M/O	Obs	Model	M/O
Tissue PCBs (ng/g ww)												
SD1	92.7	6668.6	71.9	74.3	1764.7	23.8	155.0	932.5	6.0	112.3	213.6	1.9
SD3	52.7	3211.2	61.0	NA	NA	NA	93.4	388.2	4.2	70.2	102.4	1.5
SD6	54.4	1192.5	21.9	89.2	328.0	3.7	55.7	168.2	3.0	44.7	60.4	1.4
SD7	27.6	1754.0	63.6	NA	NA	NA	115.1	264.4	2.3	56.9	61.0	1.1
SD8	62.1	1290.7	20.8	109.5	404.7	3.7	67.6	190.8	2.8	46.8	54.7	1.2
SD10	26.3	368.2	14.0	35.4	146.5	4.1	51.6	62.5	1.2	10.1	17.0	1.7
Tissue DDTs (ng/g ww)												
SD1	5.6	421.9	75.3	9.1	104.1	11.5	12.0	63.0	5.2	6.1	19.3	3.2
SD3	3.5	163.7	47.3	NA	NA	NA	5.1	21.2	4.2	3.8	7.6	2.0
SD6	2.1	104.5	49.8	9.0	28.2	3.1	3.9	14.1	3.6	2.4	4.9	2.0
SD7	2.5	149.0	60.8	NA	NA	NA	6.8	22.4	3.3	6.2	5.6	0.9
SD8	8.6	94.9	11.0	11.0	29.1	2.6	6.1	13.8	2.3	2.1	3.9	1.9
SD10	1.4	63.0	45.0	6.1	24.6	4.1	6.6	10.6	1.6	1.9	2.9	1.5
Tissue Chlordanes (ng/g ww)												
SD1	0.6	29.1	47.7	0.7	8.1	11.3	0.6	4.7	7.4	0.5	1.3	2.4
SD3	1.3	54.2	42.0	NA	NA	NA	1.0	6.8	6.5	2.4	1.6	0.7
SD6	0.3	5.4	16.4	1.4	1.7	1.2	0.3	1.0	3.5	1.3	0.4	0.3
SD7	2.7	53.4	19.7	NA	NA	NA	1.8	7.8	4.2	10.0	1.0	0.1
SD8	0.2	6.0	40.0	0.8	2.1	2.8	0.3	1.1	4.3	0.2	0.4	2.4
SD10	0.2	3.5	23.3	0.2	1.6	8.4	0.3	0.8	3.2	0.1	0.3	5.0

Water column chemistry comparison

The relative influence of dissolved contaminants in the water column was evaluated by comparing modeled bioaccumulation under different hypothetical scenarios of water column contamination. Average sediment and dissolved chemistry data from stations SD6 and SD10 were used for these analyses, as measured tissue data were available for all four biota types.

Three water chemistry scenarios were evaluated with the SQO bioaccumulation model, differing only in the type of dissolved contaminant data: 1) baseline, water column measured dissolved contaminant data used in the model (MeasW), 2) water column dissolved contaminant data estimated by equilibrium partitioning model (PredW), and 3) no dissolved contaminants (dissolved concentration set to zero, SedOnly).

Model tissue concentration results for PCBs, DDTs, and chlordanes are shown in Figure 21 for station SD6 and Figure 22 for SD10. A similar pattern of model outcome was obtained for the three scenarios when applied to each species and station. Predicted tissue concentration was always highest for the baseline (measured dissolved concentration) scenario, intermediate for the estimated concentration data, and lowest when dissolved contaminants were not included. Predicted spotted sand bass tissue concentrations were 14-26% of the baseline value (mean of PCBs, DDTs, and chlordanes) when dissolved concentration was set to zero (Table 13). The relative change for the SedOnly scenario was similar for shiner perch (15-29%). Much larger effects were obtained when the SedOnly scenario was applied to topsmelt (8-17% of baseline) or zooplankton (0% of baseline). The magnitude of the effect appeared to be proportional to the percentage of benthos in the diet of each species.

Substitution of estimated values for dissolved contaminants (PredW scenario) reduced predicted tissue concentrations to 31-71% of baseline (mean of species), depending upon station and contaminant type (Table 13). The magnitude of the PredW effect seemed to vary according to contaminant type, with PCBs showing more impact than DDTs or chlordanes.

The variability in the relative effect of the PredW scenario on total tissue contaminant concentrations is likely influenced by variability in the equilibrium partitioning model to accurately represent measured dissolved concentrations for individual congeners and other components of the chemical groups. This variability is illustrated in Figures 23-25, which compare the measured and predicted dissolved concentrations for each PCB, DDT, and chlordane component for each of the biota sampling stations. The relative difference between measured and predicted concentrations for a given congener or component was highly variable among stations. For example, predicted dieldrin concentration was less than the measured value for four stations (SD1, 3, 6, and 7), and greater than measured for two stations (SD6 and 10). Potential factors influencing this variability include sediment TOC, which varied from 0.6% to 1.9% among stations, and temporal/spatial variability in the linkage between sediment and dissolved contaminants, as shown in Figure 10.

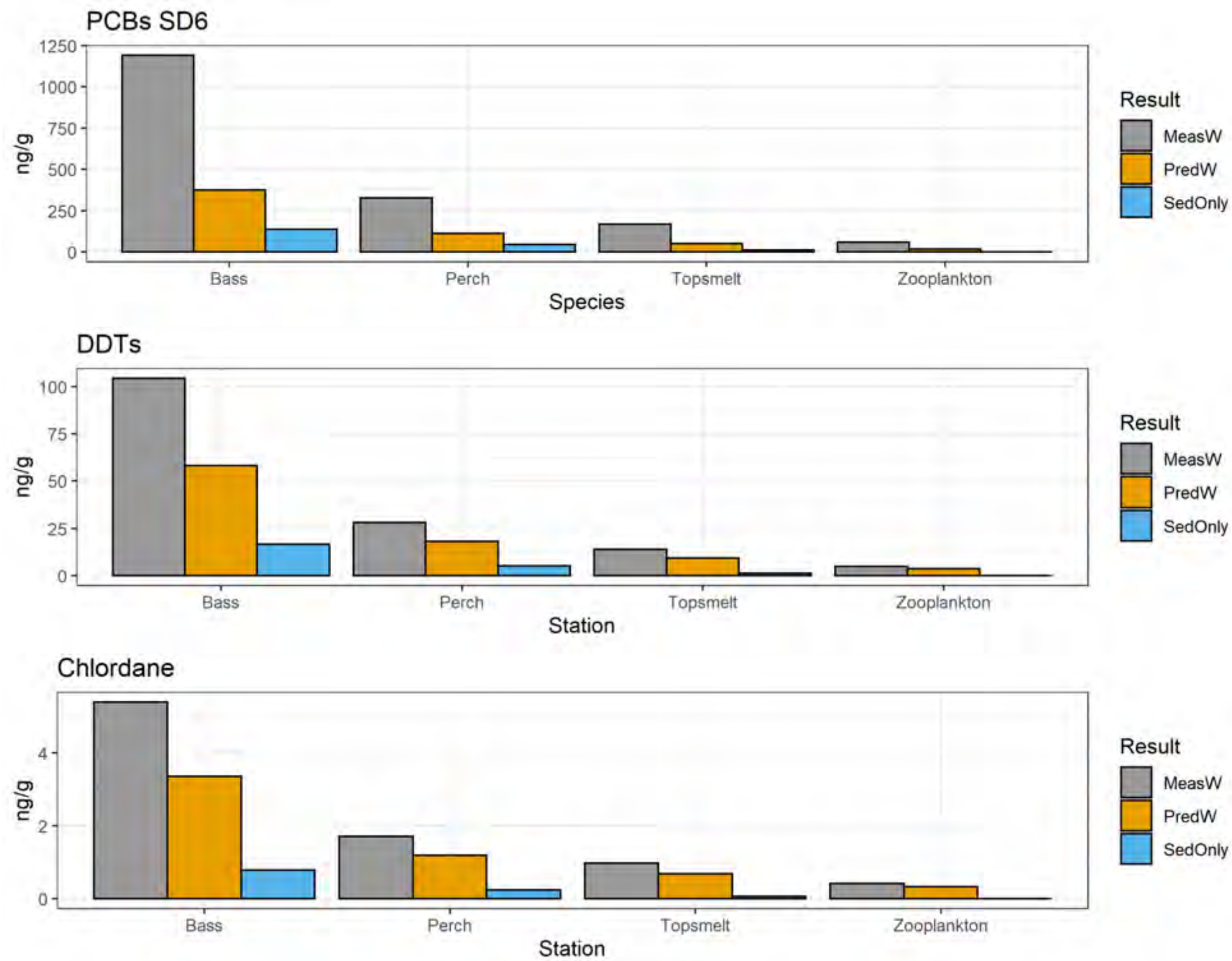

Figure 21. SD6 bioaccumulation model estimates based on different water column contaminant scenarios. MeasW = passive sampler measurement; PredW = model estimate; SedOnly = water column concentration set to zero.

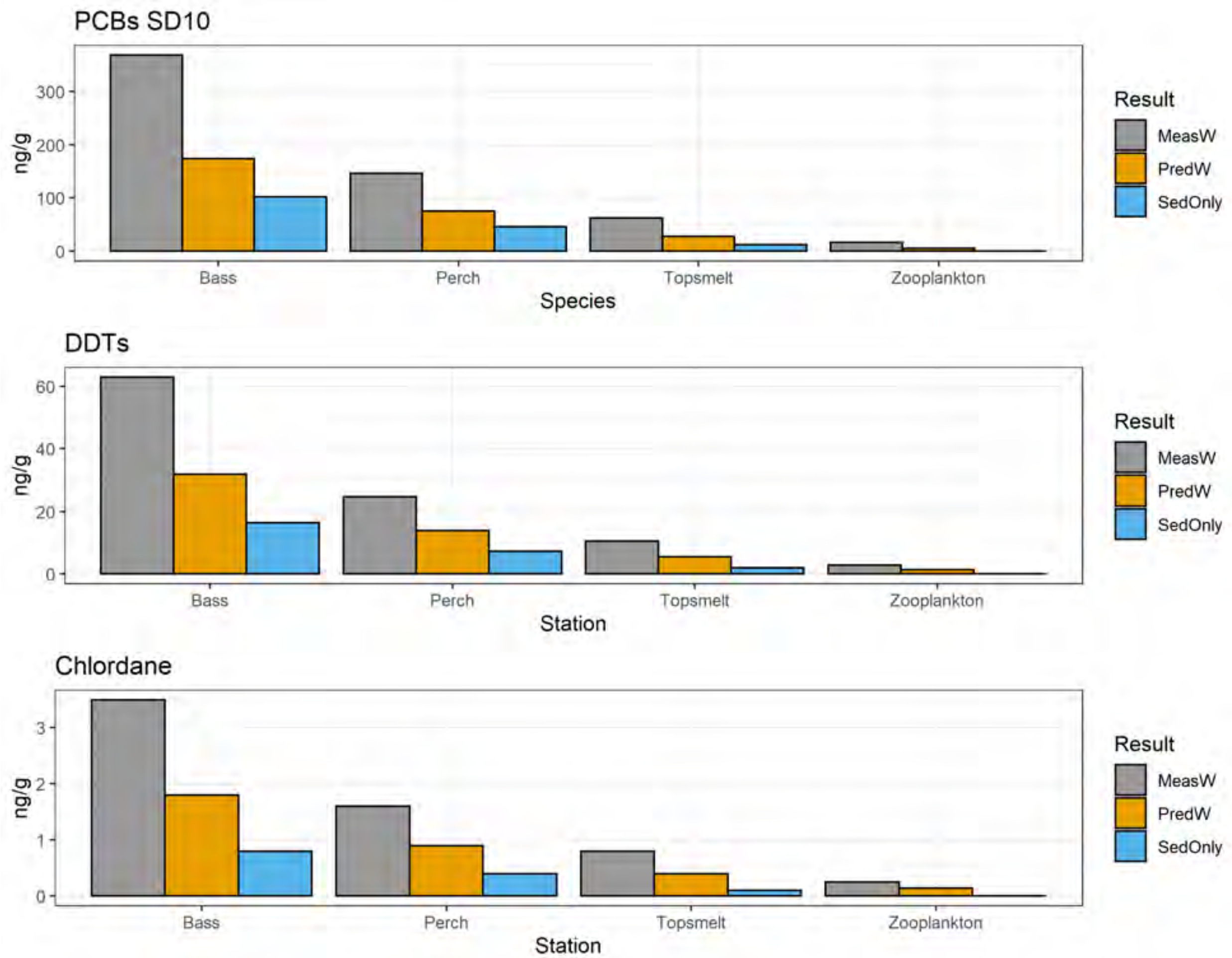

Figure 22. SD10 bioaccumulation model estimates based on different water column contaminant scenarios. MeasW = passive sampler measurement; PredW = model estimate; SedOnly = water column concentration set to zero.

Table 13. Predicted tissue concentrations resulting from different water column contaminant concentrations. Results are shown for stations SD6 and SD10. MeasW = baseline model; PredW = estimated dissolved concentration; SedOnly = no dissolved contaminants.

SD6
0.6% TOC

	Tissue PCBs (ng/g ww)					Tissue DDTs (ng/g ww)					Tissue Chlordanes (ng/g ww)				
Model Compartment	MeasW	PredW	% of MeasW	SedOnly	% of MeasW	MeasW	PredW	% of MeasW	SedOnly	% of MeasW	MeasW	PredW	% of MeasW	SedOnly	% of MeasW
Spotted sand bass	1192.5	374.4	31.4	138.7	11.6	104.5	58.1	55.6	16.6	15.9	5.4	3.4	62.2	0.8	14.7
Shiner Perch	328.0	113.8	34.7	45.4	13.8	28.2	18.1	64.3	5.2	18.3	1.7	1.2	69.8	0.2	14.3
Topsmelt	168.1	51.7	30.8	11.8	7.0	14.1	9.3	66.1	1.4	10.0	1.0	0.7	71.2	0.1	7.2
Zooplankton	60.4	17.1	28.3	0.0	0.0	4.9	3.7	75.4	0.0	0.0	0.4	0.3	81.0	0.0	0.0

SD10
1.5% TOC

	Tissue PCBs (ng/g ww)					Tissue DDTs (ng/g ww)					Tissue Chlordanes (ng/g ww)				
Model Compartment	MeasW	PredW	% of MeasW	SedOnly	% of MeasW	MeasW	PredW	% of MeasW	SedOnly	% of MeasW	MeasW	PredW	% of MeasW	SedOnly	% of MeasW
Spotted sand bass	368.2	173.8	47.2	101.7	27.6	63.0	31.8	50.5	16.5	26.2	3.5	1.8	51.4	0.8	22.9
Shiner Perch	146.5	75.3	51.4	45.7	31.2	24.6	13.9	56.5	7.3	29.7	1.6	0.9	56.3	0.4	25.0
Topsmelt	62.5	27.5	44.0	12.0	19.2	10.6	5.5	51.9	2.0	18.9	0.8	0.4	50.0	0.1	12.5
Zooplankton	17.0	5.6	33.1	0.0	0.0	2.9	1.4	47.2	0.0	0.0	0.3	0.1	56.0	0.0	0.0

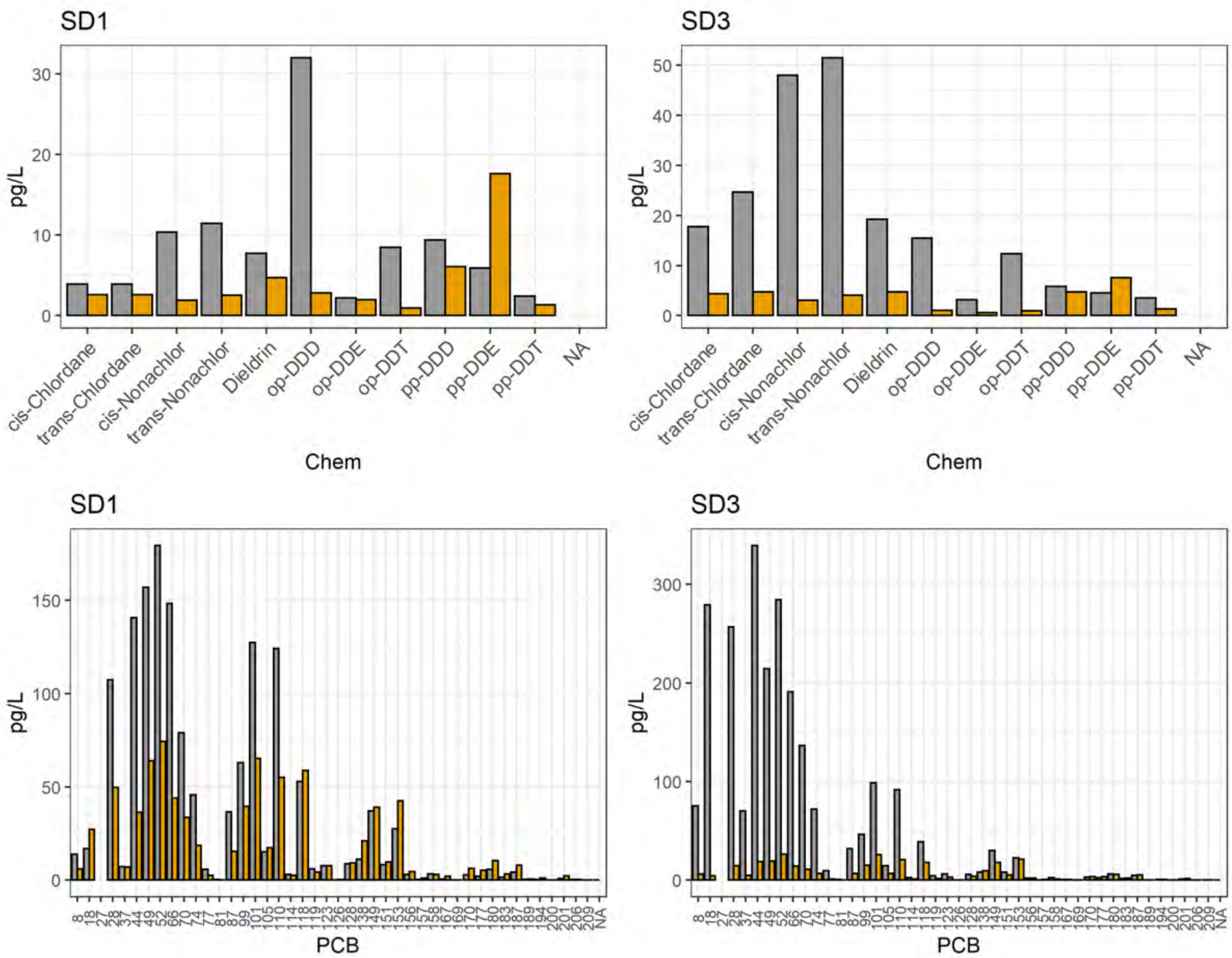

Figure 23. Comparison of measured (using passive samplers) and predicted (using the food web model) dissolved concentrations for SD1 and SD3. Gray bars show passive sampler results; gold bars show predicted concentrations.

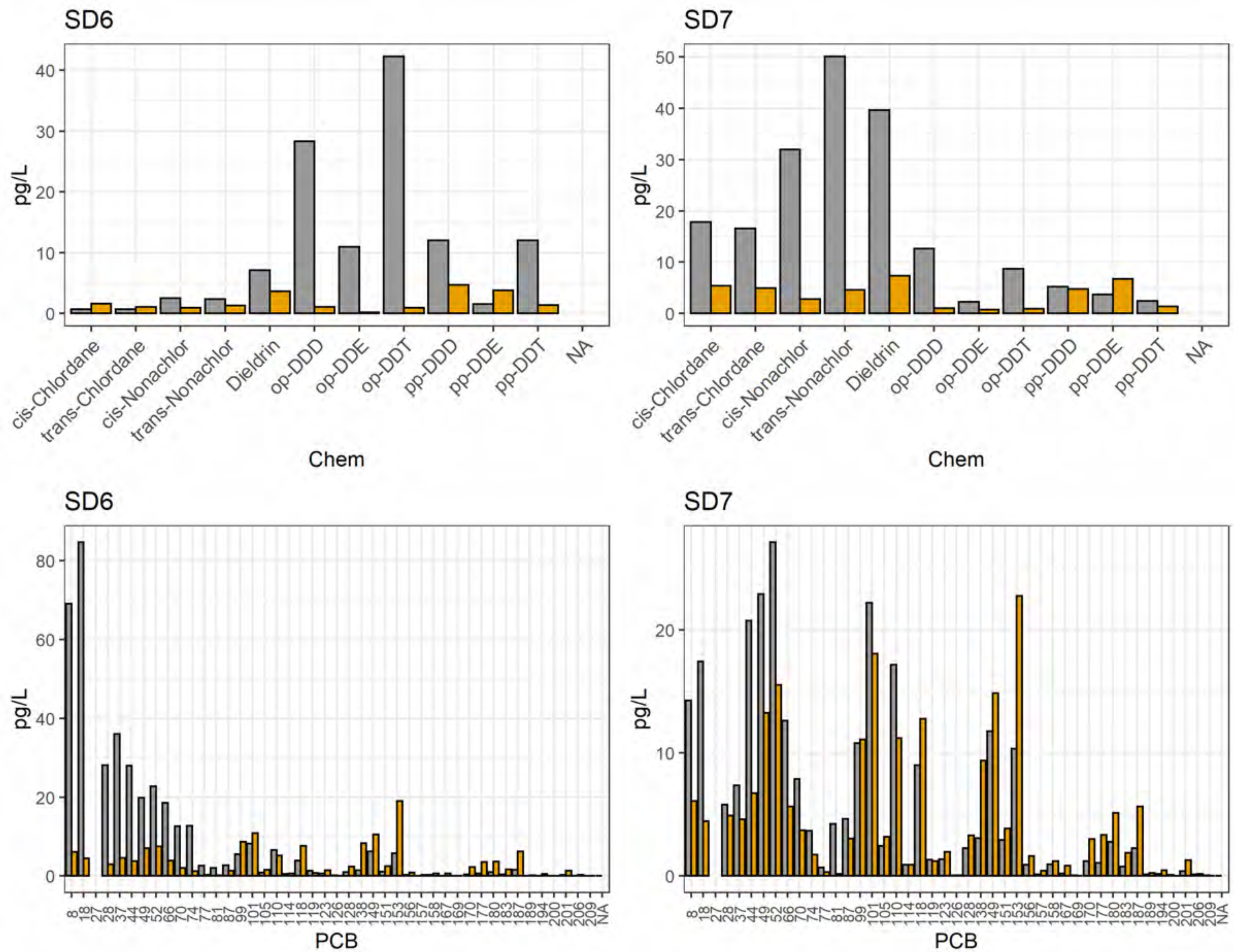

Figure 24. Comparison of measured (using passive samplers) and predicted (using the food web model) dissolved concentrations for SD6 and SD7. Gray bars show passive sampler results; gold bars show predicted concentrations.

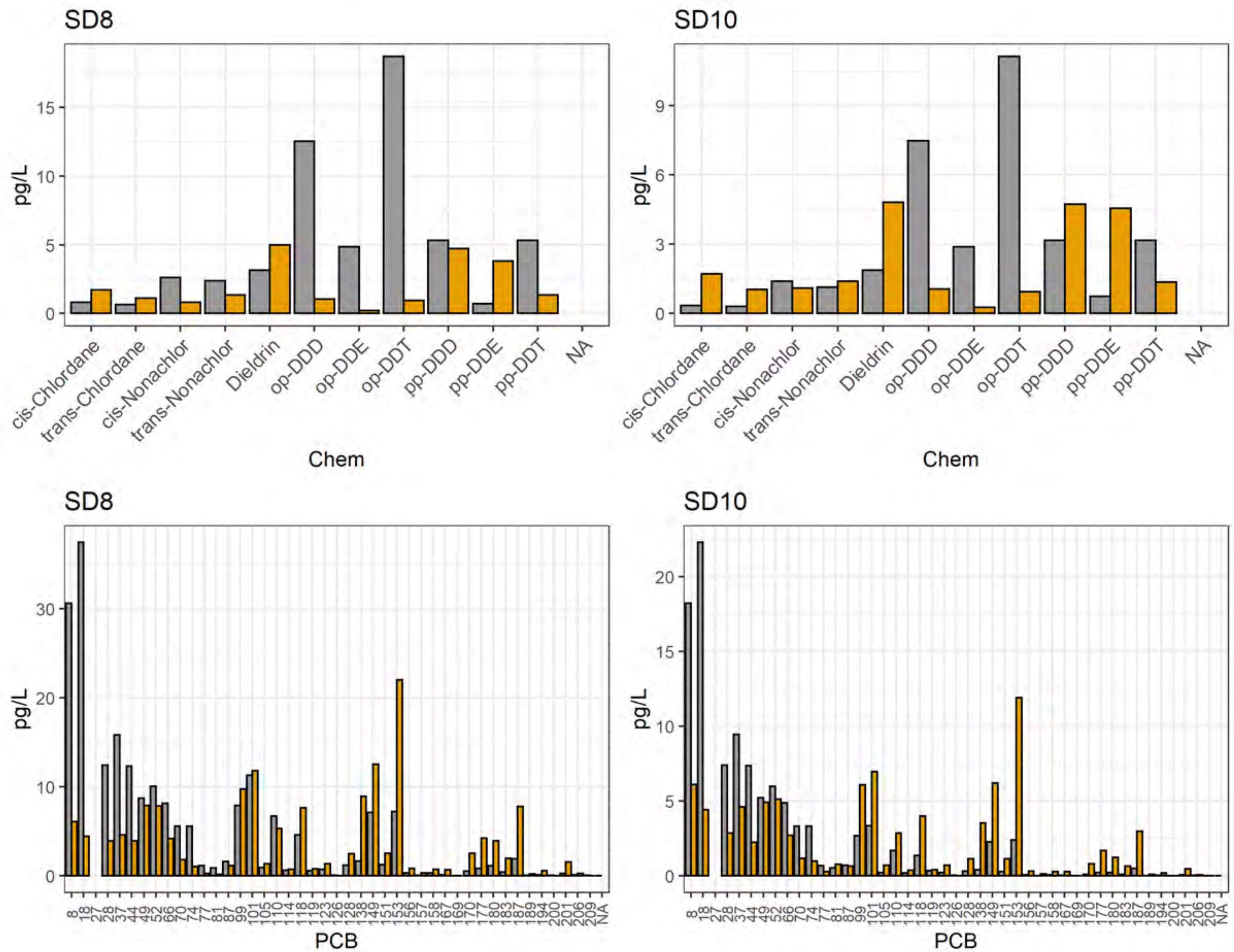

Figure 25. Comparison of measured (using passive samplers) and predicted (using the food web model) dissolved concentrations for SD8 and SD10. Gray bars show passive sampler results; gold bars show predicted concentrations.

Assessment site size comparison

Bioaccumulation model predictions have greater accuracy when the sediment and water chemistry inputs are representative of the forage range of the target species. The bioaccumulation analyses presented in the previous “Station chemistry comparison” section are limited in that chemistry data from only one location per station were available for use. It is likely the sediment and water chemistry input data for these analyses were not representative of the forage area due to spatial variability, especially for sites located near contaminant sources (e.g., SD1, 3, and 7) where small-scale variations are to be expected. The objective of this set of bioaccumulation analyses was to investigate the influence of different assessment site areas (with corresponding changes in contaminant concentrations) on bioaccumulation model predictions. Four assessment areas were evaluated for each biota collection station:

- **Station (P_Station),** representing the sediment/water chemistry measured at the biota collection site in 2018. Data used for these analyses were the mean of Event 1 and 2 sediment and water column samples obtained in conjunction with biota sampling at stations SD1, 3, 6, 7, 8, and 10 (Figure 1).
- **Biota collection area (P_Area)**, representing the areas sampled to collect fish and zooplankton samples for chemical analysis at each station. In some cases, different collection areas were used for different biota types. In this case, different chemistry inputs were calculated for each area. Sediment chemistry and TOC concentrations for these areas were calculated by Windward based on Figures 2-6, using the same methods referenced in their bioaccumulation report (Toll 2019).
- **Bay region (P_Region)**, representing the North, Central, and South regions typically used in previous bioaccumulation studies in San Diego Bay. Sediment chemistry and TOC concentrations for these regions were the same as those used in the Windward bioaccumulation study (Toll 2019).
- **Entire bay (P_Bay)**, representing the entire area of San Diego Bay. Sediment chemistry and TOC concentrations for this area were the same as the site-wide values used in the Windward bioaccumulation study (Toll 2019).

The sediment chemistry and TOC data for biota collection areas, bay regions, and the entire bay were average surface area weighted concentrations based on a PCB congener dataset compiled by Windward. DDT and chlordane data were not available for these analyses. All bioaccumulation model analyses for each site size variation were conducted using concentrations of PCB118. This congener was shown by Toll (2019) to provide a good representation of total PCB distribution and bioaccumulation in San Diego Bay. Regression analysis using SCCWRP sediment data from the current study also demonstrated a strong relationship between PCB118 and total PCBs (sum of congeners measured by SCCWRP), as shown in Figure 26. Dissolved PCB118 values for the biota collection area, bay regions, and the entire bay analyses were calculated using a linear regression based SCCWRP data for sediment and dissolved PCB118 concentrations (Figure 27).

The sediment and dissolved PCB118 and sediment TOC data used in the analyses are summarized in Table 14. Note that the same chemistry data for the bay regions and entire bay were used for each analysis for a station within that region. All bioaccumulation analyses used the same model and associated parameters as used in previous analyses for this study (e.g., Figure 18).

Model results for each combination of station and areas are shown in Figures 28-33. The predicted tissue PCB118 concentrations for each site area variation are shown and compared to the measured concentration in biota collected from the site (Obs). Model analyses were not conducted for shiner perch for stations SD3 and 6 because this species was not collected from either site for comparison.

A similar trend in model results for PCB118 was observed for the site area evaluations for stations SD1, 3, and 7 (Figures 28, 29 and 31), which had the highest PCB sediment contamination among the 6 biota collection sites. Predicted tissue concentrations for all species at these sites declined as the assessment site area increased. Topsmelt and zooplankton predictions for P_Region and P_Area were similar to the measured station tissue concentrations (Obs) of PCB118. Predicted spotted sand bass predicted tissue concentrations for each station/site size combination were always substantially higher than measured concentrations, even for bay regions and the entire bay.

Predicted tissue results for SD6, 8, and 10 showed different patterns of variation with increasing site size. Predicted tissue concentrations for P_Area at SD6 and 8 were lower than P_Region, and P_Bay (Figures 30 and 32), a result consistent with the relatively lower sediment concentrations near the collection sites, which were located distant from commercial/industrial areas in the east Bay. SD10 predicted tissue concentrations tended to increase with increasing site size, resulting in the P_Station result being most similar to the observed value for all species (Figure 33). The SD10 predicted results were somewhat unexpected, since the measured sediment PCB118 concentration was about 4 times higher that estimated sediment concentrations used for P_Area and P_Region (Table 14). The likely cause of this apparent discrepancy is a measured dissolved PCB118 concentration for the station that is lower than the regression-based estimates for P_Area and P_Region. The increase in SD10 predicted tissue concentration for P_Bay is likely due to the higher average estimated sediment PCB118 concentration for the entire bay (1.7 ng/g) relative to the South region (0.2 ng/g).

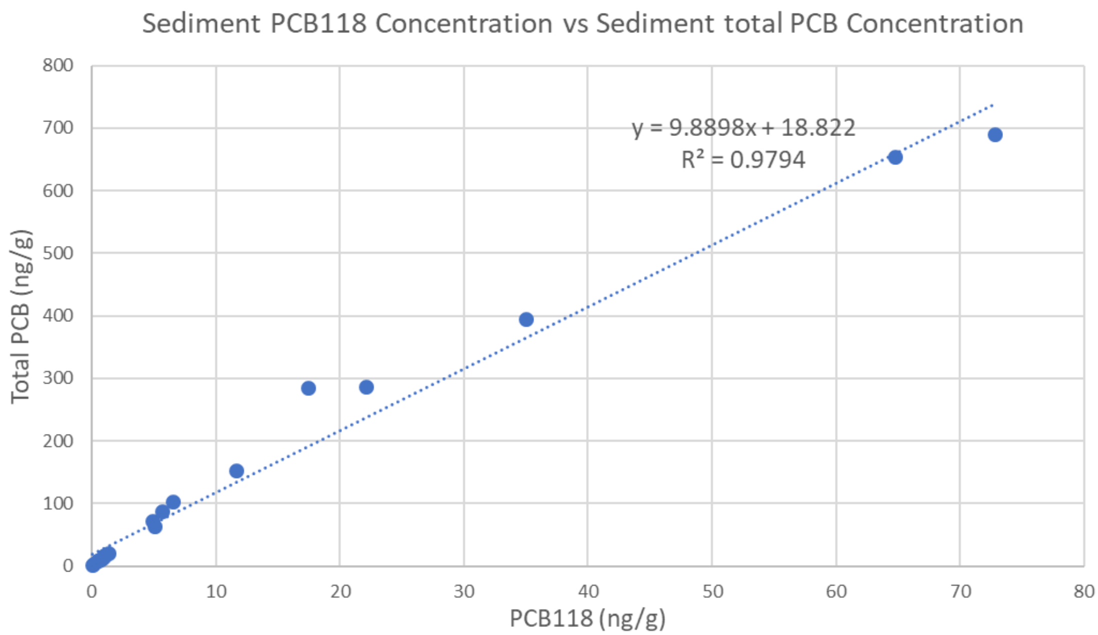

Figure 26. Relationship between sediment total PCBs and PCB118 (SCCWRP sediment data).

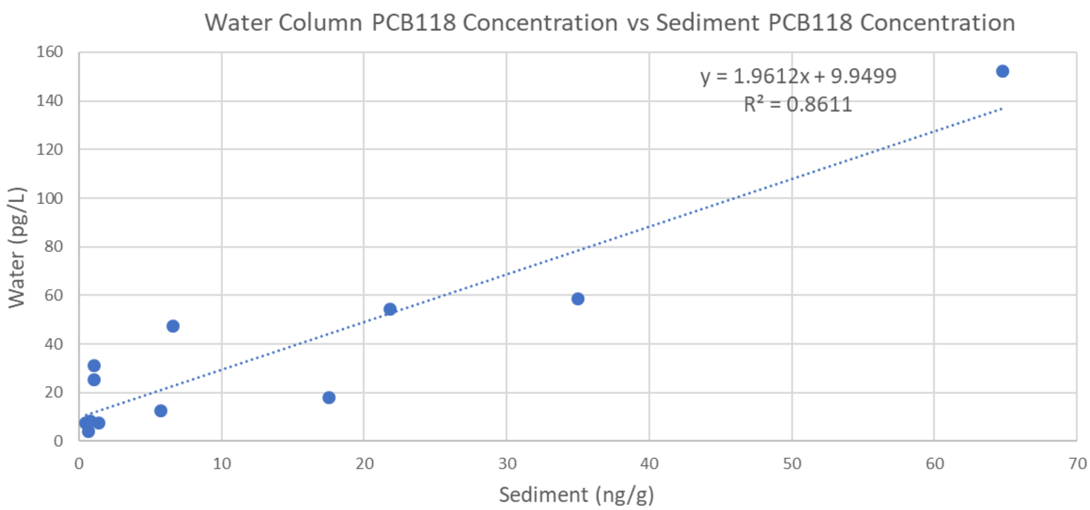

Figure 27. Relationship between dissolved PCB118 (passive sampler data) and sediment PCB118 (SCCWRP sediment data).

Table 14. Sediment and water column parameters used for site size comparison.

Station	Region	Sediment PCB118 (ng/g dw)				
		Point[a]	Area1[b]	Area2[b]	Region[c]	Bay[d]
SD1	North	49.9	24.04	0.6	2.1	1.7
SD3	North	19.66	5.78		2.1	1.7
SD6	Central	0.79	0.41		2.6	1.7
SD7	Central	6.16	5.25	5.0	2.6	1.7
SD8	Central	1.22	0.49		2.6	1.7
SD10	South	0.75	0.15		0.2	1.7

[a] Mean of measured values for station; [b] Primary and secondary biota collection areas (Windward data); [c] North, Central, or South (Windward data); [d] Entire bay (Windward data)

Station	Region	Dissolved Water Column PCB118 (pg/L)				
		Point[a]	Area1[e]	Area2[e]	Region[e]	Bay[e]
SD1	North	105.5	57.0	11.1	14.1	13.3
SD3	North	36.2	21.3		14.1	13.3
SD6	Central	19.4	10.8		15.0	13.3
SD7	Central	30.0	5.2	5.1	15.0	13.3
SD8	Central	16.4	10.9		15.0	13.3
SD10	South	6.2	10.2		10.3	13.3

[e] Calculated by regression (Figure 27) using corresponding sediment estimates from Windward data.

Station	Region	Sediment TOC (%)				
		Point[a]	Area1[b]	Area2[b]	Region[c]	Bay[d]
SD1	North	1.92	0.77	0.3	0.7	0.85
SD3	North	1.42	1.14		0.7	0.85
SD6	Central	0.56	0.49		1.0	0.85
SD7	Central	1.9	0.98	4.7	1.0	0.85
SD8	Central	0.83	0.82		1.0	0.85
SD10	South	1.52	1.18		0.9	0.85

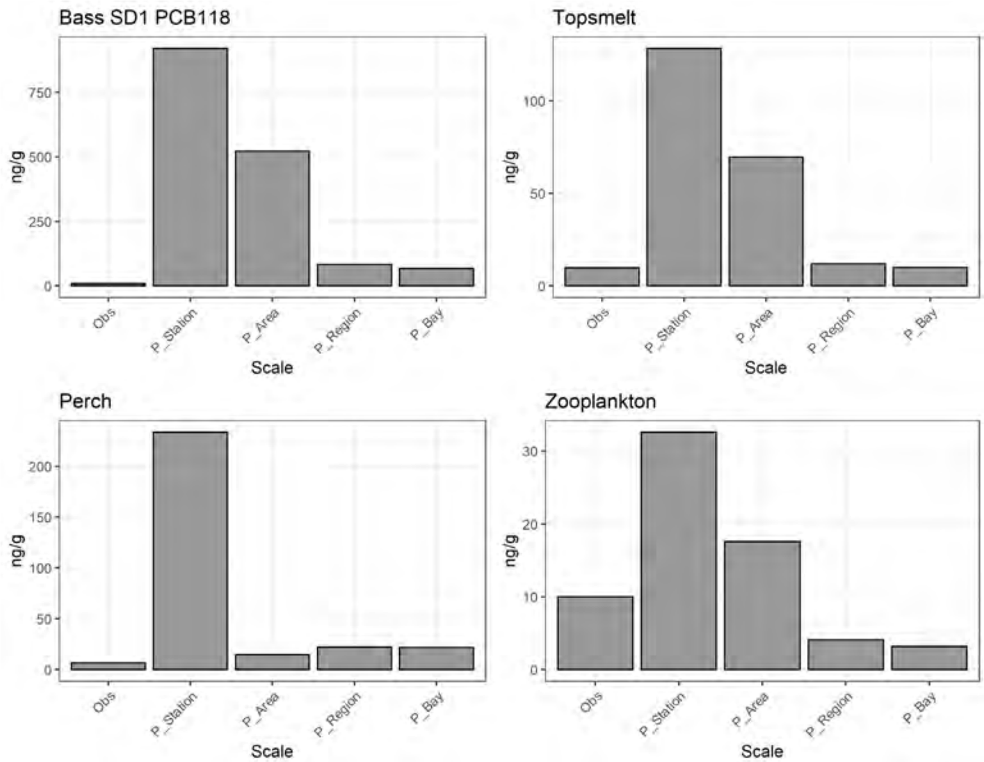

Figure 28. SD1 bioaccumulation model estimates based on varying sediment contamination area.

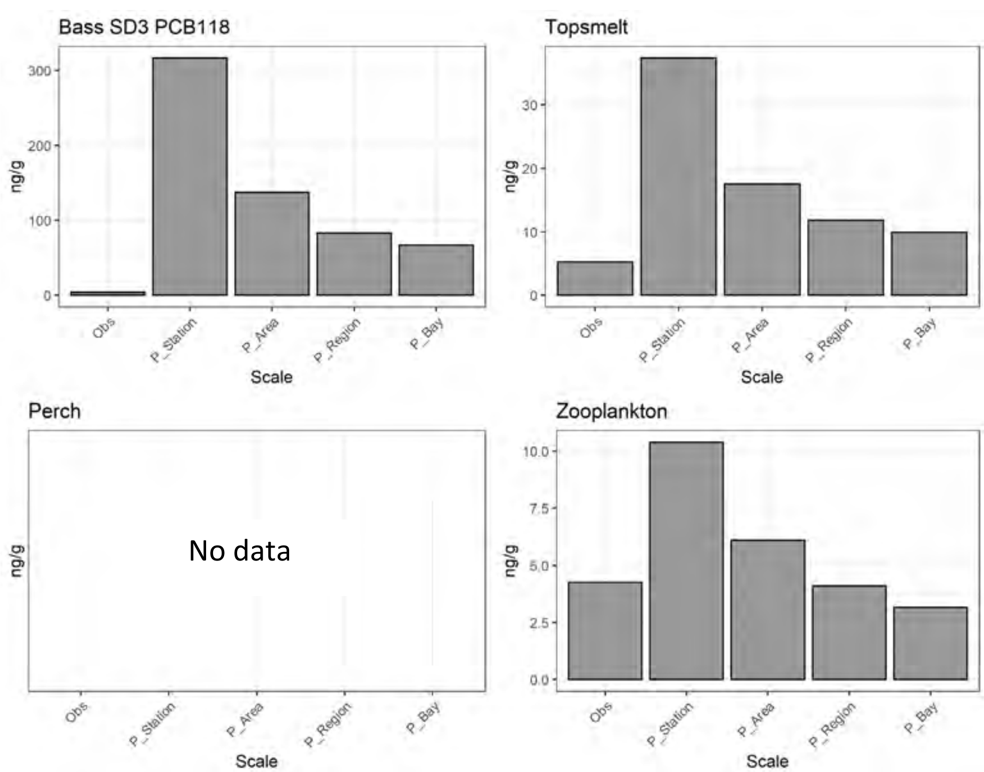

Figure 29. SD3 bioaccumulation model estimates based on varying sediment contamination area.

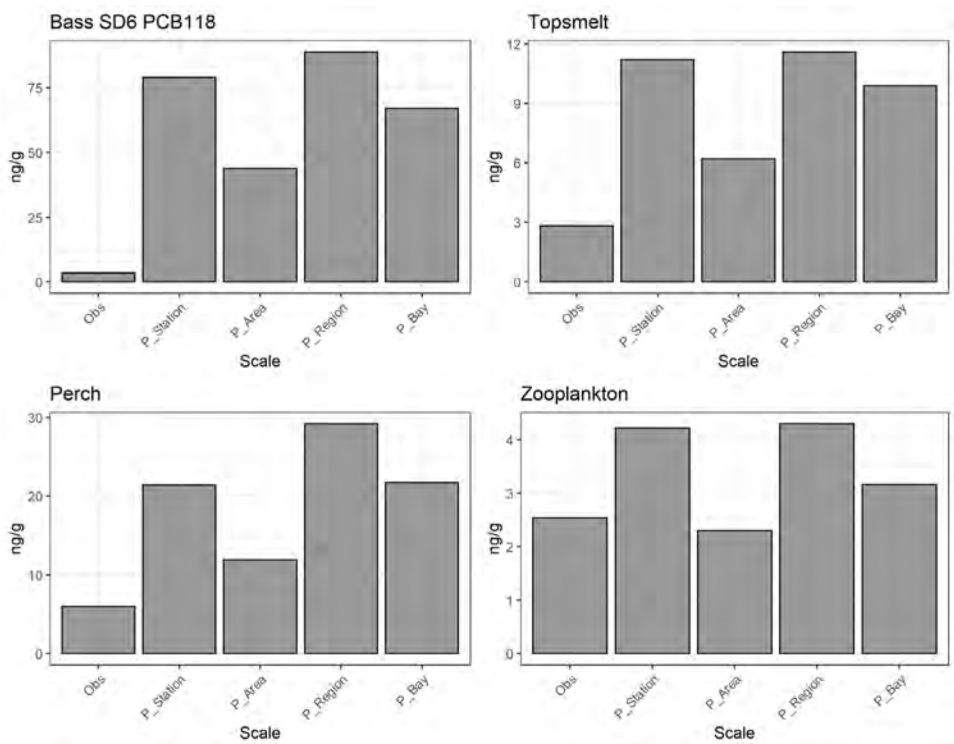

Figure 30. SD6 bioaccumulation model estimates based on varying sediment contamination area.

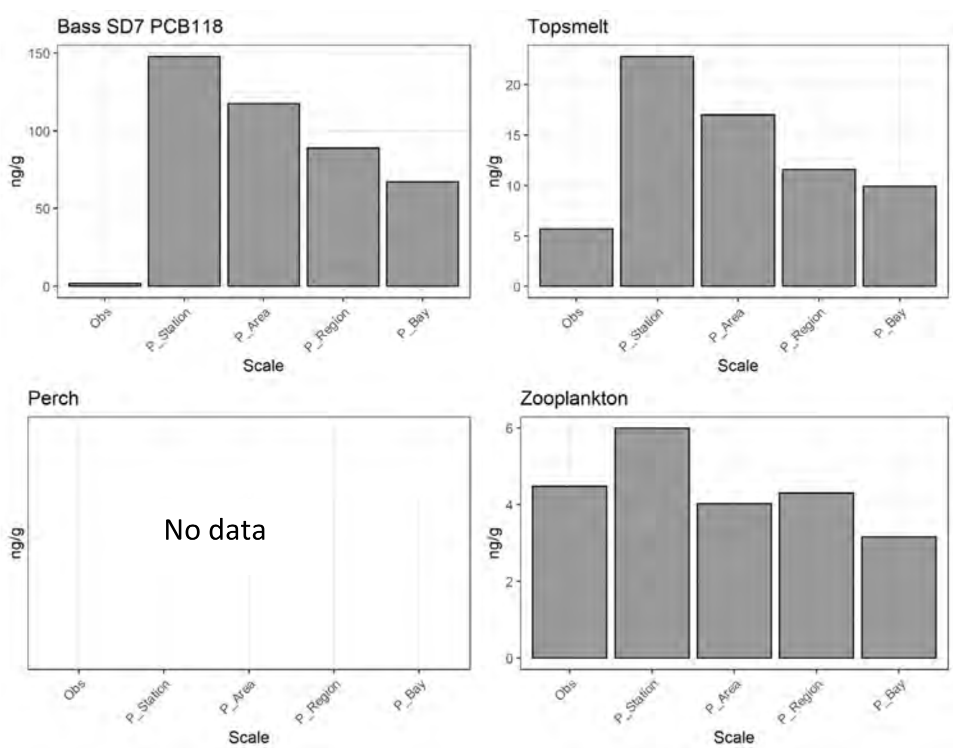

Figure 31. SD7 bioaccumulation model estimates based on varying sediment contamination area.

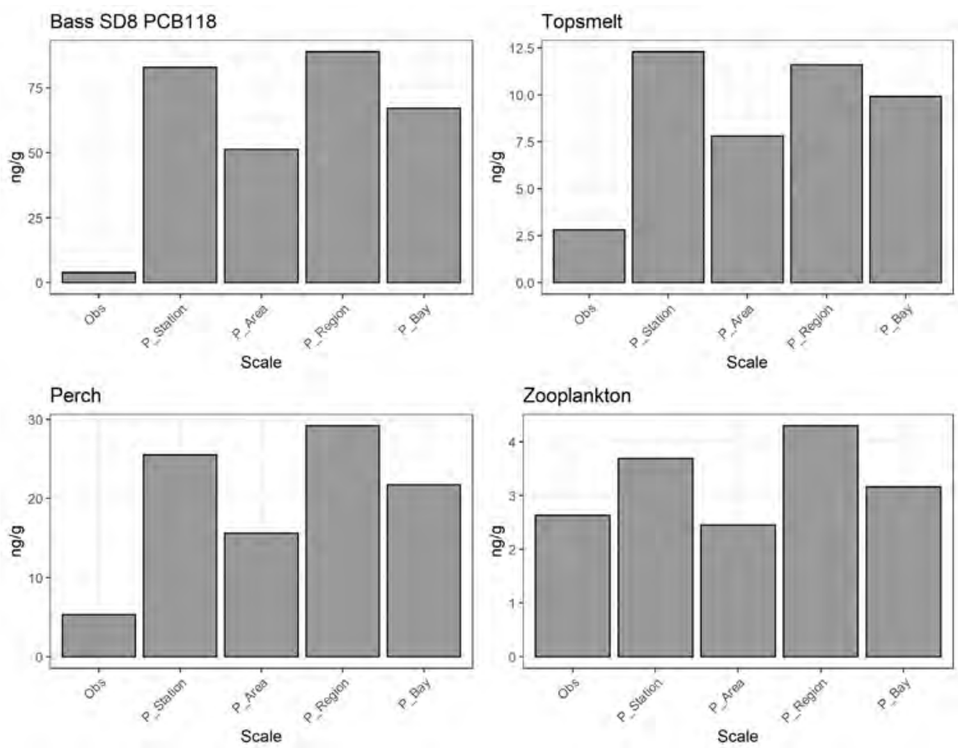

Figure 32. SD8 bioaccumulation model estimates based on varying sediment contamination area.

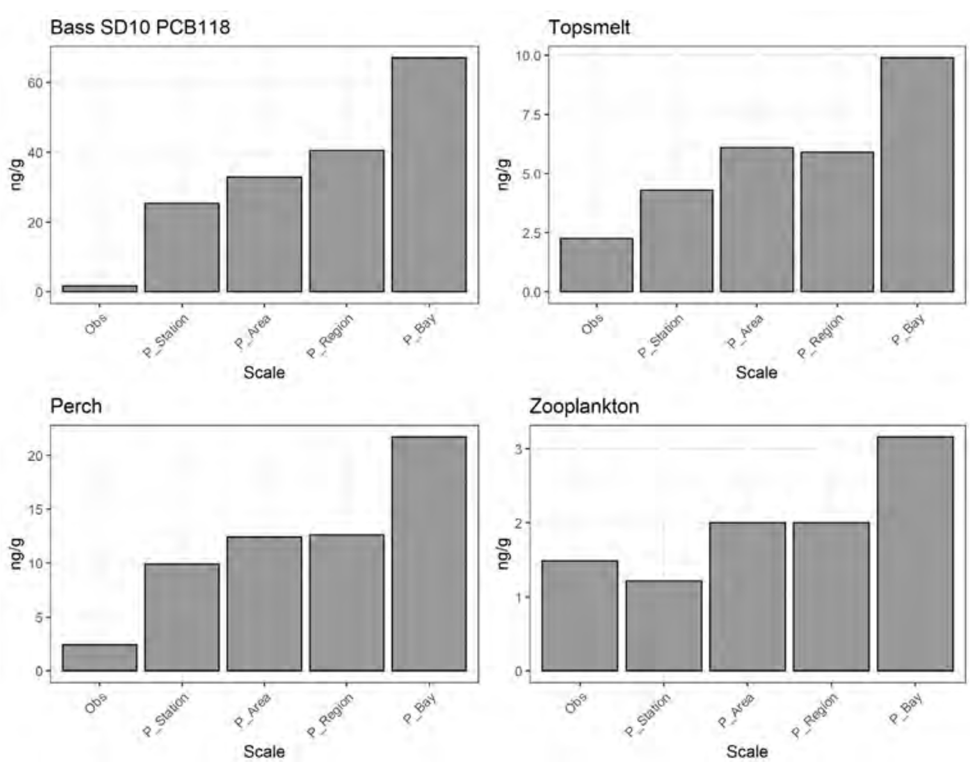

Figure 33. SD10 bioaccumulation model estimates based on varying sediment contamination area.

Bioaccumulation model comparison

The bioaccumulation model used in the analyses by Windward (Toll 2019) differed from the SQO model used in this study in terms of food web structure and model parameters. Most biotic and abiotic model parameters were the same, but the Windward model differed in terms of log Kow and some biotic parameters (Table 15). The development of the Windward bioaccumulation model was based on measurement of all 209 PCB congeners in spotted sand bass tissue samples, dissolved and particulate water grab samples (obtained by collection of approximately 20 L of water per sample), and surface sediment samples (Toll 2019). A relationship between PCB118 and total PCBs (as the sum of 209 congeners) was developed and PCB118 was modeled. For the SQO bioaccumulation models presented, a subset of PCB congeners in fish tissue, sediment, and dissolved water concentrations (from passive samplers) were determined.

The Windward model food web contained three biotic compartments: small invertebrates (e.g., benthic infauna), primary consumers (small fish such as gobies and anchovies), and spotted sand bass. The SQO model food web contains multiple compartments for invertebrates (e.g., polychaetes, amphipod, bivalve, crab) and primary consumer fish (e.g., planktivore, benthivore, mixed diet), and provides predicted tissue concentrations for multiple target species (e.g., spotted sand bass, shiner perch, and topsmelt) as summarized in Table 16.

Comparison of model types used predicted tissue PCB118 concentrations based on site-wide sediment concentrations reported by Toll (2019). Results were compared for the three biotic food web compartments used in the Windward model: small invertebrates, primary consumers, and spotted sand bass. Tissue concentration results from the Windward model (Table 17) were extracted from figures in the Toll report and are thus approximations.

Three variations of the SQO model were compared (Table 15):

- SQO v1 – original (baseline) version of bioaccumulation model used in Tier 2 Human Health SQO assessment framework. The only modifications to the model were changes to site-specific environmental conditions (e.g., sediment TOC, temperature, salinity) and spotted sand bass lipid content
- SQO v2 – model changed to include Windward model parameters (e.g., Kow), porewater PCB118 concentration, and four food web compartments (e.g., small invertebrates, primary consumers, spotted sand bass, and a mixture of phytoplankton and zooplankton to represent ingestion of water column particles.
- SQO v3 – SQO v2 model modified so that water column particle ingestion was represented solely by phytoplankton.

The estimated spotted sand bass tissue PCB118 concentration from the SQO v1 model (92.5 ng/g ww) was 4.6 times that obtained using the Windward model (20 ng/g ww, Table 17). Estimates for the small invertebrate and primary consumer compartments are not directly comparable because of differences in food web structure. However, PCB118 values reported for the Windward model fell within the range of estimates for comparable SQO v1 compartments.

Modification of the SQO model to emulate most elements of the Windward model (SQO v2; Table 15) resulted in a lower estimate of PCB118 for spotted sand bass (49.8) that was 2.5 times higher than the Windward model estimate (Table 17). SQO v2 results for the small invertebrate and primary consumer compartments were approximately double those for the Windward model. Estimates of PCB118 for shiner perch and topsmelt increased by 30-40%, relative to SQO v1.

Alteration of the SQO v2 model to shift the dietary fraction of zooplankton to phytoplankton resulted in further reductions in PCB118 concentrations for all food web components (Table 17). The resulting values were still elevated relative to the Windward model but were within a factor 2 of those reported by Toll (2019).

The factors responsible for the differences in tissue estimates between the Windward and SQO v3 models are not known at this time. Possible causes may include differences in how exposure to suspended sediment particles are handled between models, model structure, exposure concentrations, and Kow or tissue lipid use.

Table 15. Bioaccumulation model parameters.

Parameter	Category	Value			
		Windward[a]	SQO v1[b]	SQO v2[c]	SQO v3[d]
PCB118 log Kow		6.8	6.69	6.8	6.8
Sediment PCB118 (ng/g dw)		1.74	1.74	1.74	1.74
Suspended particulate PCB118 (ng/g dw)		1.32	na		
Water PCB118 (ng/g)		1.0E-05	1.0E-05	1.0E-05	1.0E-05
Porewater PCB118 (ng/g)		1.2E-04	4.76E-05	1.2E-04	1.2E-04
Sediment TOC fraction		0.0085	0.0085	0.0085	0.0085
Water particulates OC fraction		0.016	0.016	0.016	0.016
Temp		17	17	17	17
Dietary transfer efficiency constant A		8.5E-08	8.5E-08	8.5E-08	8.5E-08
Dietary transfer efficiency constant B		2	2	2	2
NLOM-octanol PC		0.035	0.035	0.035	0.035
NLOC-octanol PC		0.35	0.35	0.35	0.35
Dietary AE of lipid	Small inverts	0.75	0.75	0.75	0.75
Dietary AE of NMOM	Small inverts	0.75	0.75	0.75	0.75
Dietary AE of water	Small inverts	0.55	0.55	0.55	0.55
Dietary AE of lipid	Fish	0.9	0.9	0.9	0.9
Dietary AE of NLOM	Fish	0.5	0.6	0.5	0.5
Dietary AE of water	Fish	0.55	0.55	0.55	0.55
Weight (kg)	Small inverts	2.50E-04	T16	2.50E-04	2.50E-04
Lipid fraction	Small inverts	0.015	T16	0.015	0.015
Water fraction	Small inverts	0.7	T16	0.7	0.7
Fraction of porewater ventilated	Small inverts	0.05	T16	0.05	0.05
Weight (kg)	Primary consumers	0.022	T16	0.022	0.022
Lipid fraction	Primary consumers	0.015	T16	0.015	0.015
Water fraction	Primary consumers	0.77	T16	0.77	0.77
Fraction of porewater ventilated	Primary consumers	0.05	T16	0.05	0.05
Weight (kg)	Spotted sand bass	0.25	0.6	0.25	0.25
Lipid fraction	Spotted sand bass	0.015	0.015	0.015	0.015
Water fraction	Spotted sand bass	0.76	0.79	0.76	0.76
Fraction of porewater ventilated	Spotted sand bass	0	0	0	0
Diet% sediment	Small inverts	50%	T16	50%	50%
Diet% particulates and plankton[e]	Small inverts	50%	T16	25/25%	50/0%
Diet% sediment	Primary consumers	2%	T16	2%	2%
Diet% particulates and plankton[e]	Primary consumers	13%	T16	3/10%	13/0%
Diet% small invertebrates	Primary consumers	85%	T16	85%	85%
Diet% sediment	Spotted sand Bass	0%	0%	0%	0%
Diet% particulates and plankton[e]	Spotted sand Bass	1%	1%	0/1%	1/0%
Diet% small invertebrates	Spotted sand Bass	74%	64%	74%	74%
Diet% primary consumers	Spotted sand Bass	25%	35%	25%	25%

[a] Calibrated using San Diego Bay data
[b] Model parameters used in HHSQO Tier 2 assessment (Bay et al. 2017); T16 - see Table 16 for values
[c] Includes modifications used by Windward, plus inclusion of zooplankton
[d] Includes modifications used by Windward, with removal of zooplankton
[e] SQO model values show percentage of phytoplankton/zooplankton

Table 16. SQO bioaccumulation model food web composition for target species. Only those components relating to spotted sand bass, shiner perch, or topsmelt are shown.

		Dietary Composition (fraction) of food web component																	
Code	Food Web Component	P	M	I1	I2	I3	I4	I5	I6	I7	I8	I9	F2	F4	F5	F6	Spotted Sand Bass	Shiner Perch	Topsmelt
S	Sediment				0.9	0.9	0.3	0.15	0.1	0.3	0.44				0.05	0.05		0.05	0.05
P	Phytoplankton			1	0.05	0.05	0.35	0.65	0.45	0.65	0.01	0.3	0.2		0.1		0.01	0.1	0.2
M	Submerged Macrophyte										0.1								0.2
I1	Zooplankton				0.05	0.05	0.35	0.2	0.45	0.05	0.1	0.3	0.35		0.2			0.1	0.08
I2	Small polychaete													0.2	0.05	0.05		0.1	
I3	Large polychaete													0.2	0.05	0.1		0.1	0.01
I4	Amphipod										0.2		0.2	0.15	0.25	0.15	0.01	0.2	0.4
I5	Cumacean										0.15		0.15	0.15	0.25	0.15		0.2	0.01
I6	Mysid											0.4	0.1		0.05	0.2	0	0.15	0.05
I7	Bivalve mollusk																0.28		
I8	Decapod crab																0.35		
I9	Crangon shrimp													0.25		0.2			
F2	Forage fish - planktivore															0.05	0.1		
F4	Forage fish - benthivore																0.15		
F5	Forage fish - mixed diet i													0.05		0.05	0		
F6	Forage fish - mixed diet ii																0.1		

Table 17. Comparison of bioaccumulation model estimates for PCB118.

	Tissue PCB 118 (ng/ g ww)			
Model Compartment	Windward[a]	SQO v1[b]	SQO v2[c]	SQO v3[d]
Small invertebrates	5.1	2.7-13.7	9.1	7.0
Primary consumers	12.1	3.2-50.6	24.4	17.5
Spotted sand bass	19.7	92.5	49.8	37.8
Shiner Perch	na	18.1	24.9	18.1
Topsmelt	na	8.1	10.6	8.2
Zooplankton	na	2.6	2.5	2.5

[a] Calibrated using San Diego Bay data
[b] Model parameters used in HHSQO Tier 2 assessment (Bay et al. 2017)
[c] Includes modifications used by Windward, plus inclusion of zooplankton
[d] Includes modifications used by Windward, with removal of zooplankton

SUMMARY

This study (including work reported by Wood 2019), in combination with independent studies reported by Toll (2019) and Douglas (2019), provides a comprehensive investigation of dissolved contaminant occurrence, fate, and bioaccumulation in San Diego Bay. This study is noteworthy in the extensive application of passive sampling technology and bioaccumulation models to investigate factors influencing bioaccumulation of organochlorines by fish.

Key findings

- Dissolved PCBs, DDTs, chlordanes, and dieldrin occur in the water column in all areas of San Diego Bay (Wood 2019). This finding underscores the importance of accurately characterizing water column (particulate and dissolved) concentrations in future bioaccumulation studies and tracking changes over time as cleanups take place.

- Forensic evaluation (Douglas 2019) supports the conclusion that water column and sediment contamination patterns are strongly influenced by resuspension of sediment contamination. Ship actions, tides, and other hydrodynamic processes contribute to resuspension of sediment contamination and transport of resuspended sediment contamination.

- Movement of sediment particles and water throughout the bay suggests that sediment assessment and management activities will be most effective when conducted over broad, rather than small, spatial scales.

- Overlying water column contaminant concentrations were strongly associated with concentrations in nearby sediment. Sites with the highest sediment organochlorine concentrations almost always had the highest water column concentrations, and significant linear regression relationships were present between sediment and water column PCBs.

- Pore water and sediment-water interface PCB concentration data suggest that a net flux of PCBs from sediment to the sediment-water interface is occurring at all locations studied. These findings support a conclusion that sediment remediation efforts are likely to improve water quality and reduce PCB bioaccumulation in local biota.

- Water column PCB concentrations were higher in Event 2 (Sept-Oct), compared to Event 1 (March-June). This observation suggests that temporal factors could be important modifiers of sediment flux or water column transport in San Diego Bay. Future studies should include a temporal component in their study to provide more representative data.

- Preliminary mass balance calculations support a conclusion that PCB flux from sediment is the primary source of water column contamination. The residence time of water in most portions of the bay appears to be longer than the time needed for PCB flux from sediment to produce the observed concentrations in the water column.

- Variability in tissue contaminant concentrations was observed in spotted sand bass, shiner perch, topsmelt, and zooplankton. Regression analysis found that variation in sediment contamination could account for 45-99% of tissue contaminant variation for some species/events. The cause for a lack of significant regressions in other cases was not determined but could potentially be due to the use of sediment concentrations that were not representative of exposure areas for the species in question or lack of controls for the age of higher trophic level fish. This study was not designed to explain the variability in the correlation between sediment and tissue contamination. Future investigations (both field studies and modeling) should consider this relationship (i.e., explaining variability in the correlation between sediment and tissue contamination) as a study design objective.

- SQO bioaccumulation model estimates for fish tissue contaminants frequently exceeded observed values for the same species collected from the site. The magnitude of the difference between model and observed values seemed to be associated with fish life history characteristics, likely diet composition or forage range, or estimating the appropriate chemical exposure environment factors. Spotted sand bass, with the highest dietary proportion of benthic invertebrates, had the highest relative model overestimation (mean = 42 for PCBs). Topsmelt, the fish with the lowest dietary contribution from sediment biota, showed the least model overestimation (mean = 3.3).

- “Hot spots” (e.g., SD1, 3, and 7) have higher spatial variation in sediment contamination. Therefore, the concentrations measured at the single sediment sampling locations used in this study are more likely to misrepresent what fish sampled from the same area were exposed to. Collection of representative chemistry data (sediment and water column), using multiple sampling stations and compositing (for tissues) is needed to reduce uncertainty in the relationship between exposure and tissue concentrations.

- Bioaccumulation of contaminants from the water through respiration and trophic transfer via dietary uptake can be major determinants of tissue contaminant concentrations in some species. Dissolved contaminants in the water column were estimated to account for 71-92% of fish tissue contamination. The greatest impacts of water contamination were present in topsmelt. This result is likely due to the relatively large portion of plankton, organisms that bioaccumulate contaminants exclusively from the water column, in their diet. These findings underscore the importance of using accurate and representative water column (dissolved and particulate) contaminant data in bioaccumulation studies.

- Estimation of water column concentrations using the equilibrium partitioning model included in the SQO assessment framework provided generally conservative results (lower dissolved concentration) compared to concentrations modeled with passive sampling. However, this relationship was variable among congeners and chemical types, indicating that complex processes are involved. Direct measurement of dissolved and particulate concentrations should be considered to improve confidence in bioaccumulation model application and interpretation.

- Bioaccumulation model predictions based on four assessment site scale scenarios (e.g., station, collection area, region, all bay) often showed large differences. Bioaccumulation model results are likely to have increased reliability when the underlying sediment and water chemistry are spatially representative of the fish forage area.

- Comparisons of the SQO bioaccumulation model to the calibrated model used by Windward illustrated the importance of model parameter selection and exposure characterization. Differences in spotted bass bioaccumulation estimates were reduced from five-fold to within a factor of two when the SQO model structure and parameters were modified to be similar to those of the Windward calibrated model.

RECOMMENDATIONS

Results from this study suggest several bioaccumulation study design elements that should be followed to improve confidence and reliability of the results. In general, these recommendations are consistent with those included in the recent amendments to the Water Board’s Water Quality Control Plan for Enclosed Bays and Estuaries of California (SWRCB 2018).

- The sampling design for bioaccumulation assessment should include features to ensure that the chemical data used for modeling are spatially and biologically representative. Multiple sediment locations, selected in an objective manner to be spatially representative, should be sampled. A minimum of three sediment locations is specified in the Water Quality Control Plan (Plan). A greater number of stations is recommended to increase confidence in the results.
- Sampling area should be as large as feasible to account for variability in fish movement and spatial variation in contamination. Areas less than one square kilometer should be avoided.
- Collection and analysis of multiple samples for water column (particulate and dissolved) chemistry is recommended. Water column contaminant data have a strong influence on bioaccumulation model results and samples should be representative of spatial and temporal variation at the site.
- Analysis of all 209 PCB congeners should be conducted for sediment, water, and all tissue types to establish relationship between the congener(s) modeled to total PCBs (as sum of 209 congeners). Quantification of all 209 PCB congeners is also recommended because it allows for a more accurate determination of total PCBs than a subset of congeners. Furthermore, correction factors can be developed and applied to the sum of congener subsets to more accurately estimate total PCB concentrations.
- Analysis of multiple composite samples from more than one species of fish is recommended. A minimum of five samples per species (as recommended by the Plan) should be analyzed. Collection of samples at different times of the year is also recommended to account for potential temporal variation. Analysis of individuals of known age and repeat sampling across years is also recommended for determination of bioaccumulation rates and changes over time.
- Use of estimated water column chemistry concentrations is likely to reduce the accuracy of model results and should be avoided.
- Use of a bioaccumulation model calibrated to the site is recommended for use in planning or evaluating significant management actions. The SQO Tier 2 model was developed to be applicable statewide for the primary purpose of establishing the likelihood of linkage between sediment and tissue contamination. The general nature of the SQO model parameters, together with likely variations in environmental and biological conditions in various bays, may increase model uncertainty for some applications. Confidence in model application and interpretation will be increased if the accuracy of model outputs is assessed and optimized through calibration efforts. Such efforts may not require extensive investments in sampling or analysis to be productive. Model assessment and calibration efforts should be conducted in a transparent process, with oversight/approval by the appropriate regulatory agencies.

REFERENCES

Amec Foster Wheeler Environment & Infrastructure. 2016. Shallow Water Habitat Bioaccumulation (SWHB) Study prepared for the City of San Diego. June, 2016.

Amec Foster Wheeler Environment & Infrastructure. 2017. Regional Harbor Monitoring Program (RHMP) 2013 Aquatic Food Web Bioaccumulation Study. January 2016.

Arnot, J.A. and F.A.P.C. Gobas. 2004. A food web bioaccumulation model for organic chemicals in aquatic ecosystems. *Environmental Toxicology and Chemistry* 23:2343-2355.

Bay, S.M., D.J. Greenstein, A.N. Parks, and C.Q.T. Zeeman. 2016. Assessment of Bioaccumulation in San Diego Bay. Technical Report 953. Southern California Coastal Water Research Project, Costa Mesa, CA.

Bay, S.M., A.N. Parks, A.R. Melwani, and B.K. Greenfield. 2017. Development of a sediment quality assessment framework for human health effects. Technical Report 1000. Southern California Coastal Water Research Project. Costa Mesa, CA.

Carilli, J., J. Leather, P-F. Wang, and J. Guerrero. 2019. San Diego Bay 2018 PCB Assessment Using Passive Samplers. Naval Information Warfare Center Pacific.

Chadwick, B., J. Leather, K. Richter, S. Apitz, D. Lapota, D. Duckworth, C. Katz, V. Kirtay, B. Davidson, A. Patterson, P. Wang, S. Curtis, G. Key, S. Steinert, G. Rosen, M. Caballero, J. Groves, G. Koon, A. Valkirs, K. Meyers-Schulte, M. Stallard, S. Clawson, R.S. Montee, D. Sutton, L. Skinner, J. Germano, and R. Cheng. 1999. Sediment Quality Characterization Naval Station San Diego: Final Summary Report.

Douglas, G.S. 2019. Analysis of PCB Source Signatures Within San Diego Bay. Expert Report of Dr. Gregory S. Douglas. NewFields Environmental Forensics Practice, Rockland, MA.

Gobas, F.A.P.C. and J. Arnot. 2010. Food web bioaccumulation model for polychlorinated biphenyls in San Francisco Bay, California, USA. *Environmental Toxicology and Chemistry* 29:1385-1395.

OEHHA. 2008. Development of Fish Contaminant Goals and Advisory Tissue Levels for Common Contaminants in Sport Fish: Chlordane, DDTs, Dieldrin, Methylmercury, PCBs, Selenium, and Toxaphene. Office of Environmental Health Hazard Assessment. Oakland, CA.

OEHHA 2018. Health Advisory and Guidelines for Eating Fish from San Diego Bay (San Diego County). Office of Environmental Health Hazard Assessment. Oakland, CA.

SWRCB. 2018. Ammendments to the Water Quality Control Plan for Enclosed Bays and Estuaries of California - Sediment Quality Provisions. California State Water Resources Control Board (SWRCB). Sacramento, CA.

Toll, J. 2019. Development and Application of a San Diego Bay PCB Bioaccumulation Model for Spotted Sand Bass in the Matter of: San Diego Unified Port Districy, Et Al. V. Monsanto Co., Et Al. Expert Report of John Toll, Ph.D. Windward Environmental LLC, Seattle, WA.

United States Environmental Protection Agency (USEPA). 2000. Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment. Status and Needs.

Wood Environment and Infrastructure Solutions (Wood). 2019. Influence of Dissolved Organochlorines on Bioaccumulation in San Diego Bay. Final Report. Submitted to: Port of San Diego, Planning and Green Port; City of San Diego, Transportation and Storm Water Department.

ATTACHMENT 1: CHEMICAL ANALYSIS METHODS

The target analytes are listed in Table A1-1. PRCs to be used in determining the fractional equilibration of PSDs with the water column are listed in Table A1-2. Table A1-3 provides a summary of the analytes to be measured, sample matrices, analytical methods, and target reporting limits. The laboratory methods and standard operating procedures (SOPs) are summarized below (Table A1-4). The samplers will be extracted and analyzed by gas chromatography/mass selective detection (GC/MSD) in the selected-ion monitoring (SIM) mode following procedures described in Fernandez et al. (2012), Fernandez et al. (2014), and Joyce et al. (2015). PSD sample data will be quantified by internal standard calibration methods.

Table A1-1. Constituents to be analyzed in sample extracts.

Sediment TOC	**PCBs**	**PCBs cont.**	**PCBs cont.**
	PCB 8	PCB 95	PCB 157
Water DOC	PCB 11	PCB 97	PCB 158
	PCB 18	PCB 99	PCB 167
Tissue % lipid	PCB 27	PCB 101	PCB 168
	PCB 28	PCB 105	PCB 169
Chlordanes	PCB 29	PCB 110	PCB 170
cis-Chlordane	PCB 31	PCB 114	PCB 174
trans-Chlordane	PCB 33	PCB 118	PCB 177
cis-Nonachlor	PCB 37	PCB 119	PCB 180
trans-Nonachlor	PCB 44	PCB 123	PCB 183
Oxychlordane	PCB 49	PCB 126	PCB 187
	PCB 52	PCB 128	PCB 189
Dieldrin	PCB 56	PCB 132	PCB 194
	PCB 60	PCB 137	PCB 195
DDTs	PCB 64	PCB 138	PCB 198
op-DDD	PCB 66	PCB 141	PCB 199
op-DDE	PCB 70	PCB 146	PCB 200
op-DDT	PCB 74	PCB 149	PCB 201
pp-DDD	PCB 77	PCB 151	PCB 203
pp-DDE	PCB 81	PCB 153	PCB 206
pp-DDT	PCB 87	PCB 156	PCB 209

Table A1-2. Proposed list of performance reference compounds (PRCs) for LDPE film passive samplers.

Compound	No. Cl	log K_{ow}
PCB 30	3	5.4
PCB 50	4	5.6
PCB 98	5	6.1
PCB 155	6	6.6
PCB 184	7	6.9
PCB 204	8	7.3
13C p,p'- DDE	4-Cl	6.9

Table A1-3. Chemical analyses of water, passive sampler, and sediment samples

Analyte	Matrix	Extraction Method	Analysis Method	Target Reporting Limits [a]	Units
Total Organic Carbon (TOC)	Sediment		SCCWRP SOP 2	0.02	%
Dissolved Organic Carbon (DOC)	Water		SCCWRP SOP 4	0.1	mg/L
Chlorinated Pesticides	Sediment	EPA 3545	SCCWRP SOP 3	0.15-25	µg/kg
	Water	EPA 3510	SCCWRP SOP 1	0.5-25	ng/L
	PSD	EPA/600/R-16/357	SCCWRP SOP 5	0.5-10	pg/L
Polychlorinated Biphenyl (PCB) Congeners	Sediment	EPA 3545	SCCWRP SOP 3	0.1-25	µg/kg
	Water	EPA 3510	SCCWRP SOP 1	0.5-25	ng/L
	PSD	EPA/600/R-16/357	SCCWRP SOP 5	0.001-40	pg/L

Notes:

[a.] Sediment reporting limits are on a dry-weight basis.

Field-exposed PSDs will be rinsed with deionized water and wiped clean of visible surface residue with a clean Kimwipe, cut into small pieces with solvent-rinsed stainless-steel scissors, and then placed in a solvent rinsed 300 mL glass bottle. The PSDs will then be spiked with recovery surrogates and extracted three times by sonicating in dichloromethane (DCM) for 15 minutes. The PSD extracts will then be filtered through pre-combusted (at 500°C) Na_2SO_4.

The combined extract will be concentrated, and solvent exchanged to hexane. The volume of the extract will be reduced to final volumes appropriate for the expected ambient seawater concentrations and PSD mass using a gentle stream of high purity N_2.

After addition of internal standards, extracts will be analyzed by GC/MSD in electron ionization (EI) and negative chemical ionization (NCI) modes for the target analytes (Table A1-1) and a suite of performance reference compounds (PRCs) pre-spiked into the PSDs (Table A2-2).

Calculation of Chlorinated Pesticides and PCBs in Seawater

The concentration of each target analyte in seawater, C_W, will be calculated. Compound-specific polyethylene-water partition coefficients (K_{PEW}) have been measured and will be used to calculate C_W as follows:

$$\mathbf{C_W = C^{\infty}_{PE} / K_{PEW}} \qquad \textbf{(1)}$$

Because full equilibration between the samplers and the water column following deployment is not assumed, each CW will be calculated from the concentration of analyte taken up by the sampler and the fraction of PRC released as follows:

$$\mathbf{C^{\infty}_{PE} = C_{PE} / f_{eq}} \qquad \textbf{(2)}$$

where C^{∞}_{PE} is the equilibrium analyte concentration in the PSD, C_{PE} is the concentration in the PSD, f_{eq} is the fractional equilibration of the sampler determined from PRC concentrations as described Joyce et al. (2015). For PSDs, C_W will be calculated using both the K_{PEW} and a K_{PEW} adjusted for the temperature and salinity of the specific sampling location (Lohmann 2012).

Equipment and Instrument Calibration

Table A1-5 provides calibration information for routine laboratory equipment and Table A1-6 provides calibration information for instruments. All instruments will be calibrated according to the manufacturer's recommended procedures.

Certified calibration standards used for instrument calibration will be obtained from commercial vendors (e.g., Ultra Scientific, North Kingstown, Rhode Island). PRCs will be obtained from Cambridge Isotope Laboratories, Inc. Calibration standards must contain each compound that will be quantified in the analysis.

Stock solutions containing target analytes, surrogate compounds and other inorganic compound mixtures will be made from reagent-grade chemicals. These solutions may be used to make intermediate standards from which calibration standards are prepared. All analytical stock solutions will be prepared using Class A volumetric glassware. Documentation relating to the receipt, mixing, and use of standards will be recorded in the laboratory notebooks or on data sheets.

Table A1-4. Supporting standard operating procedures (SOPs).

SOP	Description
SCCWRP SOP CHAPTER 1	Extraction of hydrophobic organics from aqueous samples
SCCWRP SOP CHAPTER 2	Determination of total organic carbon (TOC) using the Shimadzu SSM-5000a
SCCWRP SOP CHAPTER 3	Use of the Accelerated Solvent Extraction System (ASE)
SCCWRP SOP CHAPTER 4	Determination of DOC and TN in water samples
SCCWRP SOP CHAPTER 5	Use of polyethylene devices (PEDs)

Table A1-5. Calibration procedures for laboratory equipment.

Equipment	Frequency of Check	Acceptance Criteria
Balance calibration check	Daily or before use with two weights that bracket target weight(s) and Annual calibration with NIST standards by certified technician	1% performance criterion to top-loading balances, and 0.1% to analytical balances. (Expanded criteria from 0.1 to 1% for top-loaders, for no standard existed for this balance type.)
Refrigerator/ freezer temperature monitoring	Daily	Refrigerators: 4 ± 2°C, Freezers: −10 to −20°C (This ASTM standard does not address freezers, but SW-846 has noted this freezer range in some methods).
Thermometer calibration check	Glass – annually Electronic - quarterly at two temperatures that bracket target temperature(s) against an NIST traceable thermometer	Appropriate correction factors applied.
Variable volume pipettes (i.e., Eppendorf)	Monthly	3% of known of true value.
Nonvolumetric glassware/lab-ware verification (applicable only when used for measuring volumes)	By lot at the time of purchase	3% of known or true value. (Standard tolerance does not exist – Class B volumetric flasks criteria vary between 0.8 to 0.05% for 5 mL to 2,000 mL, respectively – set at 3% to maintain consistency with pipette tolerance designation).
Drying ovens	Before and after use	Compliance with method-specific requirements.

Table A1-6. Calibration procedures for laboratory instruments.

Instrument	Standard Sources	Initial Calibration			Calibration Verification		
		No. Standard	Criteria	Frequency	Standards and Conc. Range	General Criteria	Frequency
GC/MSD	Ultra Scientific (North Kingstown, RI, USA) Accustandard (New Haven, CT) Cambridge Isotope (Andover, MA, USA)	5	Value for the calibration curve R^2 shall be > 0.99 for all analytes	prior to analytical run	1 varied-level calibration standard	percent difference (PD) < 25% from initial calibration value for each analyte	Every 12 hours or 12 sample injections
TOC	Fisher Scientific (Fair Lawn, NJ, USA)	6	0.1 SD max 2.0 CV max	Prior to analytical run	0-10 ppm calib. 1 ppm inorganic/organic control 5 ppm Carbon control 0 ppm Carbon control	percent difference (PD) < 25% from initial calibration value of controls	Every 12 samples

REFERENCES

Fernandez L.A., W. Lao, K.A. Maruya, C. White, and R.M. Burgess. 2012. Passive Sampling to Measure Baseline Dissolved Persistent Organic Pollutant Concentrations in the Water Column of the Palos Verdes Shelf Superfund Site. *Environ Sci Technol. 46*:11937-11947.

Fernandez L.A., W. Lao, K.A. Maruya, and R.M. Burgess. 2014. Calculating the Diffusive Flux of Persistent Organic Pollutants Between Sediments and the Water Column on the Palos Verdes Shelf Superfund Site Using Polymeric Passive Samplers. *Environ Sci Technol. 48*:3925-3934.

Joyce, A.S., M.S. Pirogovsky, R.G. Adams, W. Lao, D. Tsukada, C.L. Cash, J.F. Haw, and K.A. Maruya. 2015. Using performance reference compound-corrected polyethylene passive samplers and caged bivalves to measure hydrophobic contaminants of concern in urban coastal seawaters. *Chemosphere 127*:10-17.

ATTACHMENT 2: CHEMICAL ANALYSIS RESULTS SUMMARY FOR SAMPLING EVENT 1 (WINTER)

INTRODUCTION

San Diego Bay provides habitat for a unique assemblage of fish species, which provides beneficial uses to both sport and sustenance fishermen; however, it is currently listed under the San Diego Regional Water Quality Control Board (SDRWQCB) Clean Water Act Section 303(d) list as impaired by polychlorinated biphenyls (PCBs). Previous efforts, including the 2013 Regional Harbor Monitoring Program (RHMP) Bioaccumulation Special Study effort (Amec Foster Wheeler 2017) and the 2014 Shallow Water Habitat Study in San Diego Bay (Amec Foster Wheeler 2016) have quantified the levels of PCBs and other constituents of potential concern (COPCs), such as pesticides, in fish from San Diego Bay at concentrations high enough to exceed human consumption guidance values. Bioaccumulation in fish tissue is strongly influenced by contaminant concentrations in both sediment and water (U.S. Environmental Protection Agency [USEPA] 2000).

Water column PCB and pesticide concentrations can account for a large proportion of the body burden in species that reside in the water column and/or feed primarily on plankton (e.g., shellfish, perch, and topsmelt). While bioaccumulation models can account for water column sources, bioaccumulation estimates associated with dissolved pesticides and PCBs are usually based on estimated concentrations because site-specific data are often lacking or are limited by high detection limits. To address the uncertainty in bioaccumulation models for pesticides and PCBs in San Diego Bay, this study will provide the data necessary to evaluate the specific contributions of sediment organochlorines, including pesticides and PCBs, to the water column via flux and transport mechanisms, and relate these data to biota measurements and bioaccumulation model estimates. Outcomes of this project will provide more confident bioaccumulation modeling tools for SQO assessment and development of sediment cleanup targets. This data summary includes the sediment and water grab data as well as the water column and sediment-water interface passive sampler data collected during the winter sampling event.

SAMPLING DESIGN

This study included two sampling events in 2018: winter and summer. Ten stations were sampled throughout San Diego Bay, with the goal to sample a range of contaminant levels (Figure 1 and Table 1). Both sampling events included collection of sediment and water column grab samples and fish and phytoplankton samples, as well as deployment of water column passive samplers and sediment-water interface passive samplers. The water column grab samples (1 L) were collected at deployment and retrieval for a subset of five stations. Biota samples were collected in the area near a subset of six stations (Figure 2). Sediment grab samples and passive samplers were collected at all ten stations. The plan was to deploy the passive samplers for approximately 30 days with water grabs collected upon deployment and retrieval, and sediment grabs collected on retrieval. During the deployment, fish and plankton collection would occur.

All samples were analyzed for chlordanes, dieldrin, DDTs, and PCBs. Total organic carbon (TOC), dissolved organic carbon (DOC), and lipid content were measured in sediment, water, and biota, respectively. The list of PCB congeners was expanded from prior monitoring efforts to align more with the Human Health Sediment Quality Objective (HHSQO) guidelines (Table 2). This expanded list of 63 PCB congeners was analyzed in the biota samples. A subset of those congeners (43 out of 63) was analyzed in the passive samplers and the water and sediment grab samples.

Table 1. Station location coordinates within San Diego Bay and corresponding samples for analysis.

Station ID	Latitude	Longitude	Water Grab	Sediment Grab	Passive Samplers *(Sediment and water column)*	Biota
SDBay-1	32.7245400	-117.2246600	x	x	x	x
SDBay-2	32.7174512	-117.2159143		x	x	
SDBay-3	32.7267390	-117.1761710	x	x	x	x
SDBay-4	32.7024000	-117.1617800		x	x	
SDBay-5	32.6929000	-117.1480000		x	x	
SDBay-6	32.6847938	-117.1600035		x	x	x
SDBay-7	32.6862720	-117.1338100	x	x	x	x
SDBay-8	32.6651840	-117.1498040	x	x	x	x
SDBay-9	32.6469360	-117.1182380		x	x	
SDBay-10	32.6258023	-117.1115252	x	x	x	x

Figure 1. Station locations in San Diego Bay.

Figure 2. Biota sampling locations in San Diego Bay.

Table 2. Constituents analyzed in samples.

Sediment TOC	PCBs	PCBs cont.	PCBs cont.
	PCB 8	PCB 95*	PCB 157
Water DOC	PCB 11*	PCB 97*	PCB 158
	PCB 18	PCB 99	PCB 167
Tissue % lipid	PCB 27*	PCB 101	PCB 168
	PCB 28	PCB 105	PCB 169
Chlordanes	PCB 29*	PCB 110	PCB 170
cis-Chlordane	PCB 31*	PCB 114	PCB 174*
trans-Chlordane	PCB 33*	PCB 118	PCB 177
cis-Nonachlor	PCB 37	PCB 119	PCB 180
trans-Nonachlor	PCB 44	PCB 123	PCB 183
Oxychlordane	PCB 49	PCB 126	PCB 187
	PCB 52	PCB 128	PCB 189
Dieldrin	PCB 56*	PCB 132*	PCB 194
	PCB 60*	PCB 137*	PCB 195*
DDTs	PCB 64*	PCB 138	PCB 198*
op-DDD	PCB 66	PCB 141*	PCB 199*
op-DDE	PCB 70	PCB 146*	PCB 200
op-DDT	PCB 74	PCB 149	PCB 201
pp-DDD	PCB 77	PCB 151	PCB 203*
pp-DDE	PCB 81	PCB 153	PCB 206
pp-DDT	PCB 87	PCB 156	PCB 209

*Measured only in tissue samples.

RESULTS

Sampling

During event 1, the sampling schedule was shifted due to issues with tenant approval and access to sites in tenant leaseholds. Passive samplers were deployed on Wednesday, March 7, 2018 for a 30-day deployment with collection scheduled for April 6. One sediment-water interface sampler was retrieved early on March 26 due to an early release of the time-release buoy. Samplers at SDBay-02 were not found and retrieval of samplers at SDBay-05 was delayed until tenant approval on April 9. Water grabs were collected on Friday, March 9 at the subset of five stations (SDBay-01, -03, -07, -08, -10) to coincide with sampler deployment. The second set of water grabs meant to coincide with sampler retrieval were delayed for tenant approval until May 1 and 2. Sediment grab samples were collected at every station on May 1 and 2 except for station SDBay-05, which was collected on June 4. All fish and plankton samples were collected during June 5 through 8 and June 14.

Water and Sediment Grab Samples

The results for water grab samples were below reporting limits for all congeners and chemical classes analyzed, except for the SDBay-07 retrieval sample which had a detectable chlordane concentration of ≤0.144 ng/L (Table 3). The sediment grab results for chlordanes, DDTs, and PCBs are presented here as the summation of the five, six, and 43 measured congeners, respectively (Table 4). A summary of the congener-specific sediment grab data is provided in the appendix (Table A1). The water DOC and sediment TOC concentrations are also reported (Table 5). The DOC concentrations were lower in May (retrieval) than March (deployment).

In general, SDBay-01, -03, -04, -05, and -07 had higher sediment contaminant levels (Figure 3). This is consistent with expectations based on the location and history of these stations. The highest sediment contaminant concentrations were at SDBay-01 (PCBs and DDTs) and SDBay-07 (chlordanes and dieldrin). Stations SDBay-02, -06, -08, -09, and -10 had the lowest sediment contaminant levels.

Table 3. Summary of the final water grab sample data for winter sampling in San Diego Bay.

	SDBay-01		SDBay-03		SDBay-07		SDBay-08		SDBay-10	
Chemical	Deployment	Retrieval*	Deployment*	Retrieval	Deployment	Retrieval	Deployment	Retrieval	Deployment	Retrieval
Sum Chlordanes (ng/L)	<0.102	<0.102 (<0.102)	<0.102 (<0.102)	<0.102	<0.102	≤0.144	<0.102	<0.102	<0.102	<0.102
Dieldrin (ng/L)	<0.605	<0.605 (<0.605)	<0.605 (<0.605)	<0.605	<0.605	<0.605	<0.605	<0.605	<0.605	<0.605
Sum DDTs (ng/L)	<1.25	<1.25 (<1.25)	<1.25 (<1.25)	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25
Sum PCBs (ng/L)	<0.054	<0.054 (<0.054)	<0.054 (<0.054)	<0.054	<0.054	<0.054	<0.054	<0.054	<0.054	<0.054

*Duplicate sample values in parentheses. ‘<’ symbol represents a non-detect with the value equal to the method detection limit (MDL)
‘≤’ symbol represents a detection but at an estimated concentration lower than the MDL

Table 4. Summary of the final sediment grab sample data for winter sampling in San Diego Bay.

Chemical	SDBay-01	SDBay-02	SDBay-03	SDBay-04	SDBay-05	SDBay-06	SDBay-06 Duplicate	SDBay-07	SDBay-08	SDBay-09	SDBay-10
Sum Chlordanes (ng/g dw)	3.57	≤0.017	12.4	7.84	1.50	0.115	0.105	14.2	0.332	0.431	0.268
Dieldrin (ng/g dw)	0.330	<0.121	0.561	0.727	0.189	<0.121	<0.121	1.64	<0.121	<0.121	<0.121
Sum DDTs (ng/g dw)	10.4	<0.250	3.55	2.51	2.30	<0.250	<0.250	5.89	≤0.366	0.748	≤0.646
Sum PCBs (ng/g dw)	394	2.40	285	71.4	152	7.20	6.70	86.3	20.6	10.2	9.37

‘<’ symbol represents a non-detect with the value equal to the MDL ‘≤’ symbol represents a detection but at an estimated concentration lower than the MDL

Table 5. Summary of the final sediment TOC and water DOC concentrations.

Chemical	SDBay-01	SDBay-02	SDBay-03	SDBay-04	SDBay-05	SDBay-06	SDBay-07	SDBay-08	SDBay-09	SDBay-10
Sediment TOC (%)	1.92	0.31	1.35	1.81	1.71	0.42 (0.41)*	1.95	0.92	1.13	1.56
Water DOC-Deployment (mg/L)	0.94	NC	1.04 (1.10)*	NC	NC	NC	1.17	1.27	NC	1.55
Water DOC-Retrieval (mg/L)	0.83 (0.82)*	NC	0.89	NC	NC	NC	0.79	0.95	NC	0.94

NC=Not collected *Duplicate sample values in parentheses ‘<’ symbol represents a non-detect with the value equal to the MDL
‘≤’ symbol represents a detection but at an estimated concentration lower than the MDL

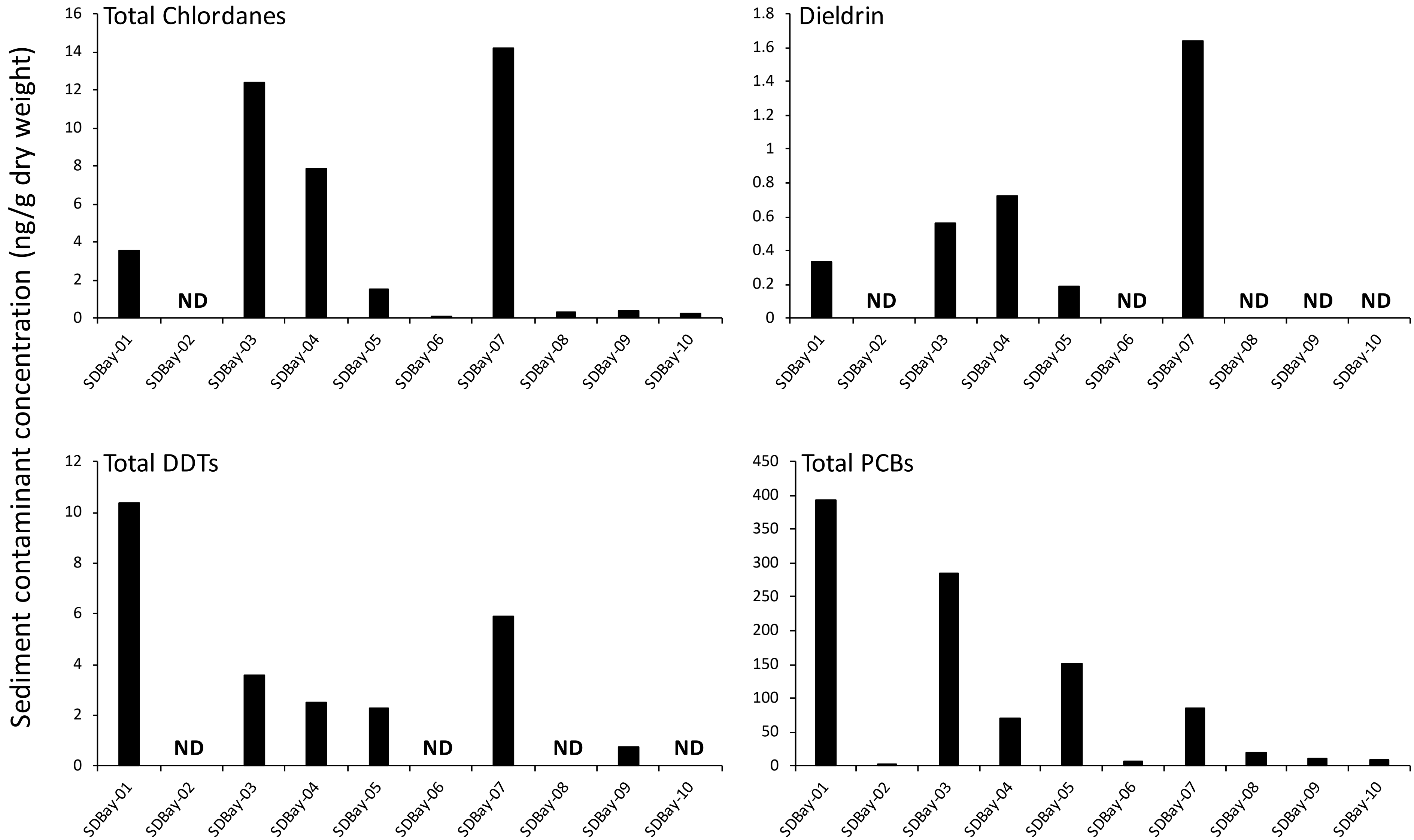

Figure 3. Summary of sediment contaminant concentrations in San Diego Bay. ND=not detected

Passive Sampler Results

Data from the passive samplers deployed in the water column provide a time-averaged dissolved contaminant concentration. Since these samplers were deployed in triplicate at each station, the summary results are presented as an average concentration (Table 6). A summary of the congener-specific data is provided in the appendix (Tables A2 and A3). In general, SDBay-01 had the highest contaminant concentrations, and SDBay-02 had the lowest contaminant concentrations (Figure 4). This is consistent with the trends observed for total PCBs and DDTs measured in the sediment. Dieldrin concentrations ranged from non-detect to 7.38 pg/L; chlordane concentrations ranged from 2.66-17.7 pg/L; Total DDT concentrations ranged from 3.80-21.9 pg/L; and Total PCB concentrations ranged from 60-785 pg/L. Although the range of concentrations for total PCBs and DDTs was larger relative to the other contaminants, the high end of those ranges is dominated by the concentration at SDBay-01. Unlike the water grab samples, the passive samplers were able to detect quantifiable concentrations at every station, except for dieldrin at SDBay-02.

Sediment-water interface passive samplers were also extracted and analyzed to determine the concentration of dissolved contaminants just above the sediment surface as well as the dissolved fraction within the top 10-40 cm of the sediment surface (Table 7). A summary of the congener-specific data is provided in the appendix for the overlying water (Table A4) and sediment portions (Table A5) of the samplers. The sampler for SDBay-02 was not retrieved. As such, no results are available, and that effort went towards additional analysis for the sub-surface portion of samplers at stations SDBay-03 and -05. They were split into two portions (upper and lower) to determine if a concentration gradient was observable within the sediment. Overall, higher concentrations were measured in the sediment portion compared to the overlying water portion of the samplers (Figure 5). Additionally, the overlying water concentration was frequently higher than the mid-depth water concentration measured using the water column samplers. The results from the additional sediment sampler analysis showed mixed results. For SDBay-03, the lower sediment portion showed similar or slightly elevated concentrations compared to the upper sediment portion. For SDBay-05, the opposite trend was observed in which the lower sediment portion showed similar or lower concentrations compared to the upper sediment portion.

Table 6. Summary of the mean (n=3) water column passive sampler contaminant concentrations.

Chemical	SDBay-01	SDBay-02	SDBay-03	SDBay-04	SDBay-05	SDBay-06	SDBay-07	SDBay-08	SDBay-09	SDBay-10
Sum Chlordanes (pg/L)	9.66	2.66	16.2	8.86	8.23	4.95	17.7	4.96	7.25	5.25
Dieldrin (pg/L)	4.70	≤2.08	4.75	4.27	4.87	3.68	7.38	4.97	5.83	4.81
Sum DDTs (pg/L)	21.9	4.54	8.22	6.13	7.12	3.81	7.56	3.80	5.99	4.69
Sum PCBs (pg/L)	785	60.0	295	142	248	121	189	136	92.0	69.4

*Duplicate sample values in parentheses ‘≤’ symbol represents a detection but at an estimated concentration lower than the MDL

Table 7. Summary of the sediment-water interface passive sampler contaminant concentrations.

Chemical		SDBay-01	SDBay-03	SDBay-04	SDBay-05	SDBay-06	SDBay-07	SDBay-08	SDBay-09	SDBay-10
Sum Chlordanes (pg/L)	Above surface	9.56	45.0	17.4	16.0	1.16	36.5	13.1	13.8	6.91
	Below surface	19.5	206, 216*	120	48.6, 33.8*	66.0	120	10.3	16.1	7.40
Dieldrin (pg/L)	Above surface	<21.6	<22.8	<34.5	≤12.7	<9.47	≤14.3	<32.6	<39.1	<45.8
	Below surface	≤7.07	41.5, 48.1*	63.9	184, 57.9*	44.2	96.6	≤7.60	9.97	<7.15
Sum DDTs (pg/L)	Above surface	6.36	37.5	28.6	31.8	<1.11	25.8	30.1	<4.58	<5.36
	Below surface	13.9	72.1, 84.3*	79.2	94.3, 97.0*	217	53.4	27.7	66.2	50.5
Sum PCBs (pg/L)	Above surface	301	907	226	451	42.7	237	299	110	171
	Below surface	825	4671, 4653*	1126	3618, 2939*	1219	433	325	162	154

*Represents the lower portion of the sub-surface sampler. ‘<’ symbol represents a non-detect with the value equal to the MDL
‘≤’ symbol represents a detection but at an estimated concentration lower than the MDL

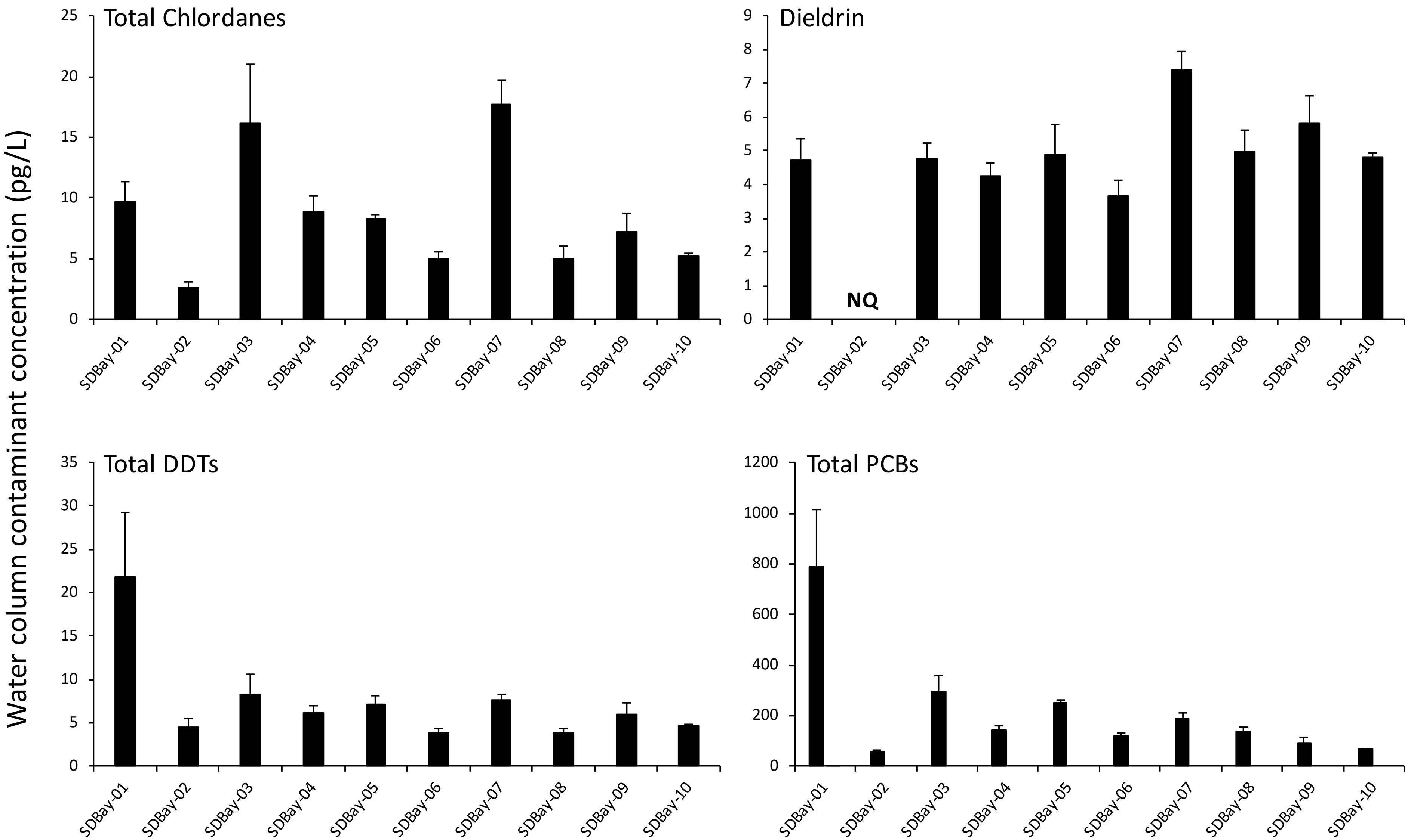

Figure 4. Summary of mid-depth water column dissolved contaminant concentrations in San Diego Bay measured using passive samplers. NQ=not quantifiable.

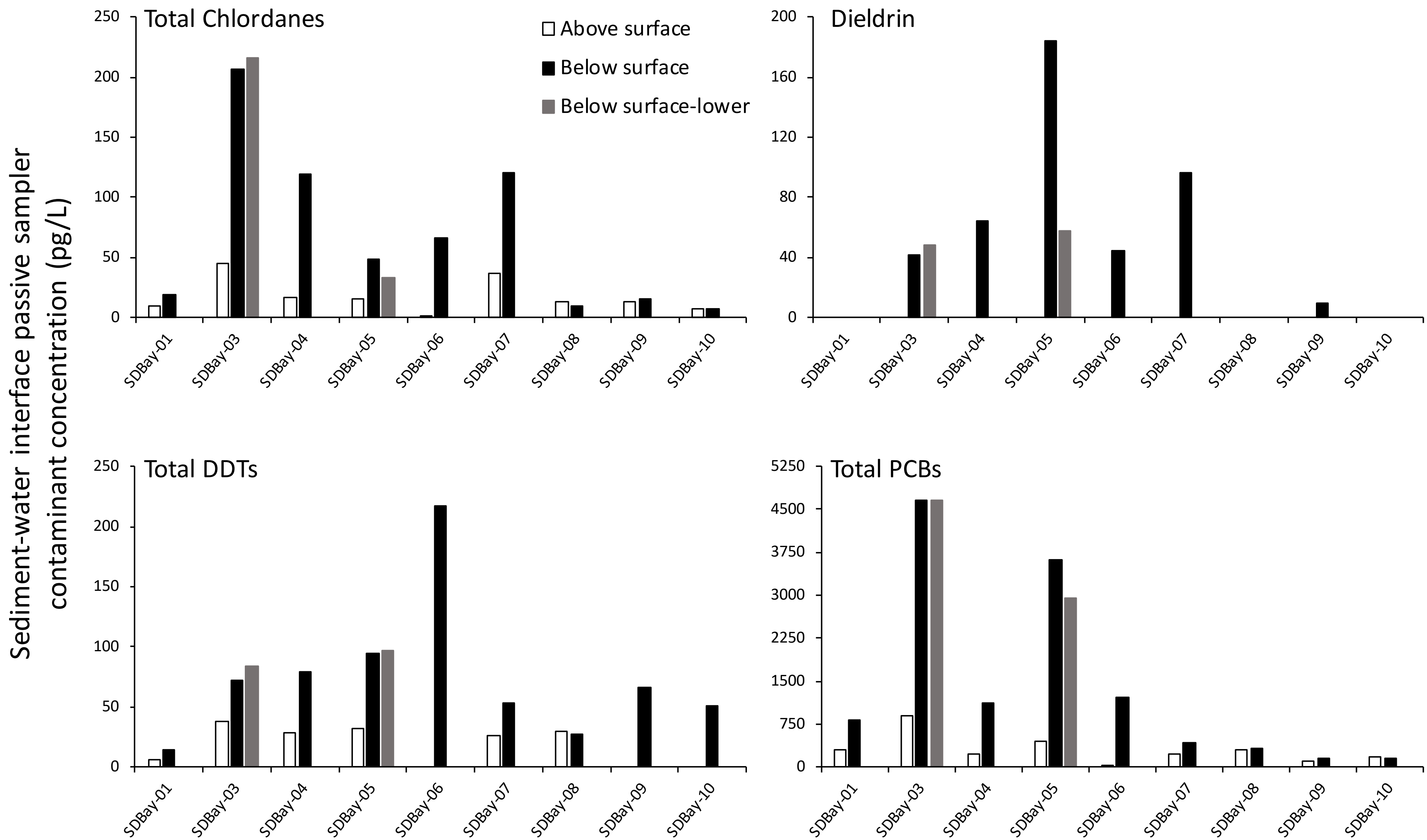

Figure 5. Summary of dissolved contaminant concentrations at the sediment-water interface in San Diego Bay measured using passive samplers. The samplers at stations SDBay-03 and SDBay-05 had a larger portion of the sampler below the sediment surface; as such, this fraction was split into an upper and lower sediment measurement. Missing white or black bars represent samples with non-detects or non-quantifiable results.

REFERENCES

Amec Foster Wheeler Environment & Infrastructure. 2016. Shallow Water Habitat Bioaccumulation (SWHB) Study prepared for the City of San Diego. June 2016.

Amec Foster Wheeler Environment & Infrastructure. 2017. Regional Harbor Monitoring Program (RHMP) 2013 Aquatic Food Web Bioaccumulation Study. January 2016.

United States Environmental Protection Agency (USEPA). 2000. Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment. Status and Needs.

ATTACHMENT 2 APPENDIX

Table A1. Congener-specific sediment grab sample data for winter sampling in San Diego Bay.

Chemical	SDBay-01	SDBay-02	SDBay-03	SDBay-04	SDBay-05	SDBay-06	SDBay-06 Duplicate	SDBay-07	SDBay-08	SDBay-09	SDBay-10
Cis-Chlordane (Alpha)	0.891	<0.044	2.77	2.10	0.417	≤0.040	≤0.026	3.95	0.083	0.097	0.061
Trans-Chlordane (Gamma)	1.05	≤0.016	4.50	2.25	0.352	0.040	0.035	4.31	0.079	0.107	0.062
Cis-Nonachlor	0.773	≤0.014	2.46	1.30	0.331	0.038	0.037	2.32	0.089	0.112	0.080
Trans-Nonchlor	0.855	≤0.017	2.64	2.19	0.400	0.037	0.033	3.65	0.081	0.115	0.065
Oxychlordane	<0.093	<0.093	<0.093	<0.093	<0.093	<0.093	<0.093	≤0.065	<0.093	<0.093	<0.093
Dieldrin	0.330	<0.121	0.561	0.727	0.189	<0.121	<0.121	1.64	<0.121	<0.121	<0.121
o,p'-DDD	0.949	<0.337	≤0.315	≤0.270	<0.417	<0.337	<0.337	0.365	<0.337	<0.337	<0.337
o,p'-DDE	<0.250	<0.250	<0.250	<0.250	<0.250	<0.250	<0.250	<0.250	<0.250	<0.250	<0.250
o,p'-DDT	<1.20	<1.20	<1.20	<1.20	<1.20	<1.20	<1.20	<1.20	<1.20	<1.20	<1.20
p,p'-DDD	2.72	<1.40	≤1.16	≤1.20	<1.40	<1.40	<1.40	1.48	<1.40	<1.40	<1.40
p,p'-DDE	6.71	<0.714	3.55	2.51	2.30	<0.714	<0.714	4.04	≤0.366	0.748	≤0.646
p,p'-DDT	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67	<1.67
PCB8	<0.408	<0.408	0.758	<0.408	<0.408	<0.408	<0.408	<0.408	<0.408	<0.408	<0.408
PCB18	<0.806	<0.806	4.55	<0.806	<0.806	<0.806	<0.806	<0.806	<0.806	<0.806	<0.806
PCB28	5.94	<0.620	9.73	<0.620	1.03	<0.620	<0.620	<0.620	<0.620	<0.620	<0.620
PCB52	18.6	<0.938	20.2	2.49	9.59	<0.938	<0.938	2.73	<0.938	<0.938	<0.938
PCB49	17.8	<0.893	16.6	1.77	7.49	<0.893	<0.893	2.52	<0.893	<0.893	<0.893
PCB44	11.7	<0.926	19.3	2.14	4.5	<0.926	<0.926	1.67	<0.926	<0.926	<0.926

Chemical	SDBay-01	SDBay-02	SDBay-03	SDBay-04	SDBay-05	SDBay-06	SDBay-06 Duplicate	SDBay-07	SDBay-08	SDBay-09	SDBay-10
PCB37	<1.06	<1.06	3.56	<1.06	<1.06	<1.06	<1.06	<1.06	<1.06	<1.06	<1.06
PCB74	7.59	<0.833	8.18	≤0.572	1.19	<0.833	<0.833	≤0.586	<0.833	<0.833	<0.833
PCB70	12.8	<0.811	15.1	1.31	4.70	<0.811	<0.811	1.24	<0.811	<0.811	<0.811
PCB66	19.6	<0.968	17.2	1.73	3.41	<0.968	<0.968	1.61	<0.968	<0.968	<0.968
PCB101	34.7	≤0.196	18.4	5.24	11.9	0.448	0.454	5.90	1.40	0.776	0.700
PCB99	19.4	<0.536	9.74	2.94	4.92	≤0.330	≤0.343	3.22	1.09	0.588	0.623
PCB119	2.04	<0.169	1.04	0.299	0.652	<0.169	<0.169	0.435	<0.169	<0.169	<0.169
PCB87	11.0	<0.330	6.57	1.39	3.96	<0.330	<0.330	1.35	≤0.221	<0.330	<0.330
PCB110	34.0	≤0.237	17.2	4.83	11.8	0.306	0.407	4.56	0.826	0.410	0.353
PCB81	<0.188	<0.188	<0.188	<0.188	<0.188	<0.188	<0.188	<0.188	<0.188	<0.188	<0.188
PCB151	4.43	0.052	2.95	1.10	1.92	0.131	0.111	1.53	0.308	0.165	0.122
PCB77	1.35	<0.244	1.49	≤0.197	0.271	<0.244	<0.244	≤0.155	<0.244	<0.244	<0.244
PCB149	20.9	0.289	11.5	5.09	11.5	0.723	0.664	6.43	1.81	1.06	0.971
PCB123	4.49	≤0.031	2.42	0.686	1.37	0.080	0.072	0.766	0.196	0.103	0.093
PCB118	35.0	0.203	17.5	4.91	11.7	0.538	0.486	5.75	1.37	0.692	0.672
PCB114	1.84	≤0.023	1.10	0.427	0.99	0.062	0.053	0.523	0.168	0.087	0.082
PCB153/168	29.5	0.398	16.4	8.13	13.1	1.28	1.14	10.7	3.48	1.86	1.94
PCB105	13.6	0.076	9.04	1.93	4.98	0.158	0.147	2.11	0.382	0.195	0.154
PCB138	25.2	0.251	12.4	5.25	10.3	0.678	0.560	6.72	1.69	0.837	0.689
PCB158	3.30	0.028	1.68	0.623	1.63	0.057	0.055	0.900	0.150	0.071	0.052

Chemical	SDBay-01	SDBay-02	SDBay-03	SDBay-04	SDBay-05	SDBay-06	SDBay-06 Duplicate	SDBay-07	SDBay-08	SDBay-09	SDBay-10
PCB187	7.56	0.189	5.85	3.14	4.19	0.549	0.515	3.92	1.56	0.697	0.662
PCB183	3.04	0.050	2.33	0.974	1.48	0.136	0.133	1.44	0.359	0.174	0.140
PCB126	0.134	<0.049	0.096	≤0.041	<0.049	<0.049	<0.049	≤0.033	<0.049	<0.049	<0.049
PCB128	7.43	0.080	3.52	1.51	3.04	0.182	0.166	1.86	0.457	0.235	0.202
PCB167	1.61	0.020	0.795	0.372	0.715	0.049	0.041	0.484	0.123	0.059	0.054
PCB177	3.21	0.071	2.43	1.16	1.67	0.202	0.188	1.55	0.578	0.244	0.236
PCB200	0.482	0.014	0.359	0.203	0.258	0.038	0.035	0.235	0.114	0.052	0.048
PCB156	4.08	0.037	2.02	0.786	2.00	0.071	0.061	1.17	0.196	0.093	0.072
PCB157	0.928	≤0.018	0.408	0.186	0.506	0.029	0.031	0.238	0.058	0.031	0.030
PCB180	12.0	0.172	9.34	3.67	5.60	0.423	0.380	5.72	1.09	0.528	0.365
PCB170	5.91	0.091	4.02	1.68	2.80	0.177	0.153	2.52	0.521	0.244	0.186
PCB201	3.83	0.094	2.99	1.46	1.86	0.212	0.204	1.77	0.635	0.262	0.221
PCB169	0.261	<0.026	0.241	0.104	0.176	≤0.016	≤0.016	0.157	0.048	≤0.019	≤0.014
PCB189	0.703	<0.016	0.519	0.233	0.366	0.031	0.029	0.318	0.096	0.042	0.036
PCB194	3.30	0.074	2.51	1.17	1.63	0.164	0.162	1.51	0.552	0.226	0.198
PCB206	2.58	0.082	1.70	1.17	1.33	0.190	0.187	1.29	0.563	0.223	0.190
PCB209	2.09	0.128	1.19	1.29	1.04	0.288	0.265	1.47	0.801	0.283	0.278

‘<’ symbol represents a non-detect with the value equal to the MDL ‘≤’ symbol represents a detection but at an estimated concentration lower than the MDL

Table A2. Congener-specific water column passive sampler data for winter sampling in San Diego Bay: SDBay-01, -02, -03, -04, and -05.

Chemical	SDBay-01 #1	SDBay-01 #2	SDBay-01 #3	SDBay-02 #1	SDBay-02 #2	SDBay-02 #3	SDBay-03 #1	SDBay-03 #2	SDBay-03 #3	SDBay-04 #1	SDBay-04 #2	SDBay-04 #3	SDBay-05 #1	SDBay-05 #2	SDBay-05 #3
Trans-Chlordane (Gamma)	3.09	2.10	2.68	0.476	0.719	0.682	3.21	6.22	4.75	2.21	2.16	1.66	1.98	1.82	1.82
Cis-Chlordane (Alpha)	2.83	2.26	2.71	0.705	1.00	0.97	3.02	5.46	4.52	2.94	2.74	2.26	2.53	2.36	2.43
Cis-Nonachlor	2.17	1.45	2.03	0.354	0.483	0.484	1.97	4.21	3.08	1.77	1.64	1.32	1.70	1.53	1.53
Trans-Nonchlor	3.09	2.00	2.56	0.567	0.767	0.764	2.76	4.56	4.81	2.95	2.81	2.13	2.50	2.23	2.26
Oxychlordane	< 0.743	< 0.743	< 0.743	< 0.743	< 0.743	< 0.743	< 0.743	< 0.743	< 0.743	< 0.743	< 0.743	< 0.743	< 0.743	< 0.743	< 0.743
Dieldrin	4.19	4.47	5.45	< 3.40	≤ 2.08	≤ 1.87	4.25	5.22	4.79	4.57	4.35	3.90	5.94	4.32	4.36
o,p'-DDD	3.83	≤ 1.60	3.07	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11
o,p'-DDE	2.29	1.63	1.98	0.416	0.49	0.615	0.427	0.778	0.619	0.537	≤ 0.322	≤ 0.228	0.592	0.512	0.445
o,p'-DDT	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90
p,p'-DDD	≤ 7.74	< 9.46	≤ 5.71	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46
p,p'-DDE	22.9	12.8	17.2	3.11	4.29	4.69	5.04	8.57	9.22	6.28	6.27	5.29	7.51	5.73	6.57
p,p'-DDT	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71
PCB8	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2
PCB18	38.3	17.4	25.9	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88
PCB28	70.6	37.3	41.0	≤ 4.16	≤ 3.18	≤ 3.27	10.5	17.5	15.4	≤ 3.05	≤ 5.09	≤ 4.26	≤ 4.85	7.02	6.19
PCB52	99.3	56.4	67.6	8.38	6.22	6.06	18.9	28.6	31.5	7.73	11.8	9.82	14.7	18.1	17.2
PCB49	88.1	48.3	55.5	7.40	5.36	5.60	14.2	19.6	24.6	6.61	10.2	7.89	11.8	14.6	14.8
PCB44	48.6	26.9	33.4	≤ 3.79	≤ 2.81	≤ 3.09	13.6	19.5	23.3	3.95	5.42	4.69	7.95	8.43	9.02
PCB37	≤ 7.54	≤ 6.03	≤ 7.10	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23

Chemical	SDBay-01 #1	SDBay-01 #2	SDBay-01 #3	SDBay-02 #1	SDBay-02 #2	SDBay-02 #3	SDBay-03 #1	SDBay-03 #2	SDBay-03 #3	SDBay-04 #1	SDBay-04 #2	SDBay-04 #3	SDBay-05 #1	SDBay-05 #2	SDBay-05 #3
PCB74	25.0	13.1	17.5	< 1.97	< 1.97	≤ 1.00	4.56	8.64	6.86	≤ 1.47	≤ 1.70	≤ 1.46	2.93	2.75	2.84
PCB70	45.3	23.3	32.1	< 2.38	≤ 1.48	≤ 1.45	7.98	12.1	12.3	2.85	3.08	≤ 2.04	6.7	5.07	5.75
PCB66	58.1	30.6	43.1	≤ 1.85	2.46	2.49	10.3	15.6	17.1	4.84	4.63	3.84	8.53	7.92	8.23
PCB101	86.5	45.3	64	4.41	5.51	5.74	17.0	29.0	31.4	14.6	14.4	11.6	25.1	20.9	22.3
PCB99	53.3	27.6	37.9	3.24	3.91	3.95	10.5	17.0	18.2	10.7	10.4	8.51	15.5	12.4	13.2
PCB119	5.51	3.11	4.03	0.322	0.347	0.369	1.22	1.83	1.83	1.11	1.00	0.873	1.75	1.44	1.5
PCB87	20.9	10.4	14.8	0.625	0.849	0.76	4.43	7.53	7.94	2.22	2.11	1.68	4.76	3.89	4.18
PCB110	70.8	37.5	56.6	2.22	2.8	2.62	12.9	22.9	26.3	8.32	7.43	5.92	16.1	12.9	14.1
PCB81	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300
PCB151	13.4	6.78	9.02	0.975	1.20	1.21	3.57	6.69	5.86	3.46	3.27	2.71	5.80	4.72	4.95
PCB77	3.31	1.83	2.60	< 0.592	< 0.592	< 0.592	0.631	1.43	1.06	< 0.592	< 0.592	< 0.592	≤ 0.544	≤ 0.382	≤ 0.548
PCB149	50.8	28.0	38.2	3.75	4.55	4.63	12.7	21.8	19.4	13.5	13.1	9.65	22.6	17.7	17.0
PCB123	9.67	6.04	7.59	0.553	0.671	0.760	2.19	3.23	2.81	1.81	1.85	1.46	3.00	2.43	2.53
PCB118	73.7	44.8	57.7	2.90	3.62	3.91	14.3	20.7	18.8	10.5	9.86	8.10	19.5	16.4	17.3
PCB114	3.20	1.94	2.52	0.252	0.287	0.316	0.901	1.46	1.20	0.913	0.853	0.675	1.30	1.07	1.17
PCB153/168	49.9	34.6	43.0	6.12	7.05	8.00	19.6	23.5	20.7	21.3	21.2	18.8	32.6	28.5	29.5
PCB105	21.7	12.9	17.2	0.667	0.843	0.898	5.17	7.71	6.87	2.54	2.43	1.86	5.35	4.54	4.77
PCB138	25.4	17.2	20.2	3.55	4.20	4.30	8.90	10.7	9.27	7.39	7.45	6.23	12.9	10.8	12.1
PCB158	3.83	2.35	2.78	0.283	0.314	0.347	1.09	1.50	1.09	0.693	0.687	0.649	1.51	1.43	1.39
PCB187	9.56	6.61	7.89	2.44	2.92	3.19	4.88	5.73	5.05	5.24	5.36	4.46	7.84	6.80	7.43

Chemical	SDBay-01 #1	SDBay-01 #2	SDBay-01 #3	SDBay-02 #1	SDBay-02 #2	SDBay-02 #3	SDBay-03 #1	SDBay-03 #2	SDBay-03 #3	SDBay-04 #1	SDBay-04 #2	SDBay-04 #3	SDBay-05 #1	SDBay-05 #2	SDBay-05 #3
PCB183	4.05	2.74	3.24	0.589	0.734	0.827	1.79	2.28	1.92	1.35	1.47	1.35	2.74	2.56	2.62
PCB126	0.287	0.193	0.269	≤ 0.022	≤ 0.029	≤ 0.035	0.095	0.131	0.126	< 0.039	0.052	0.041	0.082	0.066	0.088
PCB128	11.1	7.33	9.02	0.819	0.979	1.07	3.54	4.30	3.70	2.90	2.90	2.49	4.92	4.23	4.76
PCB167	2.30	1.62	1.91	0.229	0.27	0.279	0.791	0.914	0.812	0.628	0.686	0.544	1.11	0.991	1.07
PCB177	6.33	4.34	5.21	1.01	1.21	1.35	3.16	3.72	3.21	3.00	2.99	2.54	4.45	4.03	4.20
PCB200	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
PCB156	5.46	3.70	4.40	0.296	0.359	0.395	1.71	2.01	1.80	1.10	1.10	0.878	2.30	2.11	2.23
PCB157	1.23	0.819	1.02	0.101	0.107	0.127	0.392	0.569	0.474	0.357	0.277	0.286	0.554	0.524	0.558
PCB180	12.6	8.61	10.1	1.53	2.18	2.86	5.44	6.46	5.49	3.98	4.03	2.84	7.67	7.00	7.50
PCB170	7.42	4.98	5.99	0.888	1.08	1.19	3.08	3.68	3.22	2.24	2.37	1.85	4.29	3.84	4.03
PCB201	2.83	2.04	2.35	0.464	0.718	0.748	1.32	1.58	1.33	1.18	1.19	0.943	1.93	1.78	1.88
PCB169	< 0.018	< 0.018	< 0.018	0.049	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018
PCB189	0.52	0.378	0.445	0.055	0.117	0.149	0.232	0.28	0.174	0.169	0.190	0.160	0.254	0.296	0.305
PCB194	1.12	0.841	0.918	0.167	0.257	0.268	0.508	0.578	0.494	0.417	0.445	0.338	0.656	0.638	0.668
PCB206	0.386	0.302	0.328	0.065	0.096	0.114	0.172	0.203	0.176	0.172	0.183	0.147	0.259	0.249	0.272
PCB209	0.011	0.002	0.007	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

'<' symbol represents a non-detect with the value equal to the MDL

'≤' symbol represents a detection but at an estimated concentration lower than the MDL

Table A3. Congener-specific water column passive sampler data for winter sampling in San Diego Bay: SDBay-06, -07, -08, -09, and -10

Chemical	SDBay-06 #1	SDBay-06 #2	SDBay-06 #3	SDBay-07 #1	SDBay-07 #2	SDBay-07 #3	SDBay-08 #1	SDBay-08 #2	SDBay-08 #3	SDBay-09 #1	SDBay-09 #2	SDBay-09 #3	SDBay-10 #1	SDBay-10 #2	SDBay-10 #3
Trans-Chlordane (Gamma)	1.17	0.982	1.00	4.66	4.59	5.49	1.22	1.06	1.02	1.19	1.82	1.51	1.06	1.03	1.04
Cis-Chlordane (Alpha)	1.85	1.49	1.51	5.12	4.99	6.16	1.88	1.61	1.62	1.74	2.56	2.25	1.78	1.65	1.72
Cis-Nonachlor	1.09	0.889	0.866	2.57	2.61	3.14	1.28	1.13	< 0.091	1.25	1.90	1.51	1.12	1.07	1.11
Trans-Nonchlor	1.50	1.26	1.24	4.24	4.37	5.17	1.51	1.37	1.17	1.60	2.49	1.94	1.46	1.36	1.36
Oxychlordane	< 0.743	< 0.743	< 0.743	< 0.743	< 0.743	≤ 0.386	< 0.743	< 0.743	< 0.743	< 0.743	< 0.743	< 0.743	< 0.743	< 0.743	< 0.743
Dieldrin	4.16	≤ 3.26	3.61	6.97	7.14	8.03	5.12	4.28	5.51	5.23	6.76	5.50	4.92	4.84	4.66
o,p'-DDD	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11	< 2.11
o,p'-DDE	< 0.399	< 0.399	< 0.399	0.828	0.832	0.704	≤ 0.262	≤ 0.229	< 0.399	≤ 0.370	≤ 0.390	≤ 0.328	≤ 0.224	0.401	< 0.399
o,p'-DDT	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90	< 1.90
p,p'-DDD	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46	< 9.46
p,p'-DDE	3.91	3.32	4.19	5.86	7.12	7.33	4.32	3.86	3.23	4.69	7.28	5.99	4.72	4.35	4.59
p,p'-DDT	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71	< 2.71
PCB8	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2	< 12.2
PCB18	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88	< 8.88
PCB28	≤ 3.52	< 5.29	< 5.29	≤ 3.92	≤ 5.28	5.49	≤ 4.18	≤ 3.75	≤ 3.82	< 5.29	≤ 4.42	≤ 3.75	< 5.29	≤ 2.80	≤ 3.13
PCB52	7.18	7.36	8.01	12.5	16.1	18.0	8.19	8.02	7.34	5.52	10.6	8.41	4.25	5.34	5.76
PCB49	6.81	6.56	7.69	10.6	14.0	15.1	8.01	8.44	7.26	4.72	10.0	7.31	3.94	5.42	5.35
PCB44	≤ 3.53	≤ 3.81	≤ 3.92	5.17	6.62	8.40	≤ 3.71	4.76	≤ 3.35	≤ 2.37	4.79	≤ 3.46	< 3.94	≤ 2.36	≤ 2.40
PCB37	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23	< 9.23

Chemical	SDBay-06 #1	SDBay-06 #2	SDBay-06 #3	SDBay-07 #1	SDBay-07 #2	SDBay-07 #3	SDBay-08 #1	SDBay-08 #2	SDBay-08 #3	SDBay-09 #1	SDBay-09 #2	SDBay-09 #3	SDBay-10 #1	SDBay-10 #2	SDBay-10 #3
PCB74	≤ 1.40	≤ 1.04	≤ 1.19	≤ 1.72	≤ 1.69	≤ 1.80	≤ 1.06	≤ 1.13	< 1.97	< 1.97	< 1.97	< 1.97	< 1.97	< 1.97	< 1.97
PCB70	≤ 2.30	≤ 1.85	≤ 2.07	3.61	3.42	4.06	≤ 1.94	≤ 1.92	≤ 1.59	≤ 1.21	≤ 1.66	≤ 1.61	< 2.38	< 2.38	< 2.38
PCB66	4.04	3.45	4.08	5.45	5.31	6.17	4.72	4.05	3.76	2.79	4.18	3.25	2.93	2.50	2.66
PCB101	12.0	9.89	10.8	17.0	17.6	19.6	13.2	12.4	9.85	8.02	11.9	8.93	7.23	6.82	6.83
PCB99	9.66	7.65	8.63	10.2	10.9	12.1	11.3	9.71	8.31	6.00	9.67	7.35	6.53	5.65	6.06
PCB119	0.871	0.639	0.747	1.17	1.14	1.36	0.906	0.784	0.611	0.485	0.888	0.587	0.426	0.422	0.377
PCB87	1.50	1.15	1.40	2.72	3.00	3.40	1.37	1.14	0.952	0.858	1.46	0.937	0.69	0.686	0.613
PCB110	5.78	4.60	5.11	10.5	11.0	12.1	6.02	5.54	4.34	3.90	6.07	4.28	2.95	$2.90	2.77
PCB81	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	< 0.300	2.05	< 0.300	< 0.300
PCB151	2.78	2.27	2.45	3.54	3.73	4.23	2.91	2.61	2.07	1.39	2.25	1.68	1.19	1.1	1.11
PCB77	< 0.592	< 0.592	< 0.592	< 0.592	< 0.592	≤ 0.379	< 0.592	< 0.592	< 0.592	< 0.592	< 0.592	< 0.592	< 0.592	< 0.592	< 0.592
PCB149	11.0	10.1	10.6	13.9	14.3	16.4	14.1	12.9	10.6	6.71	10.5	8.12	6.58	6.05	6.02
PCB123	1.55	1.26	1.36	1.81	1.93	2.14	1.51	1.37	1.11	0.820	1.31	0.956	0.774	0.725	0.690
PCB118	8.23	6.99	7.72	12.0	12.5	13.8	8.77	7.96	6.13	4.62	7.51	5.44	4.19	3.97	3.83
PCB114	0.744	0.627	0.658	0.822	0.861	1.02	0.845	0.754	0.663	0.397	0.689	0.471	0.389	0.401	0.381
PCB153/168	21.6	17.1	18.2	20.9	22.6	24.8	25.1	22.7	18.2	11.1	16.2	13.1	12.6	11.7	11.4
PCB105	1.76	1.39	1.59	2.96	3.12	3.43	1.53	1.40	1.07	0.940	1.44	1.09	0.753	0.69	0.693
PCB138	9.95	7.32	7.66	9.55	8.99	9.61	10.7	7.78	8.36	3.38	4.60	4.10	3.82	3.26	3.51
PCB158	0.790	0.595	0.556	1.16	1.17	1.28	0.848	0.704	0.710	0.335	0.461	0.383	0.298	0.243	0.289
PCB187	7.59	5.60	5.58	5.47	5.52	5.91	9.00	6.71	7.61	2.28	3.32	2.93	3.05	2.86	3.01

Chemical	SDBay-06 #1	SDBay-06 #2	SDBay-06 #3	SDBay-07 #1	SDBay-07 #2	SDBay-07 #3	SDBay-08 #1	SDBay-08 #2	SDBay-08 #3	SDBay-09 #1	SDBay-09 #2	SDBay-09 #3	SDBay-10 #1	SDBay-10 #2	SDBay-10 #3
PCB183	1.97	1.51	1.48	1.84	1.76	2.01	2.25	1.73	1.89	0.575	0.88	0.785	0.673	0.624	0.655
PCB126	0.051	0.041	0.057	0.051	0.061	0.069	0.048	0.041	≤ 0.029	≤ 0.029	≤ 0.031	≤ 0.028	< 0.039	< 0.039	< 0.039
PCB128	2.72	2.17	2.36	3.06	3.16	3.67	2.91	2.57	2.02	1.24	1.86	1.48	1.18	1.17	1.08
PCB167	0.690	0.592	0.635	0.814	0.798	0.839	0.782	0.675	0.564	0.252	0.380	0.330	0.288	0.296	0.275
PCB177	4.15	3.27	3.22	3.19	3.26	3.49	5.01	4.05	3.62	1.30	1.93	1.69	1.80	1.66	1.61
PCB200	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
PCB156	0.903	0.721	0.791	1.54	1.58	1.68	0.975	0.873	0.687	0.389	0.551	0.474	0.337	0.318	0.307
PCB157	0.299	0.25	0.281	0.401	0.355	0.482	0.334	0.317	0.267	0.171	0.209	0.144	0.136	0.119	0.130
PCB180	4.52	3.40	3.06	5.16	5.13	5.05	4.67	3.32	3.79	1.23	1.80	1.49	1.27	1.23	1.25
PCB170	2.56	2.00	2.04	2.91	2.96	3.10	2.99	2.29	2.36	0.784	1.14	0.988	0.826	0.794	0.810
PCB201	1.54	1.16	1.18	1.25	1.25	1.31	1.79	1.35	1.50	0.375	0.557	0.492	0.479	0.467	0.476
PCB169	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018
PCB189	0.176	0.194	0.187	0.236	0.224	0.236	0.288	0.224	0.229	0.091	0.121	0.113	0.094	0.095	0.091
PCB194	0.562	0.415	0.428	0.464	0.453	0.480	0.689	0.524	0.562	0.148	0.209	0.184	0.197	0.193	0.186
PCB206	0.252	0.190	0.198	0.181	0.166	0.181	0.298	0.223	0.239	0.053	0.080	0.070	0.077	0.078	0.074
PCB209	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

'<' symbol represents a non-detect with the value equal to the MDL   '≤' symbol represents a detection but at an estimated concentration lower than the MDL

Table A4. Congener-specific sediment-water interface passive sampler data for winter sampling in San Diego Bay: Overlying water.

Chemical	SDBay-01	SDBay-03	SDBay-04	SDBay-05	SDBay-06	SDBay-07	SDBay-08	SDBay-09	SDBay-10
Trans-Chlordane (Gamma)	3.21	16.2	4.49	3.72	0.389	10.1	2.86	3.11	2.03
Cis-Chlordane (Alpha)	2.83	12.6	5.60	4.85	≤ 0.469	11.4	4.13	4.13	≤ 2.58
Cis-Nonachlor	1.82	6.58	2.47	2.92	0.403	4.99	2.7	2.91	2.25
Trans-Nonchlor	1.70	9.58	4.8	4.48	0.37	9.97	3.45	3.67	2.63
Oxychlordane	< 4.72	< 4.98	< 7.53	< 5.01	< 2.07	< 5.96	< 7.12	< 8.55	< 10
Dieldrin	< 21.6	< 22.8	< 34.5	≤ 12.7	< 9.47	≤ 14.3	< 32.6	< 39.1	< 45.8
o,p'-DDD	< 13.4	< 14.1	< 21.4	< 14.2	< 5.87	< 16.9	< 20.2	< 24.3	< 28.4
o,p'-DDE	< 2.53	< 2.67	< 4.04	< 2.69	< 1.11	< 3.19	< 3.82	< 4.58	< 5.36
o,p'-DDT	< 12.1	< 12.7	< 19.2	< 12.8	< 5.28	< 15.2	< 18.2	< 21.8	< 25.5
p,p'-DDD	< 60.1	< 63.5	< 95.9	< 63.8	< 26.3	< 75.8	< 90.7	< 109	< 127
p,p'-DDE	6.36	37.5	28.6	31.8	< 3.18	25.8	30.1	< 13.1	< 15.4
p,p'-DDT	< 17.2	< 18.1	< 27.4	< 18.3	< 7.53	< 21.7	< 25.9	< 31.1	< 36.4
PCB8	< 77.8	< 82.1	< 124	< 82.5	< 34	< 98.1	< 117	< 141	< 165
PCB18	< 56.4	< 59.5	< 89.9	< 59.9	< 24.7	< 71.1	< 85.1	< 102	< 119
PCB28	< 33.6	≤ 29.5	< 53.6	< 35.7	< 14.7	< 42.4	< 50.7	< 60.8	< 71.1
PCB52	≤ 20.5	44.2	< 38.2	≤ 15.9	< 10.5	< 30.2	< 36.1	< 43.3	< 50.7
PCB49	≤ 17.2	29.9	< 28.1	≤ 12.6	< 7.73	< 22.3	< 26.6	< 31.9	< 37.4
PCB44	≤ 14.7	29.6	< 39.9	< 26.6	< 11.0	< 31.6	< 37.8	< 45.3	< 53
PCB37	< 58.7	< 61.9	< 93.5	< 62.3	< 25.7	< 74	< 88.5	< 106	< 124

Chemical	SDBay-01	SDBay-03	SDBay-04	SDBay-05	SDBay-06	SDBay-07	SDBay-08	SDBay-09	SDBay-10
PCB74	≤ 9.44	38.1	< 19.9	< 13.3	< 5.47	< 15.8	< 18.9	< 22.6	< 26.5
PCB70	29.6	89.6	< 24.1	≤ 11.0	< 6.62	< 19.1	< 22.8	< 27.4	< 32.0
PCB66	61.5	150	38.8	65.6	< 6.47	< 18.6	< 22.3	< 26.8	67.6
PCB101	33	87.8	26.0	63.6	4.5	41.4	47.4	23.0	19.3
PCB99	17.5	43.4	14.1	32.4	3.72	22.5	37.2	18.0	18.7
PCB119	2.63	6.82	< 1.08	4.56	0.396	3.88	2.48	< 1.22	< 1.43
PCB87	10.5	30.8	< 3.12	18.5	≤ 0.518	7.82	4.53	< 3.55	< 4.15
PCB110	29.8	77.6	22.1	41.7	2.20	25.9	20.0	< 3.42	< 4.0
PCB81	< 1.91	< 2.01	< 3.04	< 2.02	< 0.834	< 2.4	< 2.87	< 3.45	< 4.03
PCB151	3.18	10.3	4.24	9.69	0.845	6.16	7.09	2.75	1.98
PCB77	< 3.76	< 3.97	< 6	< 3.99	< 1.65	< 4.74	< 5.67	< 6.81	< 7.96
PCB149	16.2	49.0	26.8	50.5	5.20	24.0	49.0	20.1	20.2
PCB123	3.93	9.93	3.45	6.71	0.633	4.03	3.87	1.95	1.57
PCB118	24.4	66.3	18.0	41.1	3.21	25.2	23.4	10.0	8.36
PCB114	1.30	5.40	1.84	5.15	0.573	2.46	3.98	1.84	1.71
PCB153/168	15.9	35.6	23.1	38.3	6.31	26.2	42.1	12.6	14.2
PCB105	9.49	31.9	6.21	14.3	0.785	7.47	5.49	2.97	1.57
PCB138	13.4	20.0	11.0	16.6	3.91	10.9	13.6	4.45	3.75
PCB158	1.89	3.29	1.52	2.10	0.332	1.59	1.24	0.279	< 0.089
PCB187	3.95	6.67	5.50	6.86	2.79	5.20	8.75	2.50	2.68

Chemical	SDBay-01	SDBay-03	SDBay-04	SDBay-05	SDBay-06	SDBay-07	SDBay-08	SDBay-09	SDBay-10
PCB183	1.60	2.78	1.66	2.98	0.809	1.89	2.53	0.627	0.550
PCB126	0.638	0.541	< 0.399	< 0.265	< 0.109	< 0.315	< 0.377	< 0.453	< 0.529
PCB128	4.38	9.05	4.95	7.11	1.11	4.85	6.17	2.25	2.03
PCB167	1.00	1.66	0.892	1.37	0.249	1.10	1.11	0.443	0.444
PCB177	2.26	5.15	3.79	4.60	1.43	3.10	5.97	2.18	2.47
PCB200	< 0.020	< 0.021	< 0.032	< 0.021	< 0.009	< 0.025	< 0.03	< 0.037	< 0.043
PCB156	1.46	3.93	1.47	2.85	0.342	1.86	1.69	0.217	< 0.161
PCB157	0.458	1.28	0.997	0.955	0.219	0.886	1.06	≤ 0.141	< 0.166
PCB180	5.70	7.50	4.07	6.18	1.22	4.37	4.48	1.25	1.20
PCB170	2.82	5.05	2.81	4.24	0.992	2.49	3.26	0.781	0.609
PCB201	1.11	1.52	1.29	1.43	0.534	1.02	1.61	0.433	0.461
PCB169	0.149	0.504	< 0.182	0.461	0.094	< 0.144	0.458	< 0.207	< 0.242
PCB189	0.705	1.28	1.22	< 0.045	< 0.019	< 0.054	< 0.065	1.05	1.11
PCB194	0.605	0.626	0.402	0.549	0.193	0.350	0.628	0.137	0.267
PCB206	0.135	0.214	0.215	0.197	0.103	0.191	0.267	0.091	0.107
PCB209	< 0.004	< 0.004	< 0.007	< 0.005	< 0.002	< 0.005	< 0.006	< 0.008	< 0.009

'<' symbol represents a non-detect with the value equal to the MDL

'≤' symbol represents a detection but at an estimated concentration lower than the MDL

Table A5. Congener-specific sediment-water interface passive sampler data for winter sampling in San Diego Bay: Sediment.

Chemical	SDBay-01	SDBay-03 (upper)	SDBay-03 (lower)	SDBay-04	SDBay-05 (upper)	SDBay-05 (lower)	SDBay-06	SDBay-07	SDBay-08	SDBay-09	SDBay-10
Trans-Chlordane (Gamma)	6.16	80.9	87.7	34.0	14.0	10.3	13.6	35.8	2.24	3.92	1.45
Cis-Chlordane (Alpha)	6.38	57.2	57.9	35.4	12.2	8.44	18.8	40.2	2.53	4.23	1.78
Cis-Nonachlor	3.86	28.9	30.4	19.0	11.6	7.85	12.1	14.8	2.75	3.56	2.39
Trans-Nonchlor	3.09	39.3	40.1	31.3	10.8	7.21	21.5	29.3	2.74	4.35	1.78
Oxychlordane	< 1.84	< 6.60	< 3.06	< 2.07	< 6.53	< 3.18	< 6.43	< 1.94	< 1.97	< 1.84	< 1.56
Dieldrin	≤ 7.07	41.5	48.1	63.9	184	57.9	44.2	96.6	≤ 7.6	9.97	< 7.15
o,p'-DDD	5.31	< 18.7	< 8.7	< 5.88	< 18.5	< 9.04	< 18.2	< 5.50	< 5.6	< 5.23	< 4.43
o,p'-DDE	1.01	< 3.54	< 1.64	< 1.11	< 3.5	< 1.71	< 3.45	1.61	< 1.06	< 0.988	< 0.837
o,p'-DDT	< 4.71	<16.8	< 7.82	< 5.29	< 16.7	< 8.12	74.4	< 4.95	< 5.04	< 4.70	< 3.98
p,p'-DDD	< 23.5	< 84	< 39	< 26.4	< 83.1	< 40.5	< 81.8	< 24.7	< 25.1	< 23.5	< 19.9
p,p'-DDE	7.61	72.1	84.3	79.2	94.3	97	143	51.8	27.7	66.2	50.5
p,p'-DDT	< 6.71	< 24	< 11.2	< 7.54	< 23.8	< 11.6	< 23.4	< 7.06	< 7.19	< 6.71	< 5.68
PCB8	< 30.4	≤ 104	74	< 34.1	146	135	< 106	< 31.9	< 32.5	< 30.3	< 25.7
PCB18	< 22	217	171	< 24.7	138	143	< 76.7	< 23.1	< 23.6	< 22.0	< 18.6
PCB28	< 13.1	280	222	15.1	152	112	< 45.7	< 13.8	< 14	< 13.1	< 11.1
PCB52	34.7	391	289	76.9	347	256	66.3	25.7	16.4	≤ 8.48	12.1
PCB49	29.0	244	169	41.4	254	195	59.6	20.7	16.4	7.60	13.0
PCB44	30.2	279	221	38.6	173	118	≤ 29.2	11.9	≤ 9.07	< 9.77	< 8.28
PCB37	69.4	< 82	≤ 35.1	< 25.7	< 81.0	< 39.5	< 79.8	< 24.1	< 24.5	< 22.9	< 19.4

Chemical	SDBay-01	SDBay-03 (upper)	SDBay-03 (lower)	SDBay-04	SDBay-05 (upper)	SDBay-05 (lower)	SDBay-06	SDBay-07	SDBay-08	SDBay-09	SDBay-10
PCB74	15.3	251	295	16.8	127	99.3	< 17.0	< 5.13	< 5.23	< 4.88	< 4.13
PCB70	67.5	506	596	112	298	228	< 20.6	16.4	< 6.33	< 5.90	< 5.00
PCB66	97.7	510	549	231	445	370	455	< 6.07	< 6.18	< 5.77	< 4.89
PCB101	72.2	366	376	128	343	282	130	58.6	49.9	28.3	25.1
PCB99	46.8	176	210	58.1	138	133	102	36.8	45.1	25.1	27.1
PCB119	5.59	26.9	20.3	5.24	16.5	13.5	8.20	4.35	2.82	1.66	1.31
PCB87	20.8	137	145	36.1	85.0	64.7	21.0	13.0	5.99	4.38	≤ 0.472
PCB110	72.3	368	361	117	256	212	63.6	42.8	25.8	14.4	10.2
PCB81	0.832	< 2.66	1.89	< 0.836	< 2.63	< 1.28	< 2.59	< 0.782	< 0.796	< 0.743	< 0.63
PCB151	6.20	35.9	37.0	10.6	32.7	28.3	14.3	9.57	5.89	3.06	1.63
PCB77	29.6	24.4	30.3	< 1.65	< 5.20	< 2.54	< 5.12	< 1.54	< 1.57	< 1.47	< 1.24
PCB149	34.4	154	161	53.4	157	123	72.0	47.3	42.4	23.8	20.8
PCB123	8.79	32.3	34.2	7.60	20.0	16.3	9.58	5.28	3.20	1.84	1.16
PCB118	46.4	231	243	54.7	149	121	55.9	35.6	20.5	10.7	6.99
PCB114	2.86	15.1	15.0	3.92	12.3	9.91	7.36	3.70	3.31	1.56	1.41
PCB153/168	32.4	103	103	35.4	105	90.4	59.6	31.0	33.2	15.8	16.3
PCB105	17.2	118	123	21.0	53.7	43.8	14.6	12.2	4.14	2.81	1.37
PCB138	28.8	57.5	60.4	18.5	44.8	39.2	24.1	15.8	11.9	5.83	3.33
PCB158	3.55	9.80	9.84	2.25	8.60	6.31	2.03	2.06	1.03	0.442	0.196
PCB187	7.13	18.4	17.7	6.71	19.2	16.3	10.5	6.61	8.06	3.04	2.65

Chemical	SDBay-01	SDBay-03 (upper)	SDBay-03 (lower)	SDBay-04	SDBay-05 (upper)	SDBay-05 (lower)	SDBay-06	SDBay-07	SDBay-08	SDBay-09	SDBay-10
PCB183	3.06	8.53	8.89	2.60	7.58	6.34	3.15	2.54	2.20	0.924	0.611
PCB126	2.48	< 0.349	1.3	< 0.11	< 0.345	0.277	< 0.34	0.169	< 0.105	< 0.098	< 0.083
PCB128	9.12	28.0	26.9	8.85	22.2	18.1	10.3	6.62	5.23	2.47	1.55
PCB167	1.95	4.60	4.59	1.44	3.77	3.23	1.95	1.35	1.07	0.450	0.382
PCB177	4.08	13.6	12.8	5.24	12.1	10.4	7.83	4.51	6.08	2.05	1.64
PCB200	< 0.008	< 0.028	< 0.013	0.281	< 0.028	< 0.014	< 0.028	< 0.008	< 0.008	< 0.008	< 0.007
PCB156	2.62	13.2	13.0	3.07	10.1	8.27	2.73	2.99	1.52	0.640	0.423
PCB157	0.87	3.12	2.74	0.960	2.16	1.79	1.38	0.786	0.490	0.122	0.271
PCB180	12.2	23.5	23.7	5.73	19.6	17.2	5.47	6.68	5.26	1.74	1.37
PCB170	5.68	15.8	15.0	3.88	11.8	11.2	4.12	4.38	3.20	1.25	0.762
PCB201	1.89	4.91	4.58	1.48	4.03	3.51	1.75	1.43	1.58	0.493	0.403
PCB169	0.083	1.46	1.41	0.438	1.02	0.789	0.532	0.267	0.236	< 0.045	0.100
PCB189	0.373	0.294	0.580	1.16	0.617	0.549	2.87	1.16	1.22	0.985	0.947
PCB194	0.971	1.92	1.82	0.564	1.51	1.38	0.688	0.580	0.712	0.217	0.167
PCB206	0.227	0.649	0.536	0.251	0.524	0.437	0.310	0.214	0.289	0.063	0.078
PCB209	< 0.002	< 0.006	0.125	0.207	< 0.006	< 0.003	0.412	0.174	0.25	0.159	0.198

‘<’ symbol represents a non-detect with the value equal to the MDL ‘≤’ symbol represents a detection but at an estimated concentration lower than the MDL

Attachment 3: Chemical Analysis Results Summary for Sampling Event 2 (Summer)

Introduction

San Diego Bay provides habitat for a unique assemblage of fish species, which provides beneficial uses to both sport and sustenance fishermen; however, it is currently listed under the San Diego Regional Water Quality Control Board (SDRWQCB) Clean Water Act Section 303(d) list as impaired by polychlorinated biphenyls (PCBs). Previous efforts, including the 2013 Regional Harbor Monitoring Program (RHMP) Bioaccumulation Special Study effort (Amec Foster Wheeler 2017) and the 2014 Shallow Water Habitat Study in San Diego Bay (Amec Foster Wheeler 2016) have quantified the levels of PCBs and other constituents of potential concern (COPCs), such as pesticides, in fish from San Diego Bay at concentrations high enough to exceed human consumption guidance values. Bioaccumulation in fish tissue is strongly influenced by contaminant concentrations in both sediment and water (U.S. Environmental Protection Agency [USEPA] 2000).

Water column PCB and pesticide concentrations can account for a large proportion of the body burden in species that reside in the water column and/or feed primarily on plankton (e.g., shellfish, perch, and topsmelt). While bioaccumulation models can account for water column sources, bioaccumulation estimates associated with dissolved pesticides and PCBs are usually based on estimated concentrations because site-specific data are often lacking or are limited by high detection limits. To address the uncertainty in bioaccumulation models for pesticides and PCBs in San Diego Bay, this study will provide the data necessary to evaluate the specific contributions of sediment organochlorines, including pesticides and PCBs, to the water column via flux and transport mechanisms, and relate these data to biota measurements and bioaccumulation model estimates. Outcomes of this project will provide more confident bioaccumulation modeling tools for SQO assessment and development of sediment cleanup targets. This data summary includes the sediment and water grab data as well as the water column and sediment-water interface passive sampler data collected during the summer sampling event.

Sampling Design

This study included two sampling events in 2018: winter and summer. Ten stations were sampled throughout San Diego Bay, with the goal to sample a range of contaminant levels (Figure 1 and Table 1). Both sampling events included collection of sediment and water column grab samples and fish and phytoplankton samples, as well as deployment of water column passive samplers and sediment-water interface passive samplers. The water column grab samples (1 L) were collected at deployment and retrieval for a subset of five stations. Biota samples were collected in the area near a subset of six stations (Figure 2). Sediment grab samples and passive samplers were collected at all ten stations. The plan was to deploy the passive samplers for approximately 30 days with water grabs collected upon deployment and retrieval, and sediment grabs collected on retrieval. During the deployment, fish and plankton collection would occur.

All samples were analyzed for chlordanes, dieldrin, DDTs, and PCBs. Total organic carbon (TOC), dissolved organic carbon (DOC), and lipid content were measured in sediment, water, and biota, respectively. The list of PCB congeners was expanded from prior monitoring efforts to align more with the Human Health Sediment Quality Objective (HHSQO) guidelines (Table 2). This expanded list of 63 PCB congeners was analyzed in the biota samples. A subset of those congeners (43 out of 63) was analyzed in the passive samplers and the water and sediment grab samples.

Table 1. Station location coordinates within San Diego Bay and corresponding samples for analysis.

Station ID	Latitude	Longitude	Water Grab	Sediment Grab	Passive Samplers *(Sediment and water column)*	Biota
SDBay-1	32.7245400	-117.2246600	x	x	x	x
SDBay-2	32.7174512	-117.2159143		x	x	
SDBay-3	32.7267390	-117.1761710	x	x	x	x
SDBay-4	32.7024000	-117.1617800		x	x	
SDBay-5	32.6929000	-117.1480000		x	x	
SDBay-6	32.6847938	-117.1600035		x	x	x
SDBay-7	32.6862720	-117.1338100	x	x	x	x
SDBay-8	32.6651840	-117.1498040	x	x	x	x
SDBay-9	32.6469360	-117.1182380		x	x	
SDBay-10	32.6258023	-117.1115252	x	x	x	x

Figure 1. Station locations in San Diego Bay.

Figure 2. Biota sampling locations in San Diego Bay.

Table 2. Constituents analyzed in samples.

Sediment TOC	PCBs	PCBs cont.	PCBs cont.
	PCB 8	PCB 95*	PCB 157
Water DOC	PCB 11*	PCB 97*	PCB 158
	PCB 18	PCB 99	PCB 167
Tissue % lipid	PCB 27*	PCB 101	PCB 168
	PCB 28	PCB 105	PCB 169
Chlordanes	PCB 29*	PCB 110	PCB 170
cis-Chlordane	PCB 31*	PCB 114	PCB 174*
trans-Chlordane	PCB 33*	PCB 118	PCB 177
cis-Nonachlor	PCB 37	PCB 119	PCB 180
trans-Nonachlor	PCB 44	PCB 123	PCB 183
Oxychlordane	PCB 49	PCB 126	PCB 187
	PCB 52	PCB 128	PCB 189
Dieldrin	PCB 56*	PCB 132*	PCB 194
	PCB 60*	PCB 137*	PCB 195*
DDTs	PCB 64*	PCB 138	PCB 198*
op-DDD	PCB 66	PCB 141*	PCB 199*
op-DDE	PCB 70	PCB 146*	PCB 200
op-DDT	PCB 74	PCB 149	PCB 201
pp-DDD	PCB 77	PCB 151	PCB 203*
pp-DDE	PCB 81	PCB 153	PCB 206
pp-DDT	PCB 87	PCB 156	PCB 209

*Measured only in tissue samples.

RESULTS

Sampling

During event 2, passive samplers were deployed on Friday, September 7, 2018 for a 33-day deployment with collection scheduled for Tuesday, October 9. Sediment-water interface samplers at SDBay-02 and -09 were not found. A dive team was required for retrieval of water column samplers at SDBay-03, -04, and -06 which caused a delay until October 18. Water grabs were collected on Friday, September 7 at the subset of five stations (SDBay-01, -03, -07, -08, -10) to coincide with sampler deployment. Sediment grab samples and the second set of water grabs occurred on Wednesday, October 10 to coincide with sampler retrieval. All fish and plankton samples were collected during October 9 through 12 and October 18.

Water and Sediment Grab Samples

The results for water grab samples were below reporting limits for all congeners and chemical classes analyzed (Table 3). The sediment grab results for chlordanes, DDTs, and PCBs are presented here as the summation of the five, six, and 43 measured congeners, respectively (Table 4). A summary of the congener-specific sediment grab data is provided in the appendix (Table A1). The water DOC and sediment TOC concentrations are also reported (Table 5). The DOC concentrations were lower in October (retrieval) than September (deployment).

Similar to Event 1, SDBay-01, -03, -04, -05, and -07 generally had higher sediment contaminant levels (Figure 3). This is consistent with expectations based on the location and history of these stations. The highest sediment contaminant concentrations were at SDBay-01 (DDTs), SDBay-05 (PCBs), and SDBay-07 (chlordanes and dieldrin). Stations SDBay-02, -06, -08, -09, and -10 had the lowest sediment contaminant levels. These trends are consistent with the results from Event 1.

Table 3. Summary of the final water grab sample data for summer sampling in San Diego Bay.

	SDBay-01		SDBay-03		SDBay-07		SDBay-08		SDBay-10	
Chemical	Deployment*	Retrieval*	Deployment	Retrieval	Deployment	Retrieval	Deployment	Retrieval	Deployment	Retrieval
Sum Chlordanes (ng/L)	<0.11 (<0.11)	<0.11 (<0.11)	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11
Dieldrin (ng/L)	<0.82 (<0.82)	<0.82 (<0.82)	<0.82	<0.82	<0.82	<0.82	<0.82	<0.82	<0.82	<0.82
Sum DDTs (ng/L)	<1.61 (<1.61)	<1.61 (<1.61)	<1.61	<1.61	<1.61	<1.61	<1.61	<1.61	<1.61	<1.61
Sum PCBs (ng/L)	<0.045 (<0.045)	<0.045 (<0.045)	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045

*Duplicate sample values in parentheses. ‘<’ symbol represents a non-detect with the value equal to the method detection limit (MDL)

Table 4. Summary of the final sediment grab sample data for summer sampling in San Diego Bay.

Chemical	SDBay-01	SDBay-02	SDBay-03	SDBay-03 Duplicate	SDBay-04	SDBay-05	SDBay-06	SDBay-07	SDBay-08	SDBay-09	SDBay-10
Sum Chlordanes (ng/g dw)	5.89	≤0.017	9.47	8.42	3.30	1.36	0.208	10.9	0.241	0.275	0.245
Dieldrin (ng/g dw)	0.333	<0.164	0.308	0.343	0.211	0.427	<0.164	0.987	<0.164	<0.164	<0.164
Sum DDTs (ng/g dw)	17.4	<0.321	4.57	4.39	1.43	2.46	≤0.354	4.02	≤0.346	≤0.544	0.698
Sum PCBs (ng/g dw)	653	0.840	295	276	62.4	690	14.1	102	16.8	7.30	10.8

‘<’ symbol represents a non-detect with the value equal to the MDL ‘≤’ symbol represents a detection but at an estimated concentration lower than the MDL

Table 5. Summary of the final sediment TOC and water DOC concentrations.

	SDBay-01	SDBay-02	SDBay-03	SDBay-04	SDBay-05	SDBay-06	SDBay-07	SDBay-08	SDBay-09	SDBay-10
Sediment TOC (%)	1.91	0.16	1.50 (1.49)*	1.03	1.69	0.70 (0.71)*	1.85	0.74	0.88	1.47
Water DOC-Deployment (mg/L)	1.17 (1.05)*	NC	1.30	NC	NC	NC	2.01	1.58	NC	1.43
Water DOC-Retrieval (mg/L)	0.83 (0.81)*	NC	0.88	NC	NC	NC	0.86	1.03	NC	1.14

NC=Not collected *Duplicate sample values in parentheses ‘<’ symbol represents a non-detect with the value equal to the MDL
‘≤’ symbol represents a detection but at an estimated concentration lower than the MDL

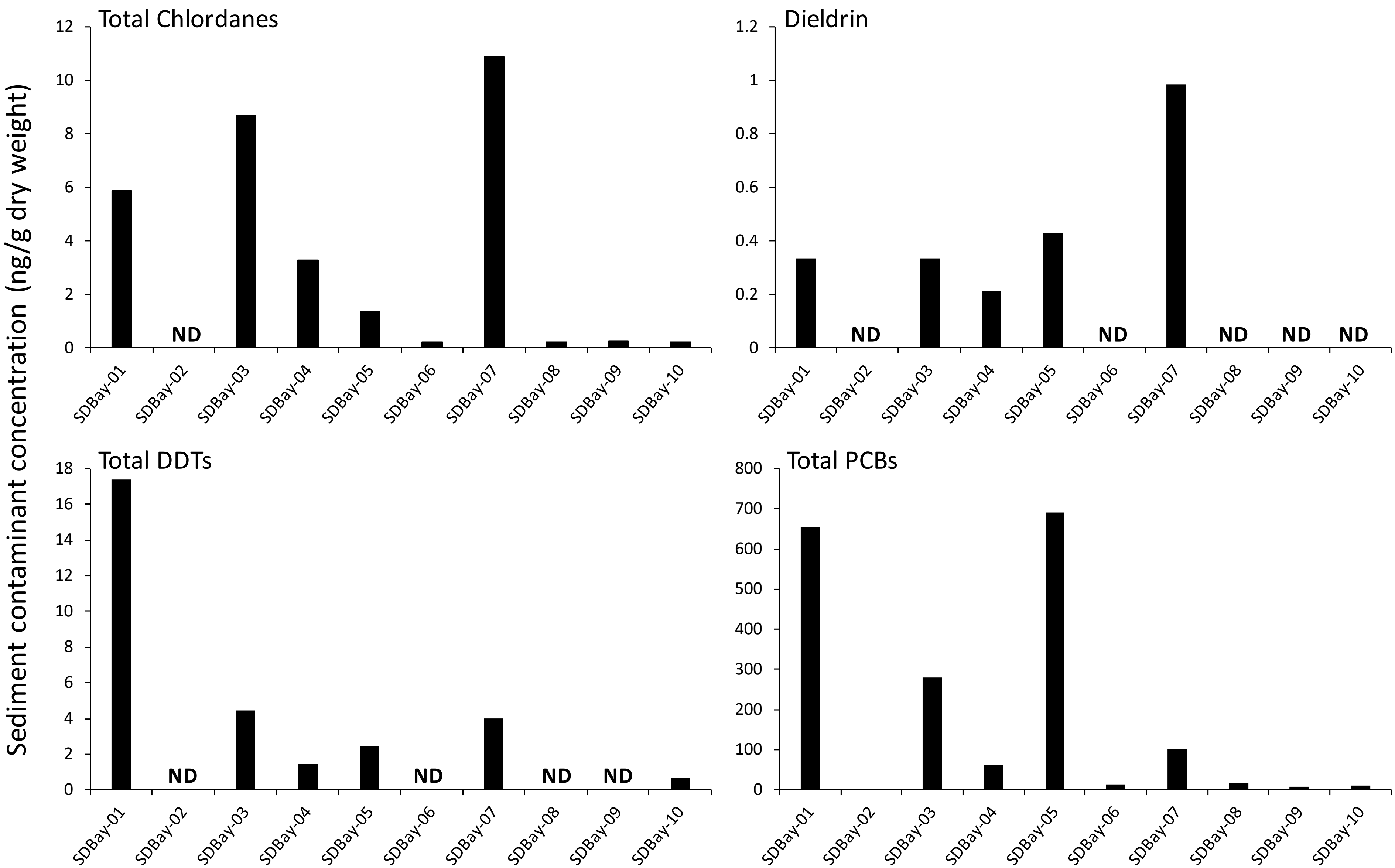

Figure 3. Summary of sediment contaminant concentrations in San Diego Bay. ND=not detected.

Passive Sampler Results

Data from the passive samplers deployed in the water column provide a time-averaged dissolved contaminant concentration. Since these samplers were deployed in triplicate at each station, the summary results are presented as an average concentration (Table 6). A summary of the congener-specific data is provided in the appendix (Tables A2 and A3). In general, SDBay-01 had the highest contaminant concentrations, and SDBay-10 had the lowest contaminant concentrations (Figure 4). This is consistent with the trends observed for total PCBs and DDTs measured in the sediment. Dieldrin concentrations ranged from non-detect to 8.14 pg/L; total chlordane concentrations ranged from 4.62-28.6 pg/L; total DDT concentrations ranged from 11.5-81.4 pg/L; and Total PCB concentrations ranged from 111-1250 pg/L. Although the range of concentrations for total PCBs and DDTs was larger relative to the other contaminants, the high end of those ranges is dominated by the concentration at SDBay-01. Unlike the water grab samples, the passive samplers were able to detect quantifiable concentrations at every station, except for dieldrin at SDBay-10. Event 2 water column passive samplers detected higher concentrations of each contaminant class when compared to the results from event 1, which was not reflected in the sediment grab sample results. For event 2, sediment-water interface passive samplers were deployed, retrieved and analyzed by Naval Information Warfare Center Pacific (NIWC-Pacific, formerly SPAWAR). These analyses are ongoing by NIWC-Pacific and are outside the scope of this contract.

Table 6. Summary of the mean (n=3) water column passive sampler contaminant concentrations.

Chemical	SDBay-01	SDBay-02	SDBay-03	SDBay-04	SDBay-05	SDBay-06	SDBay-07	SDBay-08	SDBay-09	SDBay-10
Sum Chlordanes (pg/L)	27.1	11.6	28.6	22.1	25.5	14.3	26.2	11.4	15.0	4.62
Dieldrin (pg/L)	6.59	5.38	6.39	7.23	8.14	5.04	7.06	5.44	5.84	≤4.06
Sum DDTs (pg/L)	81.4	22.3	25.9	24.5	37.3	23.8	28.9	17.0	29.6	11.5
Sum PCBs (pg/L)	1250	289	616	416	818	416	503	338	263	111

*Duplicate sample values in parentheses ‘≤’ symbol represents a detection but at an estimated concentration lower than the MDL

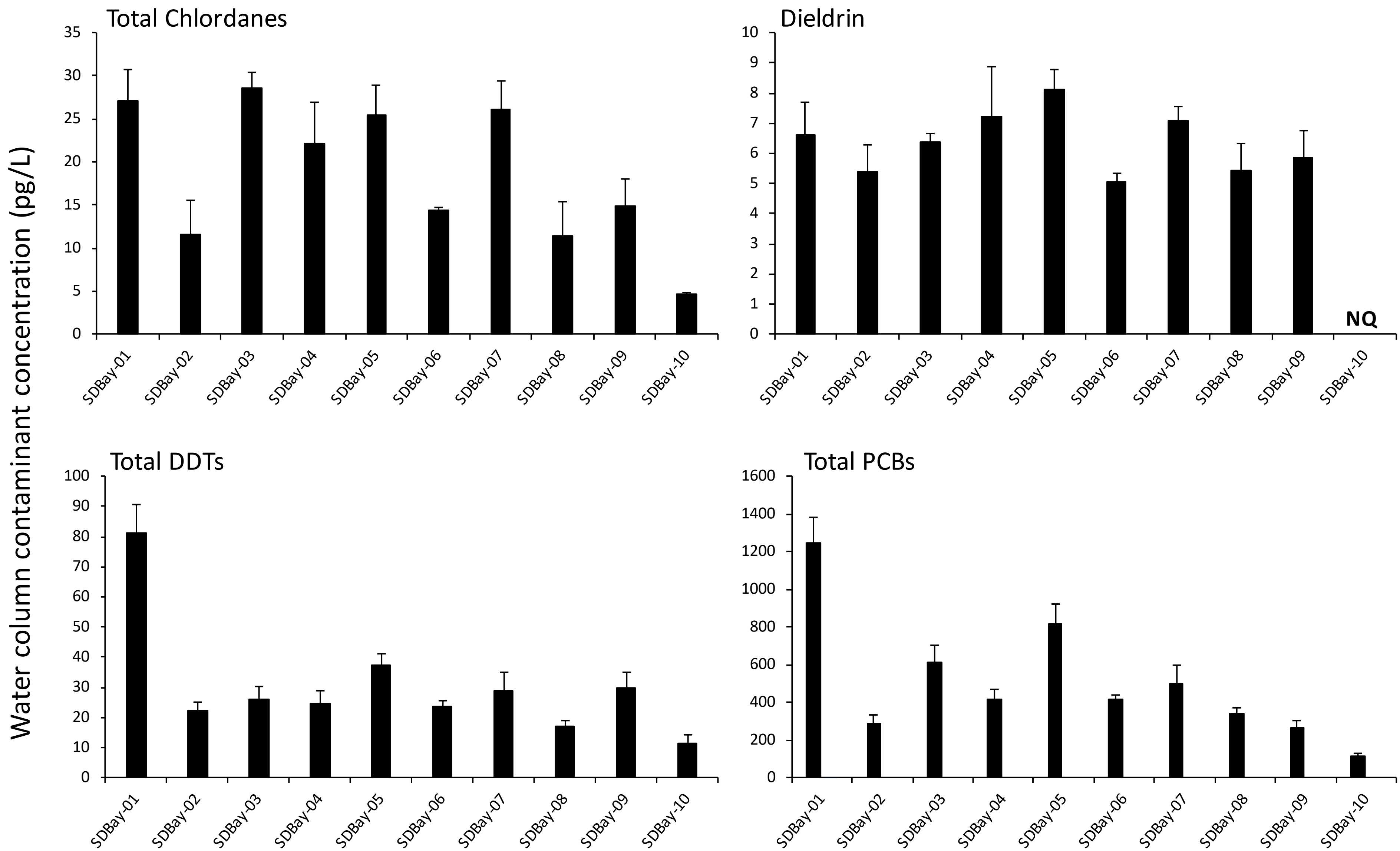

Figure 4. Summary of mid-depth water column dissolved contaminant concentrations in San Diego Bay measured using passive samplers. NQ=not quantifiable.

REFERENCES

Amec Foster Wheeler Environment & Infrastructure. 2016. Shallow Water Habitat Bioaccumulation (SWHB) Study prepared for the City of San Diego. June, 2016.

Amec Foster Wheeler Environment & Infrastructure. 2017. Regional Harbor Monitoring Program (RHMP) 2013 Aquatic Food Web Bioaccumulation Study. January 2016.

United States Environmental Protection Agency (USEPA). 2000. Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment. Status and Needs.

ATTACHMENT 3 APPENDIX

Table A1. Congener-specific sediment grab sample data for summer sampling in San Diego Bay.

Chemical (ng/g dw)	SDBay-01	SDBay-02	SDBay-03	SDBay-03 Duplicate	SDBay-04	SDBay-05	SDBay-06	SDBay-07	SDBay-08	SDBay-09	SDBay-10
Cis-Chlordane (Alpha)	1.18	< 0.054	2.17	1.81	0.868	0.326	≤ 0.053	2.90	0.057	0.062	0.054
Trans-Chlordane (Gamma)	1.96	≤ 0.017	3.63	3.17	0.933	0.407	0.068	3.45	0.064	0.067	0.061
Cis-Nonachlor	1.55	< 0.022	1.82	1.73	0.584	0.306	0.072	1.86	0.062	0.077	0.070
Trans-Nonchlor	1.20	< 0.034	1.85	1.71	0.911	0.325	0.068	2.66	0.058	0.069	0.060
Oxychlordane	< 0.172	< 0.172	< 0.172	< 0.172	< 0.172	< 0.172	< 0.172	< 0.172	< 0.172	< 0.172	< 0.172
Dieldrin	0.333	< 0.164	0.308	0.343	0.211	0.427	< 0.164	0.987	< 0.164	< 0.164	< 0.164
o,p'-DDD	1.03	< 0.503	< 0.503	< 0.503	< 0.503	< 0.503	< 0.503	≤ 0.388	< 0.503	< 0.503	< 0.503
o,p'-DDE	0.916	< 0.321	≤ 0.300	≤ 0.259	< 0.321	< 0.321	< 0.321	≤ 0.206	< 0.321	< 0.321	< 0.321
o,p'-DDT	< 1.59	< 1.59	< 1.59	< 1.59	< 1.59	< 1.59	< 1.59	< 1.59	< 1.59	< 1.59	< 1.59
p,p'-DDD	3.34	< 1.12	≤ 0.631	≤ 0.702	< 1.12	< 1.12	< 1.12	≤ 1.04	< 1.12	< 1.12	< 1.12
p,p'-DDE	12.1	< 0.658	4.57	4.39	1.43	2.46	≤ 0.354	4.02	≤ 0.346	≤ 0.544	0.698
p,p'-DDT	< 1.39	< 1.39	< 1.39	< 1.39	< 1.39	< 1.39	< 1.39	< 1.39	< 1.39	< 1.39	< 1.39
PCB8	< 0.365	< 0.365	< 0.365	< 0.365	< 0.365	1.40	< 0.365	< 0.365	< 0.365	< 0.365	< 0.365
PCB18	< 0.870	< 0.870	3.16	2.30	< 0.870	1.89	< 0.870	< 0.870	< 0.870	< 0.870	< 0.870
PCB28	4.39	< 0.600	4.95	3.48	< 0.600	2.44	< 0.600	< 0.600	< 0.600	< 0.600	< 0.600
PCB52	19.8	< 0.831	8.58	6.78	1.48	25.3	< 0.831	1.20	< 0.831	< 0.831	< 0.831
PCB49	15.2	< 0.801	7.62	6.74	0.988	7.05	< 0.801	2.28	< 0.801	< 0.801	< 0.801
PCB44	33.3	< 0.960	13.2	11.5	2.60	15.6	< 0.960	< 0.960	< 0.960	< 0.960	< 0.960

Chemical (ng/g dw)	SDBay-01	SDBay-02	SDBay-03	SDBay-03 Duplicate	SDBay-04	SDBay-05	SDBay-06	SDBay-07	SDBay-08	SDBay-09	SDBay-10
PCB37	< 0.872	< 0.872	1.50	1.54	< 0.872	< 0.872	< 0.872	< 0.872	< 0.872	< 0.872	< 0.872
PCB74	18.6	< 0.852	12.5	10.8	0.986	6.10	< 0.852	0.885	< 0.852	< 0.852	< 0.852
PCB70	31.7	< 0.640	21.1	20.5	2.35	4.59	< 0.640	1.89	< 0.640	< 0.640	< 0.640
PCB66	31.1	< 0.930	19.8	19.1	1.46	10.5	< 0.930	2.33	< 0.930	< 0.930	< 0.930
PCB101	55.6	≤ 0.116	20.6	19.4	5.05	76.0	0.982	6.63	1.19	0.578	0.819
PCB99	29.1	< 0.391	11.4	11.2	1.91	24.8	0.679	3.61	0.890	0.411	0.756
PCB119	3.23	< 0.120	1.26	1.19	0.280	2.94	≤ 0.098	0.463	≤ 0.106	< 0.12	< 0.120
PCB87	22.8	< 0.340	8.22	7.46	2.17	26.8	≤ 0.22	1.84	< 0.34	< 0.34	< 0.340
PCB110	57.6	< 0.187	19.6	18.5	5.07	79.4	0.484	5.12	0.570	0.285	0.393
PCB81	≤ 0.063	< 0.117	< 0.117	< 0.117	< 0.117	< 0.117	< 0.117	< 0.117	< 0.117	< 0.117	< 0.117
PCB151	6.31	≤ 0.022	3.12	2.92	0.846	8.96	0.228	2.09	0.246	0.106	0.132
PCB77	2.96	< 0.156	2.25	2.05	≤ 0.107	1.28	< 0.156	0.232	< 0.156	< 0.156	< 0.156
PCB149	40.7	≤ 0.109	16.1	15.3	5.06	57.3	1.42	10.2	2.03	0.853	1.40
PCB123	8.18	< 0.056	3.16	2.97	0.638	7.81	0.186	0.933	0.177	0.097	0.135
PCB118	64.8	0.079	22.1	21.5	5.07	72.8	1.06	6.58	1.08	0.553	0.836
PCB114	3.64	< 0.043	1.55	1.50	0.424	4.56	0.146	0.735	0.186	0.074	0.135
PCB153/168	42.1	0.169	17.7	17.1	5.46	51.4	2.19	11.5	2.68	1.19	2.01
PCB105	30.5	< 0.080	11.8	11.2	2.33	33.5	0.362	2.72	0.302	0.174	0.212
PCB138	42.7	0.093	15.8	14.9	4.84	56.1	1.31	7.72	1.30	0.663	0.787
PCB158	5.62	≤ 0.014	1.96	1.86	0.714	8.58	0.134	0.897	0.111	0.055	0.060

Chemical (ng/g dw)	SDBay-01	SDBay-02	SDBay-03	SDBay-03 Duplicate	SDBay-04	SDBay-05	SDBay-06	SDBay-07	SDBay-08	SDBay-09	SDBay-10
PCB187	9.12	0.089	6.36	5.98	1.75	9.94	0.980	5.31	1.21	0.460	0.704
PCB183	3.97	0.029	2.49	2.42	0.633	5.14	0.232	1.91	0.295	0.113	0.126
PCB126	0.263	< 0.049	0.117	0.135	< 0.049	0.190	< 0.049	< 0.049	< 0.049	< 0.049	< 0.049
PCB128	13.1	0.043	4.37	4.13	1.46	17.0	0.358	2.01	0.380	0.181	0.234
PCB167	2.75	≤ 0.011	0.988	0.965	0.322	3.59	0.082	0.496	0.104	0.045	0.063
PCB177	4.19	0.034	2.73	2.66	0.737	4.99	0.363	2.13	0.459	0.172	0.263
PCB200	0.551	≤ 0.008	0.392	0.383	0.114	0.659	0.069	0.344	0.084	0.033	0.053
PCB156	7.90	0.020	2.73	2.60	0.886	11.4	0.148	1.21	0.172	0.071	0.101
PCB157	1.67	< 0.021	0.516	0.513	0.203	1.95	0.054	0.324	0.047	0.031	0.032
PCB180	16.0	0.077	10.0	9.70	2.45	19.2	0.707	7.35	0.853	0.334	0.399
PCB170	8.63	0.039	5.00	4.81	1.21	10.6	0.359	3.04	0.432	0.176	0.214
PCB201	4.43	0.043	3.21	3.15	0.821	4.99	0.383	2.30	0.481	0.169	0.221
PCB169	0.401	< 0.021	0.319	0.302	0.074	0.505	< 0.021	0.229	< 0.021	< 0.021	< 0.021
PCB189	0.975	< 0.013	0.619	0.602	0.163	1.20	0.062	0.41	0.070	0.035	0.043
PCB194	4.06	0.037	2.90	2.83	0.726	4.42	0.318	2.08	0.449	0.153	0.210
PCB206	3.24	0.037	2.00	1.96	0.619	3.67	0.337	1.38	0.447	0.135	0.199
PCB209	2.09	0.051	1.29	1.27	0.524	3.01	0.474	1.15	0.575	0.149	0.257

'<' symbol represents a non-detect with the value equal to the MDL

'≤' symbol represents a detection but at an estimated concentration lower than the MDL

Table A2. Congener-specific water column passive sampler data for summer sampling in San Diego Bay: SDBay-01, -02, -03, -04, and -05.

Chemical (pg/)L	SDBay-01 #1	SDBay-01 #2	SDBay-01 #3	SDBay-02 #1	SDBay-02 #2	SDBay-02 #3	SDBay-03 #1	SDBay-03 #2	SDBay-03 #3	SDBay-04 #1	SDBay-04 #2	SDBay-04 #3	SDBay-05 #1	SDBay-05 #2	SDBay-05 #3
Trans-Chlordane (Gamma)	6.68	5.28	5.71	1.77	2.21	1.64	6.68	7.28	6.54	4.71	2.97	3.57	4.08	3.64	4.98
Cis-Chlordane (Alpha)	6.49	5.25	5.1	2.25	3.25	2.25	6.57	6.68	6.12	5.84	3.72	4.35	4.53	4.2	5.89
Cis-Nonachlor	4.38	3.38	3.9	1.46	1.73	1.34	3.72	4.26	3.65	3.33	2.19	2.65	3.52	3.1	4.32
Trans-Nonchlor	5.75	4.42	5.17	2.04	2.32	1.83	4.73	5.77	4.56	4.48	3.1	3.64	4.59	4.07	5.27
Oxychlordane	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31
Dieldrin	7.6	5.38	6.79	≤ 3.49	6.02	4.74	6.27	6.71	6.2	8.94	5.63	7.11	8.4	7.39	8.63
o,p'-DDD	6.45	5.09	6.84	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02
o,p'-DDE	3.57	2.58	3.59	0.85	1.06	1.07	0.98	1.16	0.86	0.87	0.73	0.85	1.7	1.37	1.61
o,p'-DDT	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4
p,p'-DDD	10.3	7.68	9.17	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3
p,p'-DDE	68.4	55.8	64.8	21.7	23.8	18.3	24.6	29.2	20.9	27.6	19.1	24.2	36.5	31.5	39.1
p,p'-DDT	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16
PCB8	< 10	< 10	< 10	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5
PCB18	12.4	11.1	10.5	< 9.18	< 9.18	< 9.18	≤ 7.21	≤ 5.4	≤ 7.93	< 9.18	< 9.18	< 9.18	< 9.18	< 9.18	< 9.18
PCB28	35	42	30.2	< 4.9	< 4.9	< 4.9	16.8	18.4	17	8.96	5.81	6.06	11.92	15.1	15.8
PCB52	52.2	44.6	50.8	9.2	10.5	8.58	26	31.8	26	16	12.8	14.2	25.9	31.3	39.4
PCB49	43.2	36.1	41.3	8.17	9.6	7.23	20.8	24.5	20.4	12.7	11	12.7	21.9	27.5	31
PCB44	30	27.1	29.6	4.38	6.05	4.99	17	21.5	16.9	7.28	6.63	7.67	14.6	16	19.6
PCB37	≤ 6.23	≤ 6.76	≤ 6.81	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31	≤ 3.84

Chemical (pg/)L	SDBay-01 #1	SDBay-01 #2	SDBay-01 #3	SDBay-02 #1	SDBay-02 #2	SDBay-02 #3	SDBay-03 #1	SDBay-03 #2	SDBay-03 #3	SDBay-04 #1	SDBay-04 #2	SDBay-04 #3	SDBay-05 #1	SDBay-05 #2	SDBay-05 #3
PCB74	65.1	49.2	60.5	5.67	7.13	5.45	23.1	30.1	21.6	8.94	6.45	7.27	17.9	16.7	24.4
PCB70	90.5	75.4	85.9	9.65	10.7	8.42	35.5	40.7	32.7	14.1	9.81	12.5	33.5	32.6	39.9
PCB66	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14
PCB101	151	118	145	31.7	38.1	27.6	56.9	73.6	52.5	48.3	35.5	42.7	95.7	85.6	108
PCB99	106	81.6	97.6	25.6	28.7	23.2	37.2	49	34.8	38.7	28.8	34.9	66.2	58.9	73.6
PCB119	11.3	8.79	10.7	2.23	3.05	2.24	4.42	4.69	3.21	3.53	2.63	3.21	7.13	6.17	7.61
PCB87	44	34.4	40.5	5.18	7.07	4.61	15	19.8	14.1	8.37	5.93	7.48	20.3	18.4	24.4
PCB110	143	108	136	18.2	20.6	16.3	45.9	56.7	42.8	29	22.1	26	68.6	62.2	77.1
PCB81	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18
PCB151	15.7	11.8	15	5.79	8.81	4.93	9.14	11.9	8.25	8.72	6.47	7.89	14.9	13.1	17.2
PCB77	10.4	7.66	10.4	1.12	1.16	1.1	3.53	4.14	3.16	2.13	1.39	1.86	4.03	3.39	4.57
PCB149	86.1	67.4	81.6	29.6	33.7	24.3	48.9	57.4	40.7	46.3	35.4	42.8	81.5	70.9	89.3
PCB123	23.5	18.4	21.4	4.68	6.13	3.99	7.93	10.4	7.54	6.72	5.23	6.25	12	10.7	13.2
PCB118	169	132	156	24	30.7	20.5	50.5	66.5	46.1	36.2	28.2	33.3	78.1	69.2	87.1
PCB114	8.06	6.32	7.8	2.26	3.06	2	3.61	4.68	3.3	3.66	2.82	3.4	5.95	5.31	6.31
PCB153/168	74	66.6	67.1	32.9	41.3	28.2	46.1	58.7	42.8	56.8	43.7	52.5	70.6	67.2	90.8
PCB105	57.9	45.4	56.4	5.98	8.68	5.38	18.8	25	17.9	9.24	7.39	8.51	24.4	21.4	27.2
PCB138	45.9	38.6	39	17.3	20.9	17.2	31.4	30.5	28.6	35.8	24.8	29.4	31.3	29.6	40.1
PCB158	5.49	4.74	4.76	1.43	2.05	1.23	3.79	3.64	3.36	2.2	1.79	2.23	3.56	3.47	4.74
PCB187	10.7	9.08	9.14	7.81	9.4	7.29	11.9	11.4	10.8	16.7	11.7	14.6	12.9	12.4	16.9

Chemical (pg/)L	SDBay-01 #1	SDBay-01 #2	SDBay-01 #3	SDBay-02 #1	SDBay-02 #2	SDBay-02 #3	SDBay-03 #1	SDBay-03 #2	SDBay-03 #3	SDBay-04 #1	SDBay-04 #2	SDBay-04 #3	SDBay-05 #1	SDBay-05 #2	SDBay-05 #3
PCB183	4.51	3.93	3.94	2.26	2.67	2.15	4.83	4.41	4.09	4.78	3.46	4.14	4.66	4.49	6.09
PCB126	0.75	0.62	0.77	0.15	0.2	0.14	0.38	0.47	0.32	0.25	0.15	0.18	0.48	0.38	0.46
PCB128	21.1	18.3	18.6	5.49	6.28	4.78	9.79	12.8	9.01	8.76	7.08	8.35	13.1	12.4	17.1
PCB167	3.82	3.39	3.48	1.25	1.7	1.06	2.19	2.46	2.05	2.09	1.79	2.04	2.55	2.43	3.3
PCB177	7.44	6.55	6.6	4.41	5.92	3.93	7.62	7.66	7.28	8.2	6.62	7.63	7.97	7.64	10.5
PCB200	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
PCB156	9.57	8.18	8.37	1.78	2.52	1.58	4.67	5.76	4.35	3.03	2.63	2.87	5.78	5.4	7.43
PCB157	2.37	2.02	2.14	0.47	0.61	0.42	0.9	1.17	0.9	0.68	0.6	0.7	1.02	1.1	1.49
PCB180	13.3	11.7	11.8	4.36	5.8	4.22	13.2	11.3	11.6	9.78	7.49	8.71	12.9	12.1	16.6
PCB170	8.67	7.53	7.75	3.3	4.15	3.16	8.31	7.59	7.39	7.39	5.65	6.58	7.75	7.26	9.96
PCB201	2.48	2.2	2.21	1.11	1.62	1.08	2.53	2.34	2.2	2.5	1.95	2.24	2.5	2.39	3.23
PCB169	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014
PCB189	0.55	0.51	0.49	0.23	0.33	0.21	0.56	0.51	0.54	0.51	0.44	0.51	0.55	0.49	0.71
PCB194	0.97	0.88	0.88	0.36	0.54	0.35	0.96	0.92	0.84	0.79	0.68	0.75	0.94	0.86	1.21
PCB206	0.32	0.29	0.29	0.12	0.18	0.12	0.3	0.3	0.28	0.27	0.25	0.26	0.34	0.31	0.43
PCB209	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

'<' symbol represents a non-detect with the value equal to the MDL

'≤' symbol represents a detection but at an estimated concentration lower than the MDL

Table A3. Congener-specific water column passive sampler data for summer sampling in San Diego Bay: SDBay-06, -07, -08, -09, and -10.

Chemical	SDBay-06 #1	SDBay-06 #2	SDBay-06 #3	SDBay-07 #1	SDBay-07 #2	SDBay-07 #3	SDBay-08 #1	SDBay-08 #2	SDBay-08 #3	SDBay-09 #1	SDBay-09 #2	SDBay-09 #3	SDBay-10 #1	SDBay-10 #2	SDBay-10 #3
Trans-Chlordane (Gamma)	2.19	2.12	2.04	5.71	4.5	4.76	1.42	1.65	1.81	2.39	2.11	1.85	0.97	0.91	0.96
Cis-Chlordane (Alpha)	3.05	3.27	2.78	5.86	4.62	5.02	2.01	2.31	2.69	3.13	2.8	2.56	1.43	1.48	1.43
Cis-Nonachlor	1.91	1.94	1.89	4.41	3.31	3.48	1.74	1.86	2.03	2.68	2.31	2.06	1.19	1.04	1.07
Trans-Nonchlor	2.32	2.17	2.17	6.58	4.49	4.53	1.67	1.93	2.11	3.21	< 0.085	2.28	1.3	0.98	1.1
Oxychlordane	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31	< 1.31
Dieldrin	5.25	4.72	5.14	7.32	6.51	7.36	≤ 4.41	4.82	6.06	6.91	5.27	5.35	≤ 4.13	≤ 4.13	≤ 4.06
o,p'-DDD	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02	< 3.02
o,p'-DDE	0.84	0.88	1.01	1.51	1.1	1.77	0.54	0.921	0.82	1.34	1.15	0.96	< 0.49	< 0.49	< 0.49
o,p'-DDT	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	< 2.4	<2.4	< 2.4	< 2.4	< 2.4	< 2.4
p,p'-DDD	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3
p,p'-DDE	24.8	21.2	22.6	34.3	24.5	23.4	14.9	15.2	18.5	34	28.2	23.1	14.1	8.97	11.4
p,p'-DDT	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16	< 2.16
PCB8	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5	< 10.5
PCB18	< 9.18	< 9.18	< 9.18	< 9.18	< 9.18	< 9.18	< 9.18	< 9.18	< 9.18	< 9.18	< 9.18	< 9.18	< 9.18	< 9.18	< 9.18
PCB28	< 4.9	< 4.9	< 4.9	< 4.9	< 4.9	< 4.9	< 4.9	< 4.9	< 4.9	< 4.9	< 4.9	< 4.9	< 4.9	< 4.9	< 4.9
PCB52	12	14	13.3	28.2	19.7	18.3	8.85	9.33	10.6	9.25	8.61	7.59	5.23	4.78	5.15
PCB49	10.3	12.4	12.2	24.7	16.9	15.4	8.71	8.74	10.3	9.17	8.51	6.8	5.59	4.68	4.99
PCB44	6.28	6.55	6.26	10.5	7.72	6.94	4.05	4.19	5.01	≤ 3.22	4.1	≤ 3.19	< 3.92	< 3.92	< 3.92
PCB37	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31	< 7.31

Chemical	SDBay-06 #1	SDBay-06 #2	SDBay-06 #3	SDBay-07 #1	SDBay-07 #2	SDBay-07 #3	SDBay-08 #1	SDBay-08 #2	SDBay-08 #3	SDBay-09 #1	SDBay-09 #2	SDBay-09 #3	SDBay-10 #1	SDBay-10 #2	SDBay-10 #3
PCB74	7.9	6.26	6.15	10.1	6.52	7.86	3.55	4.02	5.56	4.68	3.73	3.24	< 1.93	≤ 1.27	≤ 1.71
PCB70	11.5	10.5	10.6	20.7	15.3	14.1	5.81	6.89	7.54	7.44	6.99	6.12	4.39	3.39	3.99
PCB66	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14	< 2.14
PCB101	45	40.1	43.2	75.5	53.8	50	31.1	35.8	40	39.4	35.3	25.7	16.5	10.7	12.4
PCB99	40.1	33.6	37.9	60.1	40.5	36.4	31	36.9	39.2	38.6	30.3	22.5	17.1	9.82	12.4
PCB119	3.23	2.89	2.96	5.9	4.18	3.61	2.15	2.55	2.69	2.65	2.21	1.7	0.99	0.64	0.78
PCB87	6.06	5.62	5.77	13.1	9.73	9.3	3.87	4.25	4.77	5.58	4.29	3.23	1.65	1.11	1.26
PCB110	23.1	22	23.1	46.1	36.7	33	16.2	17.8	20.2	19.6	18.3	13.5	7.5	4.76	5.67
PCB81	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18	< 0.18
PCB151	8.12	7.4	7.88	13	8.61	7.95	5.33	5.9	6.59	5.48	4.65	3.58	1.98	1.21	1.41
PCB77	1.72	1.35	1.66	2.39	1.84	1.52	0.93	1.07	1.46	1.21	1.07	0.78	< 0.362	< 0.362	< 0.362
PCB149	45.2	41	44.6	71.2	46.7	44.3	33.4	38.5	41.5	37	32.1	24.4	15.7	10.2	11.6
PCB123	6.39	5.63	6.38	9.34	7.3	6.44	4.33	4.68	5.21	5.01	4.49	3.42	2.04	1.26	1.4
PCB118	31.9	29.1	32.3	58.3	44	39.5	23.2	25	27.4	26.5	24.1	18	10.9	6.64	7.67
PCB114	3.83	3.38	3.79	5.21	3.64	3.41	2.83	3.09	3.36	3.04	2.59	1.99	1.28	0.79	0.89
PCB153/168	58.5	52.8	58.7	56.8	52.3	49	46.2	49.9	53.7	40.7	34.6	31.7	20.9	12.7	14.9
PCB105	6.88	6.13	6.89	16.5	11.9	10.6	4.42	4.76	5.49	5.5	5.19	3.74	2.16	1.34	1.53
PCB138	34.2	29.9	34.6	23.8	24	25	22.8	26	26.1	14.1	11.5	13.8	6.57	5.67	6.4
PCB158	1.8	1.37	1.91	2.46	2.47	2.46	1.31	1.29	1.28	0.97	0.89	0.99	0.4	0.3	0.4
PCB187	19.6	17.2	19.5	9.88	9.95	10.1	12.4	13.7	14	6.63	5.38	6.25	3.68	3.47	3.7

Chemical	SDBay-06 #1	SDBay-06 #2	SDBay-06 #3	SDBay-07 #1	SDBay-07 #2	SDBay-07 #3	SDBay-08 #1	SDBay-08 #2	SDBay-08 #3	SDBay-09 #1	SDBay-09 #2	SDBay-09 #3	SDBay-10 #1	SDBay-10 #2	SDBay-10 #3
PCB183	4.4	3.82	4.39	3.32	3.38	3.38	3	3.33	3.38	1.65	1.4	1.64	0.85	0.69	0.84
PCB126	0.18	0.2	0.24	0.35	0.27	0.21	0.16	0.12	0.18	< 0.038	< 0.038	< 0.038	< 0.038	< 0.038	< 0.038
PCB128	8.22	7.24	8.17	9.82	9.32	8.39	6.21	6.61	7.19	5.49	4.58	4.1	2.55	1.54	1.84
PCB167	1.97	1.77	2.05	2.06	2.07	2.06	1.49	1.51	1.68	1.04	0.84	0.93	0.56	0.36	0.4
PCB177	8.19	7.18	8.18	6.17	6.31	6.41	7	7.33	8.2	4	3.3	3.85	2.25	1.61	1.87
PCB200	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
PCB156	2.46	2.13	2.46	4.02	4.15	3.68	1.77	1.77	2.03	1.45	1.32	1.25	0.71	0.42	0.47
PCB157	0.64	0.53	0.63	0.86	0.87	0.85	0.46	0.49	0.56	0.37	0.36	0.36	0.26	0.15	0.18
PCB180	10.1	9.48	9.67	7.89	7.96	7.87	5.57	5.76	6.07	3.16	2.89	3.17	1.64	1.8	1.7
PCB170	6.29	5.42	6.22	5.49	5.63	5.41	4.48	4.67	4.63	2.32	1.91	2.44	1.16	0.99	1.12
PCB201	2.86	2.72	2.73	1.69	1.73	1.67	1.81	1.86	1.97	0.86	0.73	0.85	0.49	0.52	0.51
PCB169	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014
PCB189	0.52	0.52	0.51	0.41	0.4	0.4	0.34	0.35	0.4	0.25	0.26	0.3	0.15	0.17	0.15
PCB194	0.91	0.86	0.89	0.64	0.67	0.62	0.68	0.65	0.71	0.29	0.28	0.31	0.22	0.24	0.21
PCB206	0.32	0.31	0.31	0.21	0.22	0.21	0.25	0.24	0.26	0.1	0.1	0.12	0.08	0.09	0.09
PCB209	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

‘<’ symbol represents a non-detect with the value equal to the MDL ‘≤’ symbol represents a detection but at an estimated concentration lower than the MDL