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FINAL REPORT
Aquatic Food Web Bioaccumulation Study of San Diego Bay

Submitted to:

The City of San Diego
Transportation and Stormwater Department
9370 Chesapeake Drive
San Diego, California 92123

Submitted by:

Amec Foster Wheeler Environment & Infrastructure, Inc.
9210 Sky Park Court, Suite 200
San Diego, California 92123

December 2016

Amec Foster Wheeler Project No.: 1615100600

THE CITY OF SAN DIEGO • STATE OF CALIFORNIA • SEMPER VIGILANS

think BLUE
SAN DIEGO

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FINAL REPORT

December 2016

Prepared for:
The City of San Diego

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Acknowledgements:
This report is the result of hard work and dedication from many individuals with a common goal to improve our understanding of the environmental conditions in San Diego Bay. This effort was made possible with generous funding by the City of San Diego and the State of California Water Resources Control Board. Special thanks to Steven Bay and Nathan Dodder of the Southern California Coastal Water Research Project (SCCWRP), Dr. Doris Vidal-Dorsch, formerly of SCCWRP, and Katie Zeeman of the U.S Fish and Wildlife Service for their peer review and collaborative support on this team effort. Coordinated final reports in preparation led by Steve and Katie, as well as Steven Steinberg of SCCWRP will add to and complement the results presented herein. Additional thanks to the San Diego Regional Water Board, in particular Julie Chan, Craig Carlisle, Chad Loflen, Sean McClain, Chiara Clemente, Tom Alo, and Lalitha Thotakura, for their support, interest, and coordination of monthly meetings specific to the ongoing bioaccumulation-related studies in San Diego Bay.

Special thanks as well to all of the exceptional support provided to implement the program and prepare this report: Jordon Volker, Thomas Valencia, and Mary Tamburro of Merkel and Associates for field sampling and infauna sorting support; Mark Baker, Misty Mercier, Rich Gossett and the rest of the crew at Physis Analytical for chemical analysis support; Pei Geng, Linda Rauto, and rest of the crew at Laboratory Data Consultants for third party peer review; and finally Tyler Huff, John Rudolph, Kevin Stolzenbach, Jeremy Burns, Butch Weinberg, and Janice Depew of Amec Foster Wheeler for a wide variety of support between the field, data analyses, and reporting-related efforts.

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ACRONYMS AND ABBREVIATIONS

>	greater than
<	less than
≤	less than or equal to
µg/g	microgram(s) per gram (parts per million)
µg/L	microgram(s) per liter
%	percent
±	plus or minus
Amec Foster Wheeler	Amec Foster Wheeler Environment & Infrastructure, Inc.
ATL	advisory tissue level
Bight ’13	Southern California Bight 2013 Regional Monitoring Program
BSAF	biota sediment accumulation factor
Cal/EPA	California Environmental Protection Agency
City	City of San Diego
cm	centimeter(s)
COC	chain of custody
COPC	constituent or chemical of potential concern
CRM	certified reference materials
CTL	critical tissue level
CTR	California Toxics Rule
CVWR	Chula Vista Wildlife Refuge
DDT	dichlorodiphenyltrichloroethane
DEQ	Oregon Department of Environmental Quality
DGPS	differential global positioning system
DMMP	Dredged Material Management Program
DO	dissolved oxygen
DOC	dissolved oxygen carbon
DQO	data quality objective
DST	decision support tool
dw	dry weight
EDD	electronic data deliverable
ER-L	effects range-low

ACRONYMS AND ABBREVIATIONS (Cont.)

ER-M	effects range-medium
GIS	geographic information system
GPS	Global Positioning System
IQR	interquartile range
IRMES	Integrated Research in Materials, Environments, and Society
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
LDC	Laboratory Data Consultants
LOEC	lowest observed effect concentration
m^2	square meters
MBC	Marine Biological Consultants Inc.
MDL	method detection limit
mg/L	milligram(s) per liter
MLLW	mean lower low water
mm	millimeter(s)
m/sec	meter(s) per second
MS	matrix spike
MSD	matrix spike duplicate
N	total nitrogen
NA	not applicable to the specific sampling effort
NAS	Naval Air Station
ng/g	nanogram(s) per gram (parts per billion)
NOAA	National Oceanic and Atmospheric Administration
NOEC	no observed effect concentration
OEHHA	Office of Environmental Health Hazard Assessment
OPR	ongoing precision and recovery
PAH	polycyclic aromatic hydrocarbon
PBDE	polybrominated diphenyl ether
PCB	polychlorinated biphenyl
Physis	Physis Environmental Laboratory
Port	Port of San Diego

ACRONYMS AND ABBREVIATIONS (Cont.)

ppb	part(s) per billion
ppm	part(s) per million
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RL	reporting limit
RHMP	Regional Harbor Monitoring Program
RPD	relative percent difference
SAP	Sampling Analysis Plan
SCCWRP	Southern California Coastal Water Research Project
SDRWQCB	San Diego Regional Water Quality Control Board
SDSU	San Diego State University
SM	Standard Method
SOP	standard operating procedure
sp.	species
SQO	sediment quality objective
SRM	standard reference material
SWAMP	Surface Water Ambient Monitoring Program
SWHB	Shallow Water Habitat Bioaccumulation
SWRCB	State Water Resources Control Board
TMDL	Total Maximum Daily Load
TOC	total organic carbon
TSS	total suspended solids
TTL	target tissue level
TVV	Tandem Van Veen
USFWS	United States Fish and Wildlife Service
USEPA	United States Environmental Protection Agency
wt	weight
ww	wet weight

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1.0 INTRODUCTION

San Diego Bay is a large natural harbor and deepwater port that supports a variety critical habitats and associated wildlife, as well as commercial, national defense, and recreational activities. A large data gap exists in understanding the ecological and human health risks that stem from the possibility of contaminants being transferred through the food web. Assessment of sediment chemistry and bioaccumulation of constituents of potential concern (COPCs) in tissues at multiple trophic levels can provide data to facilitate a better understanding of the dynamics of the trophic transfer of bioaccumulative compounds. Bioaccumulative compounds such as dichlorodiphenyltrichloroethanes (DDTs), polychlorinated biphenyls (PCBs), and mercury are known to accumulate and become magnified through the food web. Previous efforts, including a survey by the State of California Surface Water Ambient Monitoring Program (SWAMP), have quantified levels of PCBs and mercury in fish from San Diego Bay and mercury in fish from Mission Bay at concentrations high enough to exceed human consumption guidance values (http://www.oehha.org/public_info/press/SDbayPress102213.html). The transfer of contaminants through the food chain from local sources and risk to wildlife, however, have not been studied on a region-wide basis.

In 2013, the Southern California Bight Regional Monitoring Program (Bight ’13) targeted analysis of DDT and its breakdown products, PCBs, mercury, and polybrominated diphenyl ether (PBDE) concentrations in a number of trophic levels, including fish, benthic invertebrates, plankton, and bird eggs in addition to the sediments, for the first time. The Bight program is a large-scale, ongoing regional study conducted every five years that is focused on understanding the impact of anthropogenic contaminants over time on the ecology of the southern California Bight (Point Conception to the Mexican Border). A special study focused on an initial understanding of the trophic transfer of contaminants dynamic was initiated during Bight ’13. A conceptual food web model for San Diego Bay is included as Figure 1-1. Bight ’13 included benthic community and sediment chemistry as well as toxicity sampling at over 300 locations ranging from deep waters offshore to shallower waters in ports and harbors. Bight ’13 also incorporated several special studies, including one that focused on bioaccumulation which this study was able to leverage with.

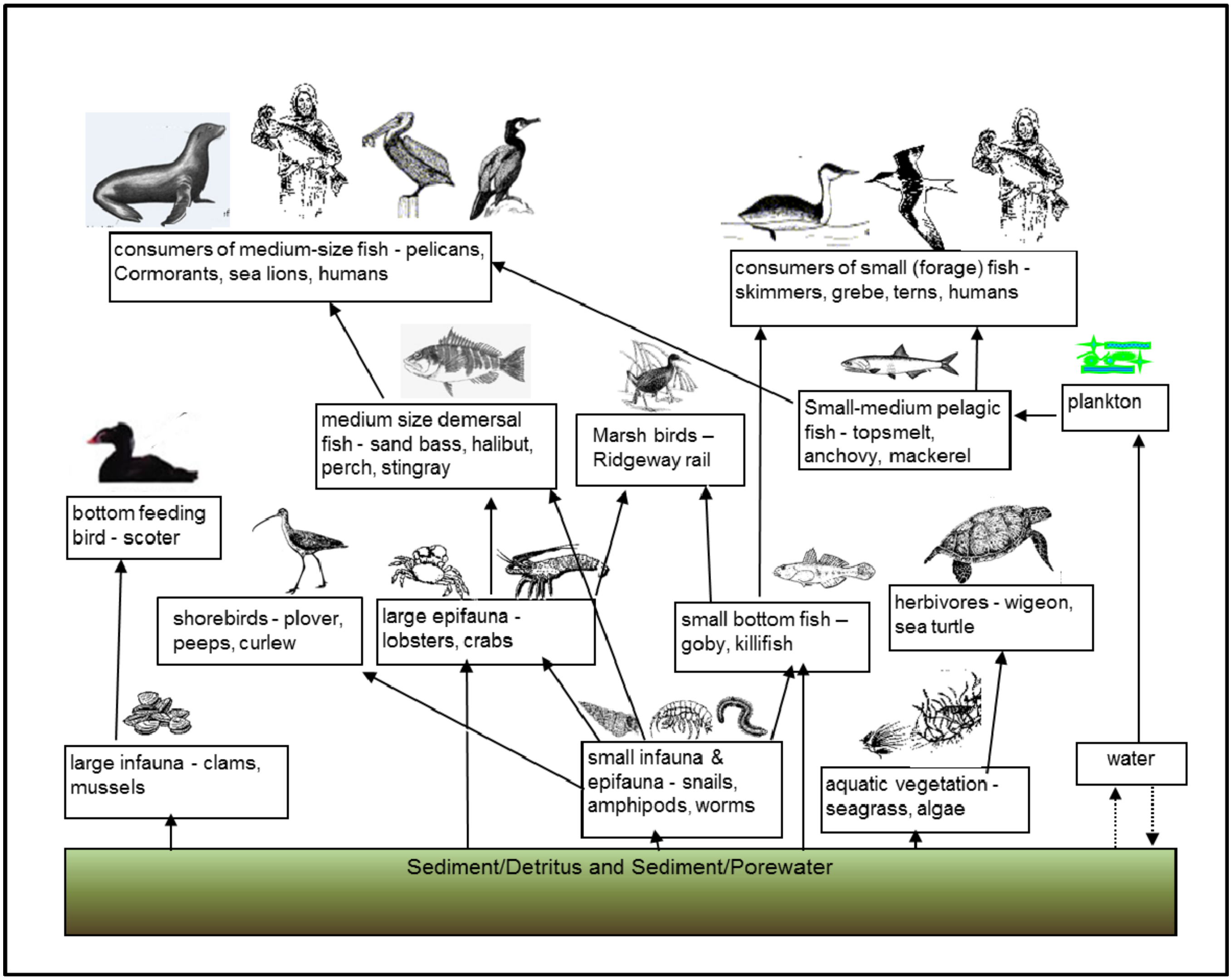

Figure 1-1. Conceptual Food Web Model for San Diego Bay

Courtesy of Southern California Coastal Water Research Project (SCCWRP)
(*San Diego Bay Bioaccumulation Report – Food Web Bioaccumulation Study*; *Bay et al., 2016 Draft Report*)

Tissue samples for Bight ’13 were collected in several embayments from Newport Harbor to San Diego Bay, where the relationships between elevated chemical concentrations in the sediments and associated biota are expected to be more prevalent compared with those of deeper offshore locations. The Bight program assessed multiple strata within San Diego Bay, including the shallow water stratum, which is defined by the Regional Harbor Monitoring Program (RHMP)[1] as waters less than 12 feet (3.66 meters) deep mean lower low water (MLLW). Bight ’13 included all waters in San Diego Bay in the survey sampling design, but, because of sampling equipment limitations, very few stations were located in waters less than

[1] The RHMP is a regional monitoring program conducted by the Port of San Diego (Port), City of San Diego (City), City of Oceanside, and County of Orange, and conducts sampling in Dana Point Harbor, Oceanside Harbor, Mission Bay, and San Diego Bay. Sampling that took place during the RHMP was inclusive of Bight ’13 sampling requirements for these four agencies.

3 meters deep MLLW. Although the 3.66-meter depth stratum was sampled during the RHMP, only three of those locations occurred in waters less than 3 meters deep, none of which were sampled for bioaccumulation. This shallow water habitat stratum is of particular interest because these regions provide a productive nursery and foraging habitat for numerous fish species and foraging grounds for birds. The shallow depths and close connections among numerous wildlife trophic levels enhance the likelihood that COPCs in these sediments might be more available to bioaccumulate through the food web. Bioaccumulation and sediment chemistry data for the shallow water stratum were an existing data gap despite Bight ’13 efforts, and precipitated the interest in a focused Shallow Water Habitat Bioaccumulation (SWHB) Study in San Diego Bay.

Another element not accounted for during Bight ’13 sampling is how zooplankton may contribute to the observed contaminant concentrations throughout the food web via trophic exchange. Zooplankton are a key part of the food web and an important potential trophic pathway for COPCs, because they are consumed by planktivorous fish, which ultimately may be consumed by birds. Very little data providing information on COPC concentrations in zooplankton has been collected, highlighting the importance of filling this data gap to better understand the function of COPCs in the food web. The aim of the zooplankton portion of the study was to better understand the role of plankton with regard to contaminant bioaccumulation through the food web, and relationships to concentrations measured in the associated water column and sediments. Collectively, both Bight ’13 and SWHB efforts have helped gather information on the ecological risk of contaminant concentrations and bioaccumulation factors among key elements of the food web. A complementary detailed evaluation of contamination in bird eggs also contributed to the ecological risk assessment. Human health risk from sport fish consumption was also evaluated by targeting legal-sized sport fish commonly caught and consumed by anglers in San Diego Bay. Sport fish tissue samples were collected by volunteer fisherman who participated in a “Fishing for Science” Derby, as well as targeted fishing efforts by staff from the Southern California Coastal Water Research Project (SCCWRP) and Amec Foster Wheeler Environment & Infrastructure Inc. (Amec Foster Wheeler).

The initial concept for studying the trophic transfer of bioaccumulative compounds was developed for Bight ’13 by a collaborative group comprising the City of San Diego (City), Port of San Diego (Port), Southern California Coastal Water Research Project (SCCWRP), San Diego State University (SDSU), United States Fish and Wildlife Service (USFWS), San Diego Regional Water Quality Control Board (SDRWQCB), Amec Foster Wheeler, and Tetra Tech (the Project Collaboration Group). The SWHB study was made possible by the same Project Collaboration Group and also supports the SDRWQCB’s Healthy Waters, Healthy People Practical Vision (SDRWQCB, 2013) by providing monitoring and assessment of key components of the food web. Monitoring and assessment were identified as key elements in carrying out this vision.

The SWHB study was designed to address the following specific questions:

1. What is the magnitude of bioaccumulation of COPCs in zooplankton, invertebrate, and fish trophic levels in the shallow water habitats of San Diego Bay?
2. What is the spatial distribution of COPCs in sediments, invertebrates, zooplankton, and fish tissues throughout shallow water habitats in San Diego Bay?

3. What is the relationship between bioaccumulative COPCs in shallow water sediments, and those observed in the local food web? Do sediments appear to contribute to observed tissue concentrations?
4. What is the spatial distribution of mercury in the water column?
5. What is the relationship among mercury in the water column, bioaccumulative COPCs in shallow water sediments, and COPCs in zooplankton?

The data collected for the SWHB study may also provide a valuable resource to support and/or calibrate models that have been developed recently to estimate the bioaccumulative risk to humans from wildlife exposure to sediments (notably in California) using the bioaccumulation Decision Support Tool (DST). The DST has been developed to support the California Sediment Quality Objective (SQO) (State Water Resources Control Board [SWRCB], 2009) process to predict potential indirect risks to humans from contaminated sediments. Zooplankton comprise a trophic level of importance in the current DST and results from this study may be used to help refine this key component of the food web model in the DST.

In addition, the data from the SWHB study will supplement sediment chemistry, benthic community, and toxicity data generated during Bight ’13 to enhance spatial variability and trend assessments.

This report provides a supplement to a separate report being prepared by SCCWRP and USFWS entitled “*Assessment of Bioaccumulation in San Diego Bay*” (Bay et al., 2016). The draft report by Bay et al. published in March 2016 (final due in July 2016) addressed four primary study objectives:

1. **Describe bioaccumulation among key components of the San Diego Bay food web.** Two major contaminant exposure pathways were evaluated in the study: bioaccumulation related to feeding on sediment-dwelling organisms (benthic pathway) and bioaccumulation related to uptake of contaminants in water column-dwelling organisms (pelagic pathway).
2. **Evaluate risk to wildlife from contaminant exposure.** Contaminant concentrations in the eggs of four species of birds were examined: California least tern, Caspian tern, double-crested cormorant, and western gull.
3. **Assess potential risk to human health resulting from consumption of fish from San Diego Bay.** Tissue contamination data for several popular sport fish, including spotted sand bass, California halibut, and pacific chub mackerel, were compared with consumption advisory levels and were also evaluated using a draft framework for assessing sediment quality relative to the SWRCB’s sediment quality objectives.
4. **Evaluate bioaccumulation model performance.** Comparisons were conducted between measured tissue contaminant concentrations and estimated concentrations obtained using the bioaccumulation model proposed to assess attainment of the SWRCB’s sediment quality objective for human health.

The objective of this report is to provide an enhanced assessment of results related to Objective 1 related to bioaccumulation among key components in the food web of San Diego Bay for which the City of San Diego provided substantial additional support. A number of outstanding questions and associated key analytical data gaps were determined after a thorough review of the reports by SCCWRP and subsequent consultation. This report addresses a number of these "wish list" items, specifically including the following:

- Additional details and photographs highlighting sampling and testing methodologies.
- A spatial assessment of bioaccumulation patterns by site, to supplement the assessment of larger areas of San Diego Bay (north, central, and south) as reported by Bay et al. (2016). Sediment and tissue concentrations of key COPCs are illustrated graphically and with maps integrated with a geographic information system (GIS).
- Comparative analysis of bioaccumulation results for PCBs following normalization for tissue lipid content.
- Evaluation of statistical relationships between sediment and tissue COPCs.
- A summary of all sediment chemical analyses and physical properties for both the RHMP and SWHB studies.
- A summary of water quality data collected during the SWHB study.
- A cursory analysis of risk to aquatic ecological receptors from bioaccumulative contaminants of concern.
- A Quality Assurance and Quality Control (QA/QC) evaluation of data collected during the SWHB study, including a third party review of analytical data performed by Laboratory Data Consultants (LDC).
- Supporting data in appendices, including complete chemistry summary tables, raw datasheets with field observations, photo logs of all species retained for analysis, raw laboratory reports, and chain-of-custody (COC) forms.

The tissue and sediment data evaluated in this report include that collected within San Diego Bay during both Bight '13/ RHMP in 2013 and the follow-on SWHB study in 2014. Supporting information in the Appendices includes all information collected during the SWHB study and some, but not all of the supporting information specific to RHMP (e.g. water quality data and profiles, and RHMP-specific logs, COCs, and QA/QC third party evaluation). Please see the full RHMP report posted on the Port of San Diego website for additional details specific to this program: https://www.portofsandiego.org/document/environment/regional-harbor-monitoring-program/rhmp-2013.html

Evaluations of data collected for an assessment of sport fish for a human health risk assessment and bird egg concentrations as a part of the wildlife assessment are not included in this report but will be included in a final report by Bay et al. (in progress, due July 2016).

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2.0 MATERIALS AND METHODS

2.1 Project Location and Sample Design

Sediment, water, and tissue samples were collected from three coordinated studies conducted in 2013 through 2015, as discussed in Section 1.0. These sampling events include Bight ’13 sampling in coordination with the RHMP 2013 monitoring (and the bird egg collection from five San Diego Bay locations as part of Bight ’13), the SWHB sampling in 2014, and the sport fish collection efforts by SCCWRP and the Fishing for Science Derby. With the exception of the locations of the sport fish and bird egg collection efforts, all locations were selected on the basis of a stratified random design, where Bight ’13 and RHMP stations were located in port and industrial areas, estuaries, marinas, and other areas in San Diego Bay at depths of 3 meters or greater, and SWHB stations were located only in waters with depths of less than or equal to 3 meters, most of which are in the south bay ecoregion and within or near eelgrass beds. Sport fish tissue samples were collected from a variety of locations in all three ecoregions of San Diego Bay during both 2014 and 2015 concerted efforts. Bird eggs were collected during the 2013 nesting season during routine surveys by colony monitors with appropriate permits.

A total of 89 stations were sampled for sediments among the studies in 2013 and 2014, including 59 stations as part of Bight ’13/RHMP sampling and 30 stations as part of the SWHB survey (see Table 2-1 and Figures 2-1 and 2-2). A subset of 10 of these stations were selected for collection of benthic fish and invertebrate tissues during Bight ’13/RHMP in August and September 2013, and 9 stations were selected for tissue collection (benthic fish, invertebrates, and plankton) during the SWHB study in April and May of 2014 (see Table 2-1 and Figure 2-3). A separate effort conducted by Marine Biological Consultants (MBC) during Bight ’13 targeted fish species and plankton in shallow habitats near the edge of San Diego Bay using purse and beach seines at an additional 9 near-shore locations, as shown in Figure 2-3. These samples were collected by MBC in October 2013. Subsamples of surface water were collected for analysis of a suite of chemical and physical parameters at all 59 Bight ’13 sediment sampling stations, and at the 9 SWHB stations selected for tissue collection.

For both Bight ’13/RHMP and the SWHB study, locations of tissue sampling stations were selected to provide at least three stations in each of three main regions of San Diego Bay: north, central, and south. Locations for the supplemental beach and purse seine efforts in 2013 also included 3 locations in each region of the bay with a single location in the north portion of the bay, six locations in the central portion of the bay, and one location in the south portion of the bay.

A total of 209 tissue samples were analyzed for both ecological and human health risk assessments. A total of 185 tissue samples, representing major components of both the benthic and pelagic food webs (bird eggs, fish tissue, invertebrate tissue, and plankton tissue) in San Diego Bay, were collected and analyzed for contaminants as part of the ecological risk assessment (see Tables 2-1 and 2-2). Results for 142 of these samples representing the fish, invertebrates, and plankton are reported herein.

Collection success of bird eggs and sportfish are summarized in this report for context, but methods and results for these two trophic levels are presented under separate cover (Zeeman, 2016 and Bay et al., 2016 draft reports). A final report that encompasses all studies is in preparation by Bay et al. and is anticipated to be completed in July 2016. A total of 44 bird eggs were collected at five locations around San Diego Bay representing four marine-dependent species. California least tern eggs were collected from four of the five locations, while eggs from western gulls, Caspian terns, and double crested cormorants were obtained from single locations. A total of 137 sport fish were collected from several locations in San Diego Bay in 2014 and 2015 with a subset of 24 representing five species submitted for chemical analysis as part of the human health risk assessment portion of this study.

A total of 87 forage fish tissue samples (collected by trawl or seine), representing 13 species, were analyzed as part of the ecological risk assessment portion of this study reported herein (see Table 2-2). Fish species included small surface feeders (e.g., anchovy and topsmelt) and medium-sized fish with a diet that included benthic organisms (e.g., black perch, round stingray, barred sand bass, spotted sand bass, and California halibut). Gobies and killifish were also retained for analysis at a few locations when captured. A total of 42 samples of benthic invertebrates (crustacea, mollusks, and polychaetes) and 13 samples of plankton were also collected throughout San Diego Bay during Bight ’13/RHMP and the SWHB study (see Table 2-2). Results of the ecological risk assessment (excluding bird egg collections) are reported in this report.

This report also includes results for sediment chemistry at all 89 locations sampled for sediments during both the Bight ’13/RHMP and SWHB studies (physical parameters and bioaccumulative constituents of concern), as well as water chemistry and physical parameters measured at the nine trawl locations during the SWHB study. Specific chemistry analytes measured during the SWHB study are provided in Section 2.2. A complete summary of sediment and water chemistry and physical parameters, as well as toxicity and benthic community analyses performed during the Bight ’13/RHMP effort, are provided separately in the final 2013 RHMP Report by Amec Foster Wheeler (Stransky et al., 2016).

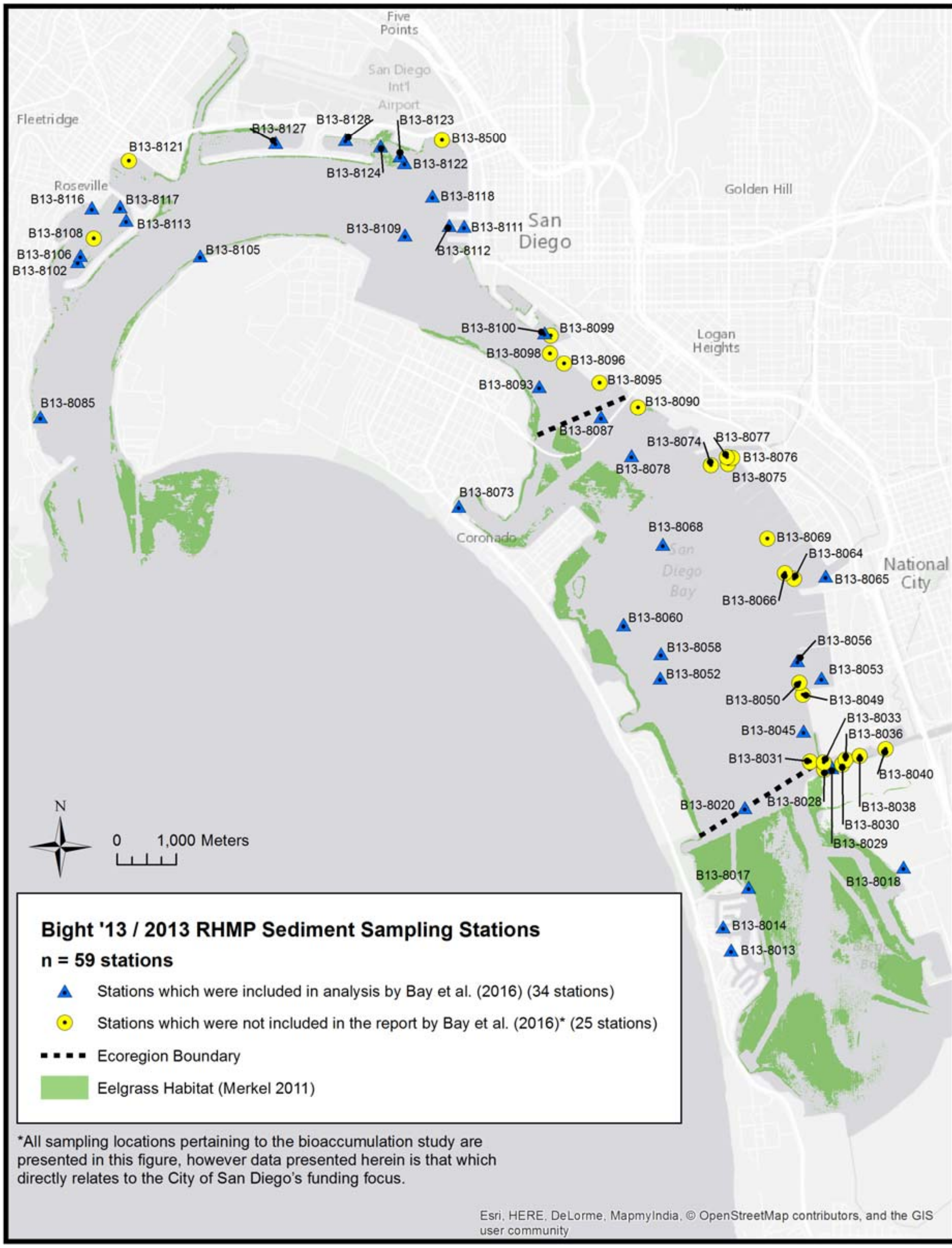

Figure 2-1. Sediment Sampling Stations for Bight'13/San Diego Bay Regional Harbor Monitoring Program

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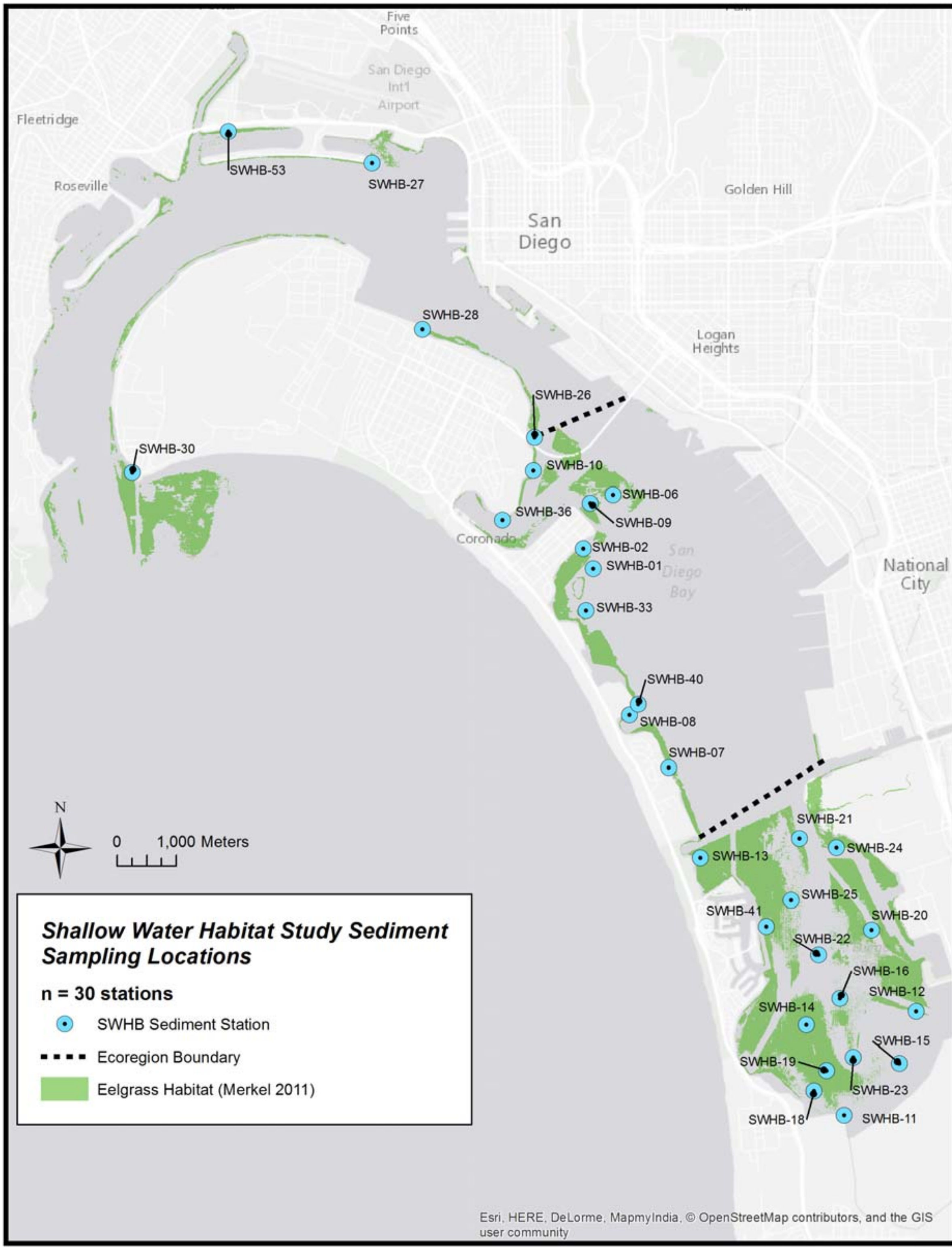

Figure 2-2. Sediment Sampling Stations for the Follow-up San Diego Bay Shallow Water Habitat Bioaccumulation Study in 2014

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Figure 2-3. Tissue Sampling Stations for Bight'13 and San Diego Regional Harbor Monitoring Programs in 2013 and the San Diego Bay Shallow Water Habitat Bioaccumulation Survey in 2014

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Figure 2-4. Fish Trawl Locations for Bight'13/San Diego Regional Harbor Monitoring Program in 2013 and the San Diego Bay Shallow Water Habitat Bioaccumulation Survey in 2014

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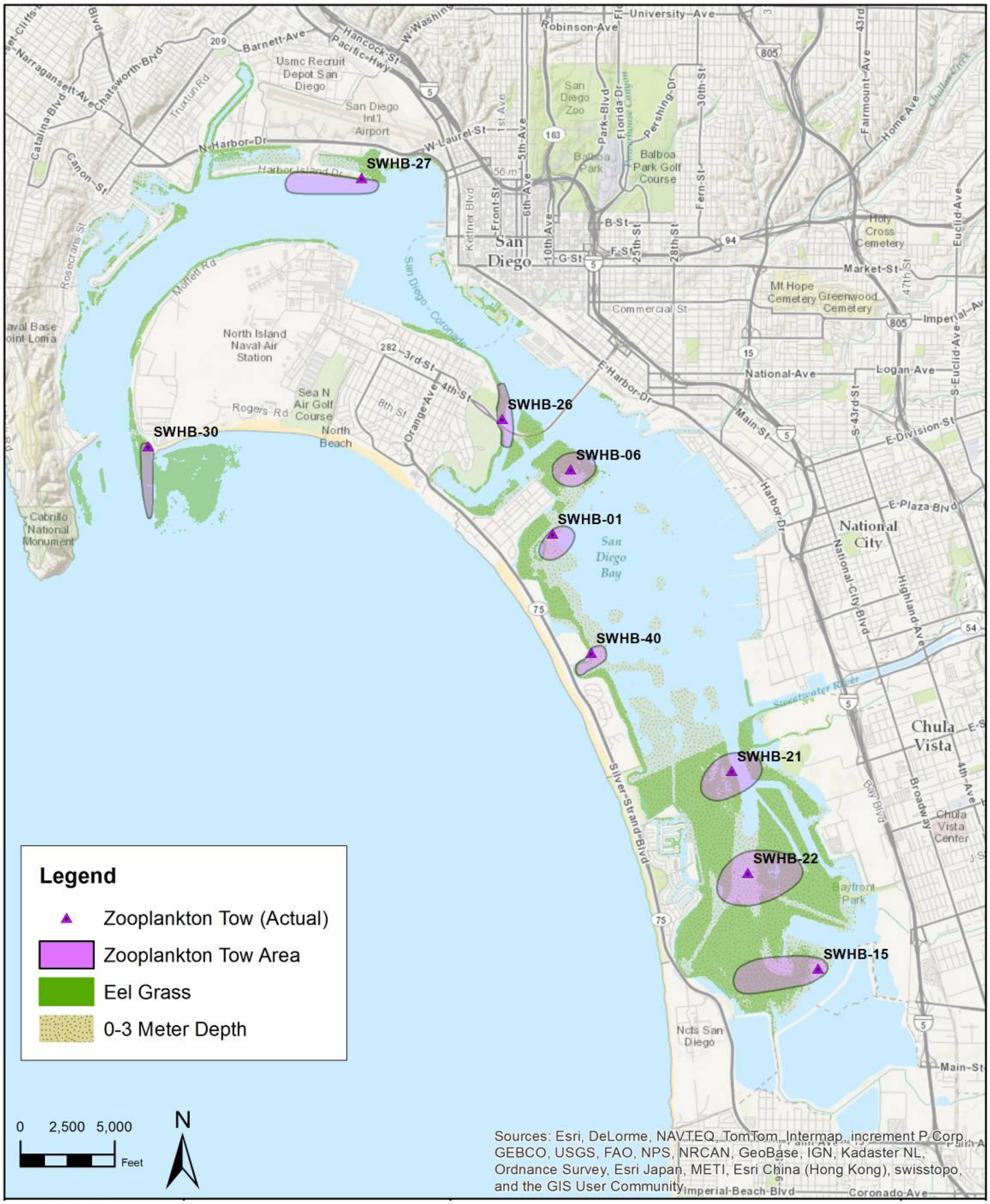

Figure 2-5. Plankton Sampling Stations for the San Diego Bay Shallow Water Habitat Bioaccumulation Survey in 2014

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Table 2-1.
Bight '13/ RHMP and SWHB Sampling Stations and Sample Types

Location	Study Identification [a,b]	Station	Latitude	Longitude	Sample Type	Results Included in This Report? (Y/N)[a]
North Bay	Bight'13/RHMP	B13-8085	32.691687	-117.238244	S,W	N
		B13-8102	32.711543	-117.232552	S,W	N
		B13-8105	32.712275	-117.213967	S,W	N
		B13-8106	32.712329	-117.232133	S,W	N
		B13-8108	32.714498	-117.230108	S,W	N
		B13-8109	32.714963	-117.182907	S,W,F,I	Y
		B13-8111	32.716092	-117.173953	S,W	N
		B13-8112	32.716190	-117.176237	S,W	N
		B13-8113	32.716887	-117.225212	S,W	N
		B13-8116	32.718402	-117.230400	S,W	N
		B13-8117	32.718569	-117.226112	S,W	N
		B13-8118	32.719885	-117.178736	S,W,F,I	Y
		B13-8121	32.724357	-117.224815	S,W	N
		B13-8122	32.724148	-117.182983	S,W,F,I	Y
		B13-8123	32.725018	-117.183684	S,W	N
		B13-8124	32.726301	-117.186644	S,W	N
		B13-8127	32.726737	-117.202524	S,W	N
		B13-8128	32.727123	-117.191922	S,W	N
		B13-8500	32.727047	-117.177330	S,W	N
	Bight'13	Lindbergh[c]	32.729188	-117.180397	B	N
		NAS[d]	32.711463	-117.211759	B	N
		SDN1	32.725850	-117.180700	F	Y
		SDN2	32.727283	-117.187933	F	Y
		SDN3	32.715050	-117.223850	F,P	Y
	SWHB	SWHB-26	32.689110	-117.163240	S,F,I,P,W	Y
		SWHB-27	32.724110	-117.187910	S,F,I,P,W	Y
		SWHB-28	32.702890	-117.180270	S	Y
		SWHB-30	32.684640	-117.224300	S,F,I,P,W	Y
		SWHB-53	32.728180	-117.209720	S	Y
Central Bay	Bight'13/RHMP	B13-8045	32.651550	-117.122464	S,W	N
		B13-8049	32.656156	-117.122617	S,W	N
		B13-8050	32.657727	-117.123113	S,W	N
		B13-8052	32.658280	-117.144340	S,W,F,I	Y
		B13-8053	32.658476	-117.119532	S,W,F	Y
		B13-8056	32.660613	-117.123390	S,W,F	Y
		B13-8058	32.661471	-117.144097	S,W	N
		B13-8060	32.665184	-117.149804	S,W,F,I	Y
		B13-8064	32.670959	-117.123959	S,W	N

Table 2-1.
Bight ’13/ RHMP and SWHB Sampling Stations and Sample Types (Cont.)

Location	Study Identification	Station	Latitude	Longitude	Sample Type	Results Included in This Report? (Y/N)[a]
Central Bay	Bight’13/RHMP	B13-8065	32.671353	-117.119134	S,W	N
		B13-8066	32.671711	-117.125316	S,W	N
		B13-8068	32.675472	-117.143841	S,W	N
		B13-8069	32.676137	-117.127961	S,W	N
		B13-8073	32.680331	-117.174759	S,W	N
		B13-8074	32.685488	-117.136521	S,W	N
		B13-8075	32.685610	-117.133926	S,W	N
		B13-8076	32.686389	-117.133315	S,W	N
		B13-8077	32.686515	-117.134088	S,W	N
		B13-8078	32.686723	-117.148594	S,W,F,I	Y
		B13-8087	32.691721	-117.153217	S,W	N
		B13-8090	32.692885	-117.147582	S,W	N
		B13-8093	32.695601	-117.162557	S,W	N
		B13-8095	32.696061	-117.153454	S,W	N
		B13-8096	32.698521	-117.158791	S,W	N
		B13-8098	32.699765	-117.160977	S,W	N
		B13-8099	32.702034	-117.160821	S,W	N
		B13-8100	32.702400	-117.161780	S,W	N
	Bight’13	SDC1	32.669300	-117.156967	F,P	Y
		SDC2	32.658950	-117.152733	F	Y
		SDC3	32.663667	-117.156267	F	Y
	SWHB	SWHB-01	32.672400	-117.154360	S,F,I,P,W	Y
		SWHB-02	32.674940	-117.155880	S	Y
		SWHB-06	32.681850	-117.151350	S,F,I,P,W	Y
		SWHB-07	32.647020	-117.142890	S	Y
		SWHB-08	32.653750	-117.148860	S	Y
		SWHB-09	32.680770	-117.154840	S	Y
		SWHB-10	32.684870	-117.163410	S	Y
		SWHB-33	32.667040	-117.155450	S	Y
		SWHB-36	32.678630	-117.168110	S	Y
		SWHB-40	32.655080	-117.147550	S,F,I,P,W	Y
South Bay	Bight ’13/RHMP	B13-8013	32.623601	-117.133460	S,W	N
		B13-8014	32.626539	-117.134678	S,W	N
		B13-8017	32.631569	-117.130840	S,W,F,I	Y
		B13-8018	32.634170	-117.107330	S,W	N
		B13-8020	32.641792	-117.131413	S,W,F,I	Y
		B13-8028	32.646603	-117.119345	S,W	N
		B13-8029	32.646936	-117.118238	S,W,F,I	Y
South Bay	Bight’13/RHMP	B13-8030	32.647272	-117.116671	S,W	N
		B13-8031	32.647579	-117.121483	S,W	N

Table 2-1.
Bight '13/ RHMP and SWHB Sampling Stations and Sample Types (Cont.)

Location	Study Identification	Station	Latitude	Longitude	Sample Type	Results Included in This Report? (Y/N)[a]
		B13-8033	32.647521	-117.119449	S,W	N
		B13-8036	32.647856	-117.116137	S,W	N
		B13-8038	32.648344	-117.114007	S,W	N
		B13-8040	32.649219	-117.110064	S,W	N
	Bight'13	CVWR[e]	32.614030	-117.110860	B	N
		D Street Fill	32.646190	-117.114550	B	N
		Salt Works	32.599240	-117.102809	B	N
		SDS1	32.646270	-117.116517	F,P	Y
		SDS2	32.607550	-117.130533	F	Y
		SDS3	32.632980	-117.138880	F	Y
	SWHB	SWHB-11	32.602590	-117.116290	S	Y
		SWHB-12	32.615830	-117.105350	S	Y
		SWHB-13	32.635470	-117.138090	S	Y
		SWHB-14	32.614160	-117.122040	S	Y
		SWHB-15	32.609230	-117.107910	S,F,I,P,W	Y
		SWHB-16	32.617500	-117.116930	S	Y
		SWHB-18	32.605730	-117.120890	S	Y
		SWHB-19	32.608280	-117.118980	S	Y
		SWHB-20	32.626290	-117.112120	S	Y
		SWHB-21	32.637980	-117.123070	S,F,I,P,W	Y
		SWHB-22	32.623100	-117.120180	S,F,I,P,W	Y
		SWHB-23	32.610000	-117.114910	S	Y
		SWHB-24	32.636810	-117.117440	S	Y
		SWHB-25	32.630070	-117.124370	S	Y
		SWHB-41	32.626690	-117.128090	S	Y

Notes:
Sample types: S = sediment, F = fish, I = benthic invertebrate, P = plankton, B = bird egg, W = water sample
dd.ddddd° = decimal degrees latitude; ddd.ddddd° = decimal degrees longitude
a. Sampling stations for all sites pertaining to the collective bioaccumulation studies are listed in this table. All data from the SWHB study and select data from the RHMP associated with tissue sampling stations are presented in this report.
b. Bight '13/RHMP = Samples collected as part of the San Diego Regional Harbor Monitoring Program conducted by Amec Foster Wheeler in 2013; Bight '13 = samples collected for SCCWRP as a part of Bight '13 by MBC; SWHB = Samples collected as part of the Shallow Water Habitat Bioaccumulation study.
c. Lindbergh Field (San Diego International Airport)
d. Naval Air Station (NAS)
e. Chula Vista Wildlife Refuge (CVWR)

Table 2-2.
Number and Type of Tissue Samples Analyzed for all San Diego Bay Bioaccumulation Studies (2013–2014)

Sample Group	Common Name	Bight ’13/ RHMP by Amec Foster Wheeler	SWHB by Amec Foster Wheeler	Bight ’13 Sampling by MBC	Duplicate Samples	Total Tissues Analyzed
Bird eggs	California least tern	NA	NA	NA	NA	18
	Caspian tern					10
	Double-crested cormorant					8
	Western gull					8
Bird Egg Total						**44**
Sport fish [a]	California halibut [b]	NA	NA	NA	NA	8
	Pacific chub mackerel					3
	Round stingray [b]					1
	Spotted sand bass [b]					10
	Topsmelt [b]					1
Sport Fish Total						**23**
Forage fish [a]	Arrow goby	0	0	1	0	1
	Barred sand bass	8	0	0	1	9
	Black perch	0	2	0	0	2
	California halibut [b]	8	11	0	1	20
	California killifish	0	0	2	0	2
	Deepbody anchovy	11	0	0	0	11
	Goby sp.	0	3	0	0	3
	Northern anchovy	0	0	2	0	2
	Round stingray [b]	1	0	0	0	1
	Shiner perch	0	6	0	0	6
	Slough anchovy	7	1	2	0	10
	Spotted sand bass [b]	2	9	0	0	11
	Topsmelt [b]	0	0	9	0	9
Forage Fish Total						**87**
Crustacea	Crustacea	7	6	0	0	13
Mollusks	Mollusks	2	9	0	0	11
Polychaetes	Polychaetes	9	9	0	0	18
Benthic Infauna Total						**42**
Plankton	Plankton	0	9	4	0	13
Tissue Grand Total						209
Tissue Grand Total Reported Herein (Forage Fish + Benthic Infauna + Plankton)						**142**

Notes:
NA = Not applicable to that specific sampling effort
a. Data from the tissue samples for both birds and sport fish are reported under separate cover (Bay et al., 2016)
b. Some fish species are included in both the sport fish and forage fish categories depending on how and when they were captured. All sport fish were captured by hook and line while forage fish were captured using trawls or seines. Two of these species (California halibut and spotted sand bass) were generally much smaller in the forage fish category relative to those captured as sport fish.

2.2 Sample Collection and Analysis

Sediment, water, and tissue collection methods specific to RHMP and the SWHB study followed methodologies outlined in project-specific Work Plans prepared for each (Amec Foster Wheeler, 2013a; Amec Foster Wheeler 2014a and 2014b). All field sampling methods for sediment chemistry sample collection were also consistent with Bight ’13 guidelines as outlined in the Bight ’13 Contaminant Impact Assessment Field Operations Manual (SCCWRP, 2013a) and Bight ’13 Quality Assurance Manual (SCCWRP, 2013b). Tissue sample processing procedures were consistent with methodology outlined in the Bioaccumulation Workplan prepared for the Bight ’13 Regional Marine Monitoring Survey (SCCWRP, 2013c). Representative photos of a variety of field collection efforts are provided in Figure 2-6.

Figure 2-6. Select Field Collection Photographs

Notes: Clockwise from top left: Sediment collection using the TVV; a benthic infauna mollusk sample processed for tissue analysis; the sieving process for sorting benthic infauna samples; sorted target fish species for tissue analysis; water sample collection during plankton tows; plankton sample processing; plankton net retrieval; otter trawling for fish tissues during SWHB sampling.

2.2.1 Water Sampling and Analysis

Water samples for analysis of physical properties and chemical analyses were collected during both RHMP and the SWHB study. Only those data collected during the SWHB study are presented in this report. Water quality data collected during Bight’13/RHMP are presented in the final report for the RHMP (Stransky et al., 2016).

Field surface measurements for pH, dissolved oxygen (DO), salinity, and temperature were recorded at 1-meter depth using a YSI ProPlus series field meter at each tissue sampling station for the SWHB study. Measurements were taken at the same depth at which water samples were collected. A Niskin bottle was used to collect water samples for chemical analysis at depths consistent with the plankton tows (approximately 1 meter below the surface). Constituents analyzed in 2014 as part of the Shallow Water Habitat Bioaccumulation Study are listed in Table 2-3.

Table 2-3.
Chemical Analyses of Water Samples Collected During the Shallow Water Habitat Bioaccumulation Study in 2014

Analyte	Analysis Method	Reporting Limits [a]	Units
Total Mercury	245.7[b]	0.02	µg/L
Dissolved Mercury	245.7[b]	0.02	µg/L
Total Organic Carbon (TOC)	SM 5310 B[b]	1.0	mg/L
Dissolved Organic Carbon (DOC)	SM 5310 B[b]	1.0	mg/L
Total Suspended Solids (TSS)	2540 D [b]	0.5	mg/L

Notes:
µg/L = micrograms per liter (parts per billion); mg/L = milligram per liter (parts per million); SM = Standard Method
a. Reporting limits were provided by Physis Environmental Laboratories.
b. United States Environmental Protection Agency (USEPA) 1986–1996. SW-846. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, 3rd Edition.

2.2.2 Sediment Sampling and Analysis

Detailed descriptions of collection procedures for sediments, criteria for acceptable samples, and conditions under which samples required re-collection are provided in the Work Plans referenced above. Sediment grab sampling for chemistry and benthic infauna tissue was conducted at all sampling stations before changing sampling equipment to begin trawl sampling. Plankton tows and water grab sampling were performed on separate days during the SWHB study.

A differential global positioning system (DGPS) was used to navigate to the target sampling stations listed in Table 2-1. The target navigational accuracy was ±3 meters. All sediment samples were collected within 100 meters of the target site. Once positioned on location, sediment samples were collected using a 0.1-square-meter (m^2) Tandem Van Veen (TVV) grab sampler. The grab was lowered at 1 meter per second (m/sec) and sample acceptability was determined on the basis of sample condition and depth of penetration of the grab. An acceptable grab for sediment chemistry was characterized by an even surface with minimal disturbance and little or no leakage of overlying water, and a penetration depth of at least 5 centimeters (cm).

Samples were collected from the top 5 cm of sediment using a stainless steel scoop that was decontaminated between collections. Sediment in contact with or within 1 cm of the metal sides of the grab was avoided to prevent sample contamination. Multiple portions of each grab were serially added to each sample. Physical parameters and chemical analytes measured in sediments are provided in Table 2-4.

Table 2-4.
Chemical Analyses of Sediment Samples Collected During Bight'13/RHMP in 2013 and the SWHB Study in 2014

Analyte	Analysis Method	Sediment Target Reporting Limits [a,b]	Units
Total Solids	160.3/SM 2540B [c]	0.1	%
Total Organic Carbon (TOC)	USEPA 9060	0.01	%
Grain Size	SM 2560D	0.1	%
Aluminum (Al)	USEPA 6020/6010B [d]	5	µg/g
Antimony (Sb)	6020/6010B [d]	0.05	µg/g
Arsenic (As)	6020/6010B [d]	0.05	µg/g
Barium (Ba)	6020/6010B [d]	0.05	µg/g
Beryllium (Be)	6020/6010B [d]	0.05	µg/g
Cadmium (Cd)	6020/6010B [d]	0.005	µg/g
Chromium (Cr)	6020/6010B [d]	0.005	µg/g
Copper (Cu)	6020/6010B [d]	0.005	µg/g
Iron (Fe)	6020/6010B [d]	5	µg/g
Lead (Pb)	6020/6010B [d]	0.005	µg/g
Mercury (Hg)	USEPA 245.7 [d]	0.02	ng/g
Nickel (Ni)	6020/6010B [d]	0.2	ng/g
Selenium (Se)	6020/6010B [d]	0.005	µg/g
Silver(Ag)	6020/6010B [d]	0.02	µg/g
Zinc (Zn)	6020/6010B [d]	0.5	µg/g
Total Phosphorus	USEPA 6020 [d]	0.05	µg/g
Total Nitrogen	USEPA 9060	0.02	µg/g
Ammonia	SM 4500-NH_3 D	0.03	µg/g
Polycyclic Aromatic Hydrocarbons (PAHs) [e]	8270D [d]	5	ng/g
Chlorinated Pesticides [f]	8270D/8270D-NCI [d]	0.05	ng/g
Total Pyrethroids [g]	USEPA 8270C-NCI [d]	0.25	ng/g
Polychlorinated Biphenyl (PCB) Congeners [h]	8270D [d]	0.1	ng/g
Polybrominated Diphenyl Ethers (PBDEs) [i]	8270D-NCI [d]	0.05	ng/g

Notes:
µg/g = micrograms per gram (part per million); mg/kg = milligrams per kilogram (part per million); ng/g = nanograms per gram (part per billion); SM = Standard Method; SOP = Standard Operating Procedure

a. Sediment minimum detection limits are on a dry-weight basis.
b. Reporting limits were provided by Physis Environmental Laboratories.
c. Standard Methods for the Examination of Water and Wastewater, 22nd Edition, Rice et al., 2013.
d. USEPA 1986–1996. SW-846. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, 3rd Edition.
e. Includes Acenaphthene, Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo[b]fluoranthene, Benzo[e]pyrene, Benzo[g,h,i]perylene, Benzo[k]fluoranthene, Biphenyl, Chrysene, Dibenz[a,h]anthracene, Di benzothiophene, Fluoranthene, Fluorene, Indeno(1,2,3-c,d)pyrene, Naphthalene, Perylene, Phenanthrene, Pyrene, 2,6-Dimethylnaphthalene, 1-Methylnapthalene, 2-Methylnapthalene, 1-Methylphenanthrene, and 2,3,5-Trimethylnaphthalene.
f. Includes 2,4'-DDD, 2,4'-DDE, 2-4'-DDT, 4,4'-DDD, 4,4'-DDE, 4,4'-DDMU, 4,4'-DDT, aldrin, BHC-alpha, BHC-beta, BHC-delta, BHC-gamma, Cholordane-alpha, Chlordane-gamme, cis-nonachlor, dieldrin, heptachlor, heptachlor epoxide, hexachlorobenzene, methoxychlor, mirex, oxychlordane, trans-nonachlor, toxaphene
g. Includes allethrin, bifenthrin, cyfluthrin, total lamda cyhalothrin, cypermethrin, danitol (fenpropathrin), deltamethrin/tralomethrin, esfenvalerate, fenvalerate, fluvalinate, cis-permethrin, trans-permethrin, prallethrin
h. Includes congeners: PCB-3, 5, 8, 15, 18, 27–29, 31, 33, 37, 44, 49, 52, 56(60), 66, 70, 74, 77, 81, 87, 95, 97, 99, 101, 105, 110, 114, 118, 119, 123, 126, 128, 137, 138, 141, 149, 151, 153, 156–158, 167–170, 174, 177, 180, 183, 187, 189, 194,195, 199(200), 201, 203, 206, and 209.
i. Includes BDE-17, 28, 47, 49, 66, 71, 85, 99, 100, 138, 153, 154, 183, 190, and 209.

2.2.3 Analysis of Tissue Samples

Chemical analyses of the samples were conducted by the Institute for Integrated Research in Materials, Environments, and Society (IRMES) in Long Beach, California (CA) (sediment total organic carbon [TOC], grain size, and total nitrogen [N]), Associated Labs of Orange, CA (TOC and dissolved organic carbon [DOC] in waters), and Physis Laboratories in Anaheim, CA (all other water, sediment, and tissue analyses).

A list of analytes measured in tissues for infauna and fish is provided in Table 2-5. In some cases where tissue volume was insufficient, analysis of PCBs, organochlorine pesticides (chlordanes and DDTs), and PBDEs was prioritized; thus, not all analytes and physical parameters were measured in all samples.

Table 2-5.
Chemical Analyses of Tissue Samples During Bight'13/RHMP in 2013 and the SWHB Study in 2014

Analyte	Analysis Method	Tissue Target Reporting Limit [a]	Units
Percent Solids	SM 2540B	0.1	%
Percent Lipids	Gravimetric	0.05	%
Selenium [b]	USEPA 6020 [c]	0.05	µg/g
Mercury [b]	USEPA 245.7 [c]	0.02	µg/g
Polycyclic Aromatic Hydrocarbons (PAHs) [d]	USEPA 8270D	5	ng/g
Chlorinated Pesticides [e]	USEPA 8270D [c]	0.05	ng/g
Polychlorinated Biphenyl (PCB) Congeners [f]	USEPA 8270D[c]	0.1	ng/g
Polybrominated Diphenyl Ethers (PBDEs) [g]	USEPA 8270D- NCI	0.05	ng/g

Notes:
µg/g = micrograms per gram (part per million); % = percent; ng/g = nanograms per gram (part per billion); SM = Standard Method
a. Tissue minimum detection limits are based on a wet-weight basis.
b. Reporting limits were provided by Physis Environmental Laboratories.
c. USEPA 1986–1996. SW-846. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, 3rd Edition.
d. Includes Acenaphthene, Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo[b]fluoranthene, Benzo[e]pyrene, Benzo[g,h,i]perylene, Benzo[k]fluoranthene, Biphenyl, Chrysene, Dibenz[a,h]anthracene, Di benzothiophene, Fluoranthene, Fluorene, Indeno(1,2,3-c,d)pyrene, Naphthalene, Perylene, Phenanthrene, Pyrene, 2,6-Dimethylnaphthalene, 1-Methylnapthalene, 2-Methylnapthalene, 1-Methylphenanthrene, and 2,3,5-Trimethylnaphthalene.
e. Includes 2,4'-DDT, 4,4'-DDT, 2,4'-DDD, 4,4'-DDD, 4,4'-DDE, 2,4'-DDE, 4.4'-DDE, 4,4'-DDMU, alpha-chlordane, gamma-chlordane, cis-nonachlor, oxychlordane, trans-nonachlor.
f. Includes congeners: PCB-18, 28, 37, 44, 49, 52, 66, 70, 74, 77, 81, 87, 99, 101, 105, 110, 114, 118, 119, 123, 126, 128, 138, 149, 151, 153, 156–158, 167–170, 177, 180, 183, 187, 189, 201, and 206.
g. Includes BDE-17, 28, 47, 49, 66, 85, 99, 100, 138, 153, 154, 183, 190 and 209.

2.2.4 Collection of Benthic Infauna Tissue Samples

Benthic infauna were collected at 10 sampling stations during Bight'13/RHMP and nine sampling stations during the SWHB study for analysis of bioaccumulative COPCs in tissues. Sample collection for infauna tissue was conducted subsequent to sediment chemistry sample collection, during the same station occupation. Samples were collected using the TVV, transferred into pre-cleaned plastic tubs, and transferred to a pre-cleaned sieve. The samples were sorted through a 0.5-millimeter (mm) stainless steel sieve and acceptable benthic infauna tissues from three trophic groups (Polychaetes, Crustacea, and Mollusks) were sorted and collected as three separate tissue samples. This process was repeated until a minimum goal of

5 grams of tissue for each group were collected. Organisms were carefully selected using clean sampling devices (picks or tweezers, or gloved hands) and placed directly on a piece of aluminum foil pre-cleaned with acetone. Each sample was photographed with a label, wrapped with the label outside of the foil, and placed in a labeled zip-lock bag or twirl-pack™ and stored cool in an ice chest until shipment to the lead analytical laboratory, Physis Environmental (Physis).

2.2.5 Collection of Fish Tissue Samples

Target fish species were collected using a semi-balloon otter trawl at 10 sampling stations during Bight'13/RHMP and nine sampling stations during the SWHB study for analysis of bioaccumulative COPCs in tissues. An additional nine near-shore sites were sampled by MBC for SCCWRP using beach or purse seines as part of the Bight'13 monitoring efforts.

Fish were collected, processed, and preserved in accordance with the Bight'13 Field Operations Manual (SCCWRP 2013a) and project-specific Work Plans for RHMP (Amec Foster Wheeler, 2013a) and the SWHB study (Amec Foster Wheeler, 2014a).

Trawl Sampling

After recording the depth at a sampling station, a pre-trawl survey of an anticipated course was conducted to determine site acceptability. Once the site was deemed acceptable, multiple trawls were performed in the same general target areas until sufficient target species were captured. Fish were collected using a semi-balloon, otter trawl with a 7.6-meter head-rope. Trawls were generally 10 minutes in duration, at a speed of 3 to 5 knots. Trawl locations were recorded both manually at multiple time points throughout each trawl using a hand-held Global Positioning System (GPS) and continuously using a GPS-enabled tablet computer using software developed for the regional Bight program by SCCWRP. At the end of the trawl, the net was retrieved and the catch was deposited into pre-cleaned tubs or holding tanks for processing.

Trawl Sample Processing

Fish were processed in the field according to the following steps:

1. After each trawl net was brought onboard, the entire catch was emptied into a large sorting tub filled with site water. Target and non-target species were separated, where non-target species were quickly counted, identified, photographed, and then returned to the harbor.
2. Target species were sized and weighed, and then retained in separate tubs with site water until desired numbers and biomass of each target species were achieved at each sampling station.
3. Processing began once the desired number and biomass of each target species were reached at each sampling station. Fish were individually measured (total length in mm), weighed (wet weight in grams using calibrated spring scales), photographed, rinsed with site water, and wrapped in heavy-duty aluminum foil that was pre-rinsed with acetone.

4. Samples were then stored in an onboard freezer until transport to permanent freezers (located at various organizations involved in sampling, depending on which sampling event), where samples were then stored in a project-dedicated chest freezer until transfer to the analytical laboratories.
5. Transfer of all samples from each location was carefully documented on COC forms (see Appendix H).

The target size range for tissue collections across studies for fish species was 50 mm to 100 mm per individual, and the minimum weight per tissue sample was 5 grams. Fish that were less than the targeted size were collected when preferred target ranges were not attained. When smaller individuals were captured, additional fish were required to attain the minimum tissue weight of 5 grams per species.

The targeted catch was pre-determined, as follows:

Primary Target Fish Species

- Barred and spotted sand bass
- Flatfish (Halibut or turbot)
- Anchovy
- Topsmelt

Secondary Target Fish Species

- Shiner perch
- Croaker
- Goby species (sp.)
- California killifish
- Queenfish

Primary target fish species that were caught during the SWHB study included barred sand bass, California halibut, Deepbody anchovy, Northern anchovy, Slough anchovy, Spotted sand bass and Topsmelt. Secondary fish species that were caught during sampling and included in the results are the Arrow goby, Black perch, California killifish, Shiner perch, various Goby species, and the Round stingray.

2.2.6 Zooplankton Sample Collection

Zooplankton Tows for Tissue Sample Collection

Plankton were collected, processed, and preserved in accordance with the project-specific Work Plans for the SWHB study specific to plankton (Amec Foster Wheeler, 2014b).

Tows to collect zooplankton for analysis of tissue were conducted at nine sampling stations by MBC during Bight ’13, and an additional nine sampling stations by Amec Foster Wheeler for the

SWHB study in 2014 (see Table 2-2). As with the fish and invertebrate sampling, the nine locations for collection of plankton during both studies included three within each of the north, central, and south regions of San Diego Bay. Several zooplankton samples collected in October 2013 required compositing to provide enough tissue mass for analytical chemistry, resulting in a single composite sample for the north portion of San Diego Bay, a single composite for the southern portion, and two samples representing the central portion. Enough tissue mass was collected during the SWHB study in May 2014 to analyze all nine individual samples collected.

Zooplankton Tow Sampling

Prior to performing a plankton tow, all sampling equipment and the net were thoroughly rinsed with site water. Once onsite, a 333-micrometer (μm) bongo net was used to collect zooplankton samples. A pre-tow survey of the planned course (without the net) was conducted to determine site acceptability. The net was then deployed and towed at a speed of approximately 1.5 knots for 15 minutes at approximately 1 meter below the surface. The length of the tows was extended at certain sites when the approximate target biomass of 5 grams of tissue was not collected within the allotted 15 minutes. Trawl locations were recorded both manually at multiple time points throughout each trawl using a hand-held GPS, and continuously using a GPS-enabled tablet computer using software developed for the regional Bight program by SCCWRP. To gather sufficient plankton, multiple trawls were performed at each location covering areas ranging from approximately 400 to 800 meters distance from the pre-assigned sampling station. The general area encompassing the multiple trawl tracks at each location is shown in Figure 2-5.

After retrieval, the net was rinsed with site water into a collection bucket at the cod end of the net. The sample was then run through a 333-μm sieve to reduce the water content of the sample and transferred to a pre-cleaned 16-ounce jar. Sufficient seawater was added to the jar to keep zooplankton alive until the samples were processed to remove excess debris. Zooplankton samples were processed by removing debris from the sample using a dissecting microscope and clean techniques at Amec Foster Wheeler. Zooplankton were then dewatered and transferred to a freezer for storage until transferred on ice to the laboratory for chemical analyses.

2.3 Quality Control

Each batch of analyses included quality control (QC) samples to ensure laboratory method performance. The QC methodology followed Quality Assurance Project Plan (QAPP) guidelines used during Bight ’13 (SCCWRP, 2013c) and RHMP (Amec Foster Wheeler, 2013b), which were also consistent with SWAMP recommendations. The QC elements included:

- **Calibration Verification.** A new response factor or calibration curve was established for each instrumental batch. A calibration verification standard was analyzed every 12 hours to check the accuracy of the calibration. The control limit for this element was ±20 percent (%) of the true value.
- **Method Blanks.** A method blank was run with each sample preparation batch (or per every 20 samples) and processed in a manner identical to that for the field samples. The control limit for blanks was less than (<) reporting limit (RL) for each analyte.

- **Sample Duplicates.** Analysis of sample duplicates was conducted at a frequency of 5% of the total sample count. The control limit for this element was a relative percent difference (RPD) of no more than 35%.
- **Matrix Spikes and Matrix Spike Duplicates.** Matrix spike and matrix spike duplicates (MS/MSD) were analyzed at a frequency of one per batch or for every 20 samples (whichever is more frequent). The control limit for MS was 50–150% recovery and the control limit for MSD was RPD less than or equal to (≤) 25%.
- **Certified Reference Materials or Laboratory Control Samples.** Method accuracy was evaluated through the analysis of either certified reference materials (CRMs) or laboratory control samples (LCSs) at a frequency of one per batch or per every 20 samples. The CRM control limit was 70–130% recovery and 50–150% for LCS.
- **Standards and Standard Recovery.** Quantification standards consisted of either isotope-labeled or structurally similar analogues to the target analytes and were included with every sample analyzed. The control limit for standard recovery was 50–150%.

All analytical data were reviewed for QC performance by the analytical laboratory and SCCWRP. QC sample results not meeting the control limits were flagged and investigated to determine the need for corrective action.

2.4 Data Analysis

2.4.1 Bioaccumulation Among Food Web Components

Methods and results for sport fish and bird eggs were summarized under separate cover (Bay et al., 2016 draft). In this report, contamination data for sediment, and tissue (forage fish, benthic infauna, and plankton) were summarized for San Diego Bay as a whole, by ecoregion, and by individual sampling station (at the 28 tissue collection stations). San Diego Bay was divided into three ecoregions (north, central, and south) for comparative analyses performed by SCCWRP as reported in Bay et al. (2016 draft). Ecoregion boundaries are shown in Figures 2-1 through 2-4. Analyses presented in this report focus on bioaccumulation relationships among species at individual sites in relation to associated sediment chemistry. Correlations between bioaccumulation of COPCs and sediment concentrations were also evaluated throughout San Diego Bay as a whole.

2.4.2 Contaminant Reporting

Results of tissue analyses for trace metals (with the exception of mercury) are reported in parts per million (ppm) as micrograms per gram (µg/g) wet weight (ww). Tissue concentrations of total mercury and organic analytes are reported in parts per billion (ppb) as nanograms per gram (ng/g) ww. Sediment chemistry results are reported on a dry weight (dw) basis, either as µg/g dw for mercury and other trace metals, or ng/g dw for organics. Results presented in this report focus on those constituents that are known to biomagnify and were detected across trophic positions; in particular, mercury, PCBs, DDTs, chlordanes, selenium, and PBDEs.

Sums, or totals, of organic contaminant classes (chlordanes, PCBs, DDTs, and PBDEs) were calculated as the sum of all detected analytes within the class. In cases where all class components were non-detect for a sample, the sum value was represented by the highest detection limit of any of the class components.

For comparative purposes total PCB data were also lipid normalized in an effort to tease out biomagnification and bioaccumulation in the food web. When comparing concentrations in various species, lipid normalization takes into account the trophic positioning of the species as well as its lipid content, allowing for determining whether differences in concentrations of a constituent observed across trophic levels is driven by lipid content (i.e., size of organisms) or is a result of bioaccumulation.

2.4.3 Biota Sediment Accumulation Factors

A biota sediment accumulation factor (BSAF) was calculated for total PCBs, DDTs, and mercury. The BSAF represents the degree of contaminant bioaccumulation in the sample, relative to the sediment. The BSAF was calculated as:

$$BSAF = C_{Tis}/C_{Sed}$$

where:

C_{Tis} = tissue contaminant concentration (μg/g ww or ng/g ww)

C_{Tis} = sediment contaminant concentration (μg/g dw or ng/g dw)

BSAF values reported herein were derived based on associated sediment and tissue results at each individual sampling location. Sediment concentrations used for BSAF calculations in the associated draft report by Bay et al. (2016) were comprised of the average of all sediment samples from the San Diego Bay region of interest. The median of all individual values was then used to represent the BSAF for each taxonomic group and region.

BSAF values for total PCBs in this report were calculated using both raw (untransformed) concentrations of COPCs, and concentrations that were normalized for TOC content in the sediments and lipid content of the tissues. BSAF values are presented for PCBs only in this report given the priority they warrant as described in the risk assessment results Section 3.0. BSAF values for total DDTs, chlordanes, dieldrin, PBDEs, PAHs, and mercury are provided for reference in the San Diego Bay bioaccumulation report by Bay et al. (2016 draft).

2.4.4 Ecological Risk Evaluation

Widely applicable nationwide ecological risk tissue screening levels are not available for bioaccumulative COPCs due to the importance of site-specific environmental conditions, site-specific food web relationships, and species specificity with regard to bioaccumulation and documented effects. Ecological risk-based screening values are available however from a variety of sources that were reviewed for this report. Applicable sources reviewed and referenced herein include the following:

- The California EPA Office of Environmental Health Hazard Assessment (OEHHA): Development of fish contaminant goals and Advisory Tissue Levels (ATLs) for common contaminants in California sportfish: chlordane, DDTs, dieldrin, methylmercury, PCBs, selenium, and toxaphene (Klasing and Brodberg, 2008).
- U.S. Fish and Wildlife Service (USFWS): Ecological risk-based screening levels for contaminants in sediments of San Diego Bay (Zeeman 2004).
- U.S. Fish and Wildlife - Initial wildlife risk-based screening levels for contaminants in tissue of aquatic biota San Diego Bay (Zeeman, draft June 3, 2016):
- Oregon Department of Environmental Quality (DEQ). Guidance for assessing bioaccumulative chemicals of concern in sediment (Oregon DEQ, 2007).
- Washington State Dredged Material Management Program (DMMP). Dredged Material Evaluation and Disposal Procedures, User Manual; Section 10. Bioaccumulative contaminants of concern and triggers for bioaccumulation testing. Seattle District U.S. Army Corps of Engineers, July 2013.
- California State Water Resources Control Board (SWRCB). Total Maximum Daily Load (TMDL) for PCBs in the San Francisco Bay, Resolution No. R2-2008-0012.
- California State Water Resources Control Board (SWRCB). TMDL for selenium in north San Francisco Bay, Resolution No. R2-2015-0048.

While a number of sources were reviewed, note that this is not an exhaustive list of the latest available ecological threshold values and associated studies; however, these references are currently cited for various programs and used for regulatory decision-making on the U.S West Coast.

3.0 RESULTS

3.1 Trawl Locations and Catch Summary

Capture of targeted fish was successful at all of the pre-designated sampling stations. Maps showing trawl tracks for both Bight'13/RHMP and the SWHB study are shown in Figure 2-4 with more detail provided in maps located in Appendix A. A map showing areas where plankton trawls were performed in support of the 2014 SWHB study is provided in Figure 2-5. A complete catch summary that includes all archived and analyzed samples is provided in Appendix C. Associated photo logs of all retained organisms that were chemically analyzed is provided in Appendix D as summarized in Table 2-2 and highlighted in Appendix C.

3.1.1 Supporting Information

Graphical and statistical analyses, along with BSAF calculation summaries, are provided in Appendix E; physical water quality parameters recorded during plankton tows approximately 1-meter from the surface are located in Appendix F; scanned field datasheets are provided in Appendix G; chain-of-custody (COC) forms are located in Appendix H; raw chemistry reports are provided in Appendix I; and the complete data validation report by LDC comprises Appendix J. A summary of draft ecological risk tissue concentrations for biota in San Diego Bay is provided in Appendix K.

3.2 Water Chemistry

Results for those analytical water quality parameters measured during the SWHB study (TOC, DOC, TSS, and total and dissolved mercury) are summarized in Table 3-1 with raw analytical data reports provided in Appendix I. Surface water measures of pH, DO, salinity, and temperature at the time of sampling are summarized in Appendix F. Water quality parameters measured during Bight '13/RHMP included a broader suite of chemicals in addition to vertical water column profiles of pH, DO, salinity, temperature, and light transmittance at the time of sampling; these values are reported under separate cover in the final report for RHMP (2016). Concentrations of TOC, DOC, and TSS during the SWHB study in 2014 were relatively consistent among all sampling stations and were also comparable with values measured during Bight '13/RHMP. A majority of the organic carbon in ambient waters of San Diego Bay exists in the dissolved fraction. Total mercury was detected in only a few samples at or near the method detection limit of 0.01 µg/L in both 2013 and 2014. Dissolved mercury was not detected in any samples in 2013 or 2014. Concentrations of PCBs, a primary bioaccumulative COPC, were not measured in the water column because of their low solubility and the extremely low levels of detection required for meaningful measurements.

3.3 Sediment Chemistry

Sediment chemistry results for seven COPCs, as well as percent fines and percent TOC measured during Bight'13/ RHMP in 2013 in San Diego Bay and during the SWHB study in 2014 are displayed as box plots in Figure 3-1. Sediment quality results for these parameters during both survey periods are summarized in Table 3-2 and depicted spatially in Figures 3-2 through 3-5 for total PCBs, DDTs, mercury and percent fines. Generally, elevated concentrations of total PCBs, chlorinated pesticides, and trace metals were located in the industrial/port stratum along the eastern shore of San Diego Bay, within the marinas, and occasionally near freshwater inputs. DDTs and chlordanes are less widespread than PCBs, with elevated concentrations only observed near Chollas Creek and within semi-enclosed embayments in north San Diego Bay. Overall, mercury exhibited a more widespread distribution, with greatest concentrations in the industrial/port and marina strata. Sediment physical characteristics as shown by the map of percent fines (Figure 3-5) varies substantially throughout the bay without a clear regional pattern.

Chemical concentrations and ranges in the shallow water strata during Bight'13/RHMP were similar to those recorded in 2014 during the SWHB survey. Concentrations in the SWHB stratum were also similar to those measured in the deep stratum in 2013, but were generally less than those measured in the marina, industrial/port, or freshwater-influenced strata. Several chemicals (arsenic, copper, mercury, and zinc) were found at concentrations that exceeded effects range-low (ER-L) sediment quality screening values (Long and Morgan, 1990; Long et al., 1995) at more than one SWHB sampling station. A single sampling station (1 of 30) had concentrations that exceeded an ER-L value for silver, total chlordanes, total DDTs, and total PCBs. Eight samples had sediment concentrations of mercury that exceeded its respective ER-M of 150 ng/g. No samples collected for the SWHB study had chemical concentrations that exceeded effects range-median (ER-M) values (Appendix Table B-1).

Toxicity and benthic community lines of evidence were not assessed during the SWHB study in 2014; thus, calculating an integrated score using the California SQO approach was not possible. Integrated SQO scores were determined for Bight'13/RHMP, with 93 percent of sampling stations in the shallow stratum categorized as unimpacted or likely unimpacted (Stransky et al., 2016).

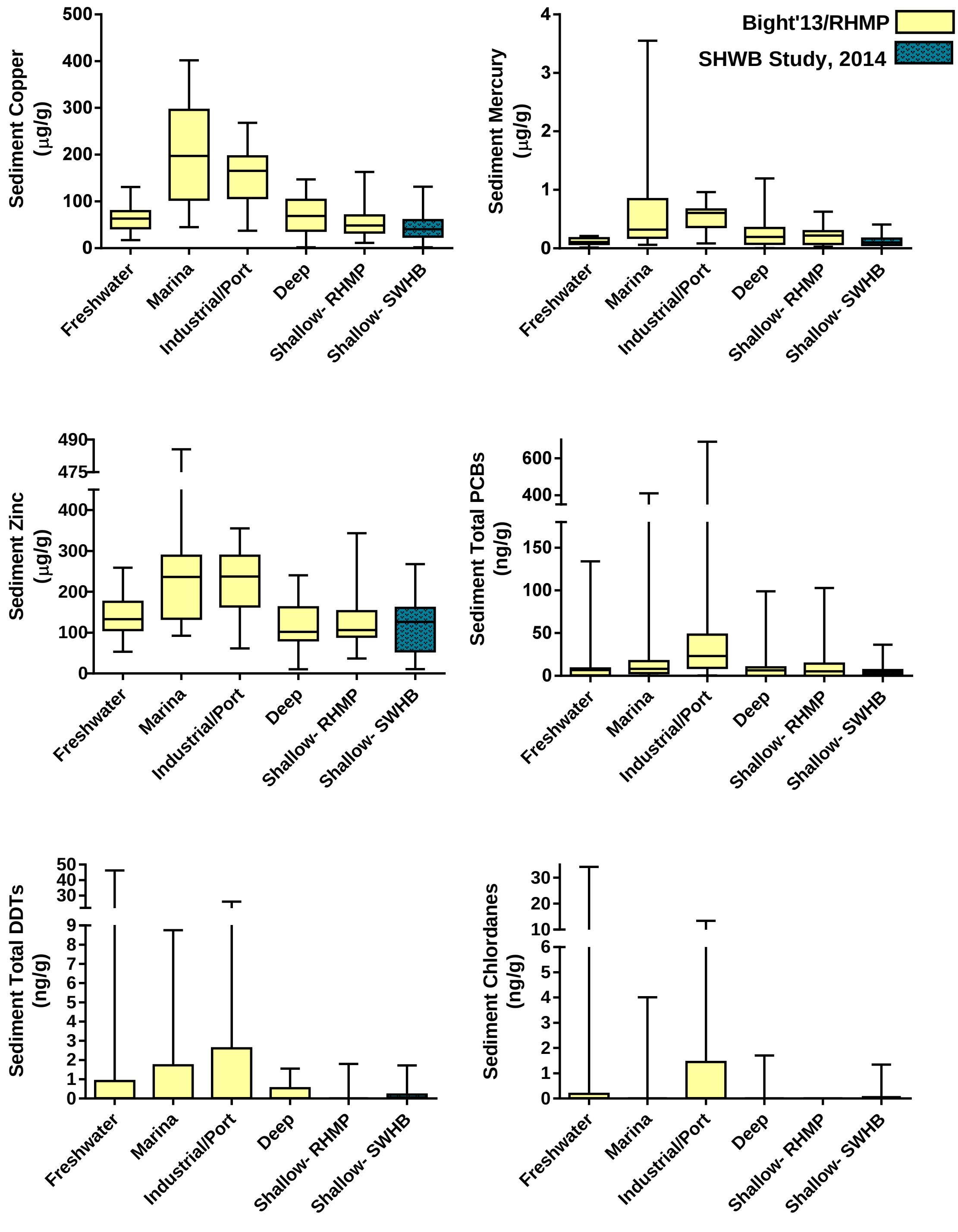

Figure 3-1. Comparison of Sediment Chemistry Results Among Sampling Strata for Bight ’13/RHMP Relative to Stations Sampled in the Shallow Water Habitats in 2014

Box plots showing the median and, quartiles, and range of data.

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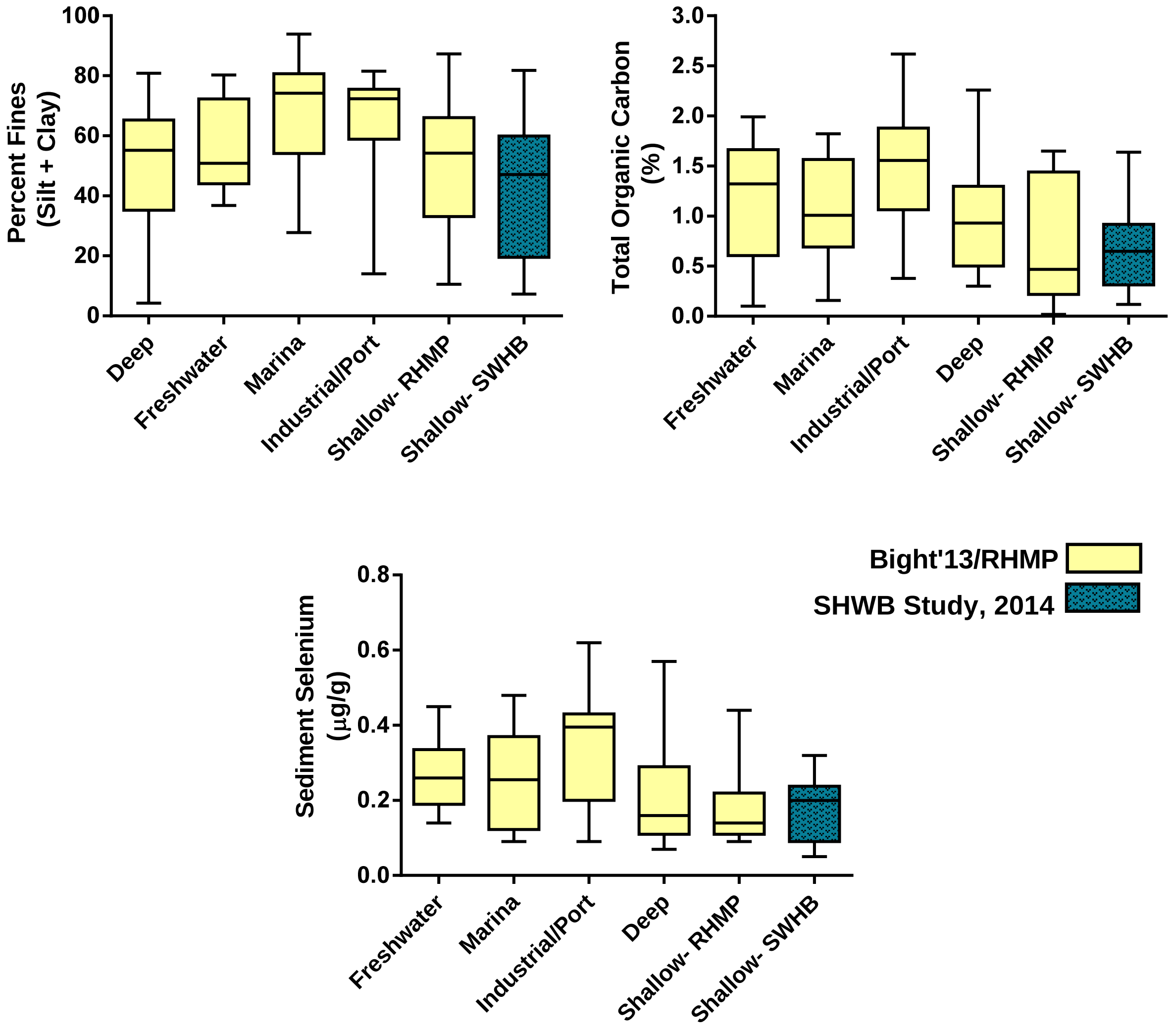

Figure 3-1 (cont.). Comparison of Sediment Chemistry Results Among Sampling Strata for Bight ’13/RHMP (solid yellow bars) Relative to Stations Sampled in the Shallow Water Habitats in 2014 (teal patterned bar)

Box plots showing the median and, quartiles, and range of data.

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Table 3-1.
Summary of Water Quality Analysis Results for the San Diego Bay SWHB Study in 2014

Location	Sampling Station	Total Mercury (µg/L)	Dissolved Mercury (µg/L)	Total Suspended Solids (mg/L)	Total Organic Carbon (mg//L)	Dissolved Organic Carbon (mg/L)
North Bay	SWHB-26	0.02	<0.01	6.0	2.2	1.7
	SWHB-27	0.01	<0.01	3.8	1.3	1.2
	SWHB-30	<0.01	<0.01	2.2	1.1	1.1
Central Bay	SWHB-01	0.01	<0.01	6.9	1.7	1.4
	SWHB-06	0.01	<0.01	4.4	1.4	1.3
	SWHB-40	0.01	<0.01	5.7	1.5	1.5
South Bay	SWHB-15	0.01	<0.01	18.2	1.9	1.9
	SWHB-21	<0.01	<0.01	5.6	1.6	1.4
	SWHB-22	<0.01	<0.01	6.1	1.8	1.7

Table 3-2.
Summary of Select Sediment Quality Analysis Results for the San Diego Bay SWHB Study in 2014

Location	Sampling Station	Mercury (ng/g)	Copper (ug/g)	Selenium (ug/g)	Zinc (ug/g)	Total PCBs (ng/g)	Total DDTs (ng/g)	Total Chlordanes (ng/g)	Fines (%)	TOC (%)
North Bay	**SWHB-26**	**121**	**33.8**	**0.13**	**79.5**	**7.1**	**<0.05**	**<0.05**	**26.3**	**0.28**
	SWHB-27	**83.6**	**24.9**	**0.09**	**57.5**	**36.5**	**<0.26**	**<0.05**	**19.8**	**0.30**
	SWHB-28	86.2	28.1	0.11	54.7	12.3	0.20	1.34	18.9	0.36
	SWHB-30	**4.1**	**2.0**	**0.05**	**10.8**	**0.6**	**<0.05**	**<0.05**	**16.9**	**0.24**
	SWHB-53	34.0	24.9	0.08	43.7	5.2	0.22	<0.05	21.7	0.32
	Mean	**65.8**	**22.8**	**0.1**	**49.2**	**12.4**	**0.16**	**0.31**	**20.7**	**0.30**
Central Bay	**SWHB-01**	**319**	**76.7**	**0.21**	**157**	**5.7**	**<0.05**	**<0.05**	**59.1**	**0.88**
	SWHB-02	42.0	15.4	0.06	36.8	1.7	<0.05	<0.05	18.3	0.28
	SWHB-06	**59.1**	**15.3**	**0.08**	**50.0**	**2.6**	**<0.05**	**<0.05**	**7.6**	**0.35**
	SWHB-07	336	120	0.31	268	6.6	<0.05	<0.05	81.8	1.64
	SWHB-08	345	131	0.31	240	8.4	<0.05	<0.05	71.5	1.22
	SWHB-09	86.7	16.8	0.06	47.4	2.8	<0.05	<0.05	7.3	0.17
	SWHB-10	188	50.7	0.14	89.5	10.2	<0.05	<0.05	35.3	0.61
	SWHB-33	405	104	0.32	224	16.3	<0.05	0.08	67.1	1.29
	SWHB-36	30.4	13.4	0.05	28.8	6.7	0.39	0.36	10.4	0.12
	SWHB-40	**212**	**61.1**	**0.19**	**143**	**4.2**	**<0.05**	**<0.05**	**47.2**	**0.62**
	Mean	**202**	**60.5**	**0.2**	**128**	**6.5**	**0.08**	**0.08**	**40.6**	**0.72**
South Bay	SWHB-11	61.0	26.1	0.17	99.1	6.4	1.72	<0.05	55.9	0.63
	SWHB-12	71.3	35.9	0.21	121	2.5	<0.05	<0.05	57.1	0.86
	SWHB-13	143	49.8	0.18	131	3.3	<0.05	<0.05	55.6	0.67
	SWHB-14	99.4	38.6	0.23	138	1.1	<0.05	<0.05	47.0	0.63
	SWHB-15	**82.8**	**36.6**	**0.26**	**118**	**1.8**	**0.93**	**<0.05**	**64.3**	**0.63**
	SWHB-16	104	44.1	0.21	150	1.7	0.30	<0.05	48.5	0.79
	SWHB-18	95.3	42.4	0.27	137	0.9	<0.05	<0.05	67.2	1.03
	SWHB-19	110	50.0	0.31	160	2.4	<0.05	<0.05	72.5	1.30
	SWHB-20	106	53.5	0.22	155	5.2	<0.05	<0.05	43.2	1.29
	SWHB-21	**62.2**	**14.7**	**0.09**	**53.0**	**2.1**	**0.11**	**<0.05**	**11.8**	**0.23**
	SWHB-22	**118**	**49.6**	**0.22**	**168**	**10.4**	**<0.05**	**<0.05**	**34.3**	**0.70**
	SWHB-23	54.1	24.4	0.18	94.7	3.9	0.25	<0.05	38.5	0.68
	SWHB-24	113	73.5	0.32	163	6.5	<0.05	<0.05	59.4	1.35
	SWHB-25	192	60.1	0.21	182	5.3	<0.05	<0.05	53.0	0.76
	SWHB-41	163	70.8	0.22	199	2.0	<0.05	<0.05	61.5	0.88
	Mean	**105**	**44.7**	**0.2**	**138**	**3.7**	**0.25**	**<0.05**	**51.3**	**0.83**

Bold Site IDs and associated values are locations where tissue collections occurred (infauna, fish, and plankton).

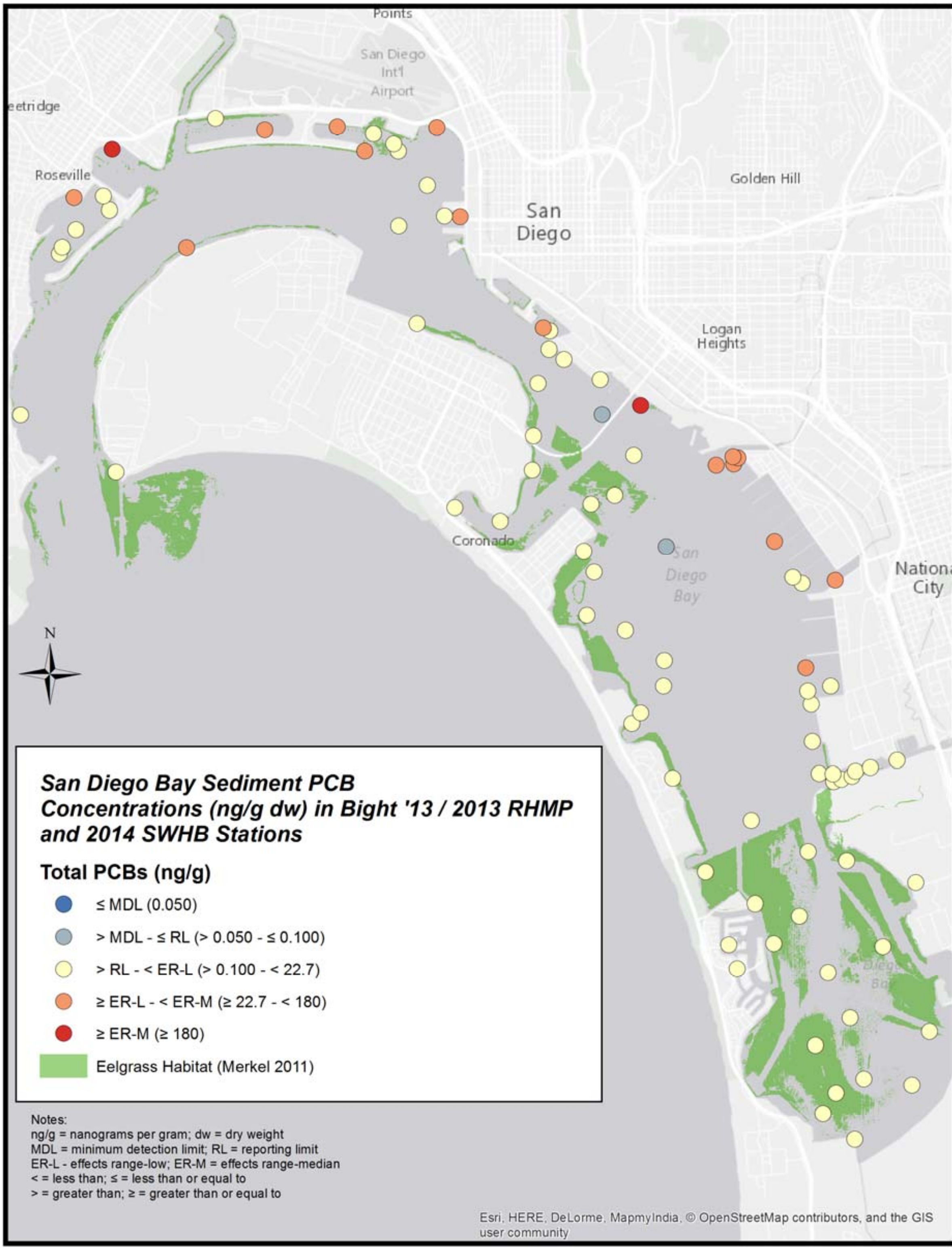

Figure 3-2. Spatial Assessment of Total PCBs in Sediments for Bight '13/RHMP and the SWHB Study

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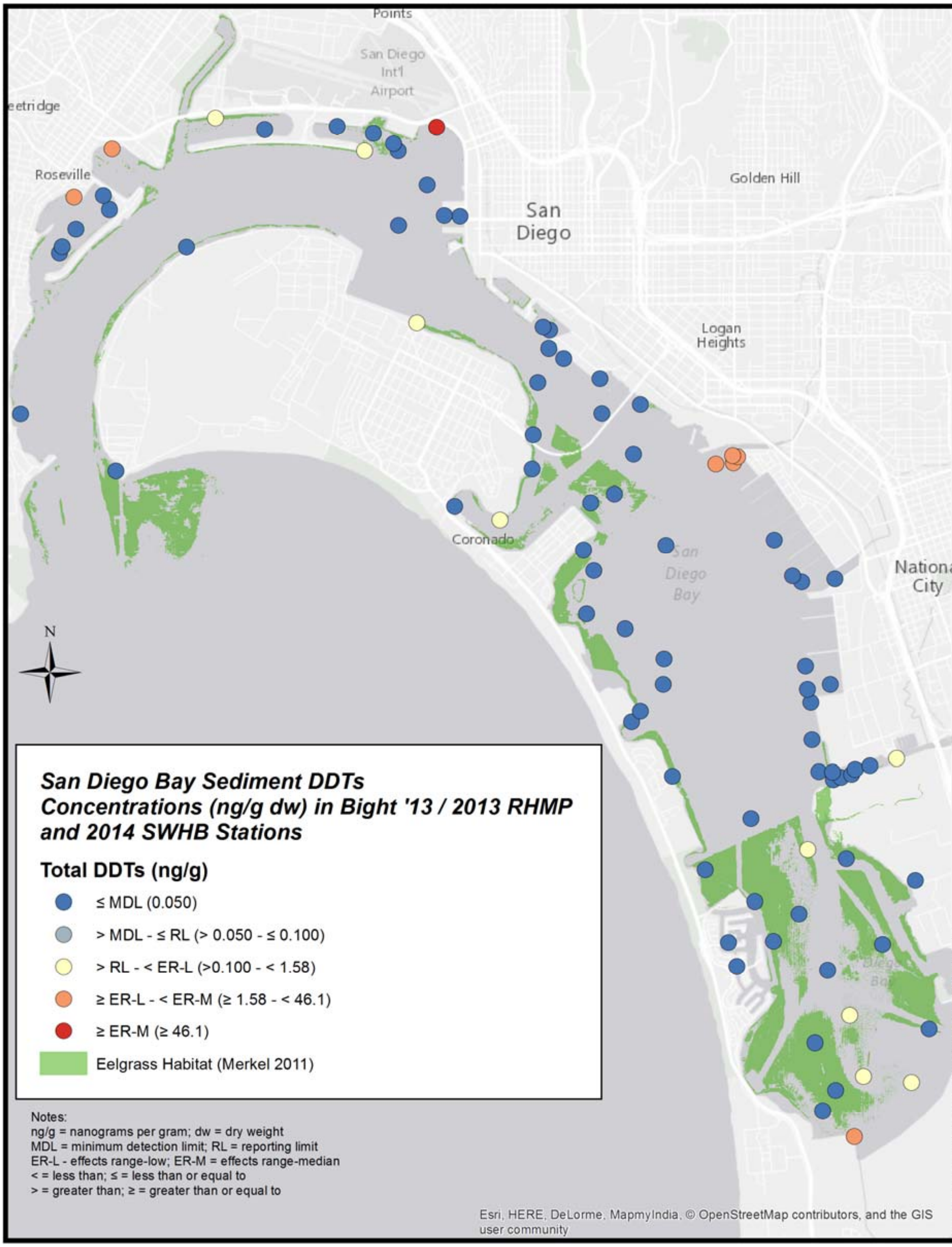

Figure 3-3. Spatial Assessment of Total DDTs in Sediments for Bight '13/RHMP and the SWHB Study

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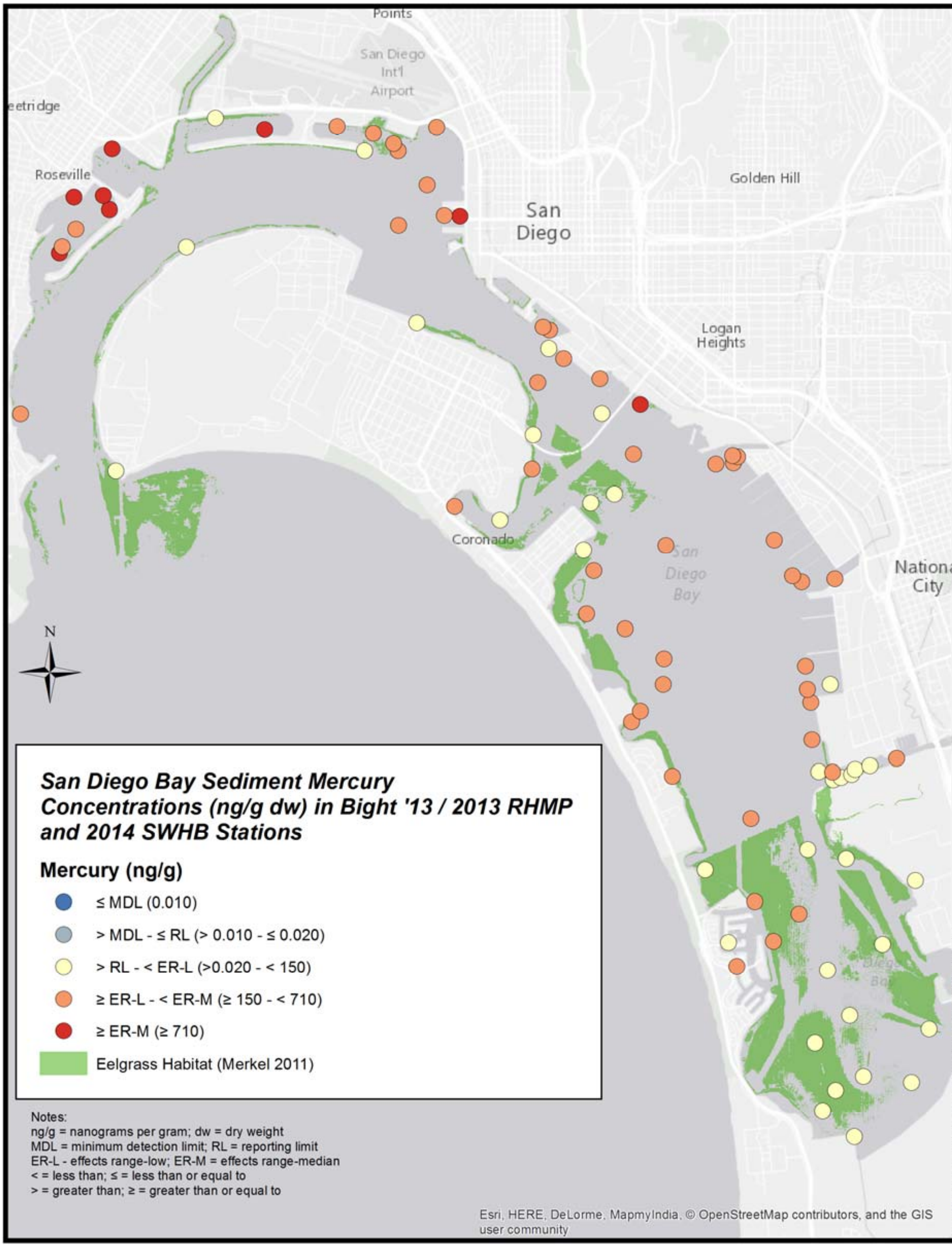

Figure 3-4. Spatial Assessment of Mercury in Sediments for Bight '13/RHMP and the SWHB Study

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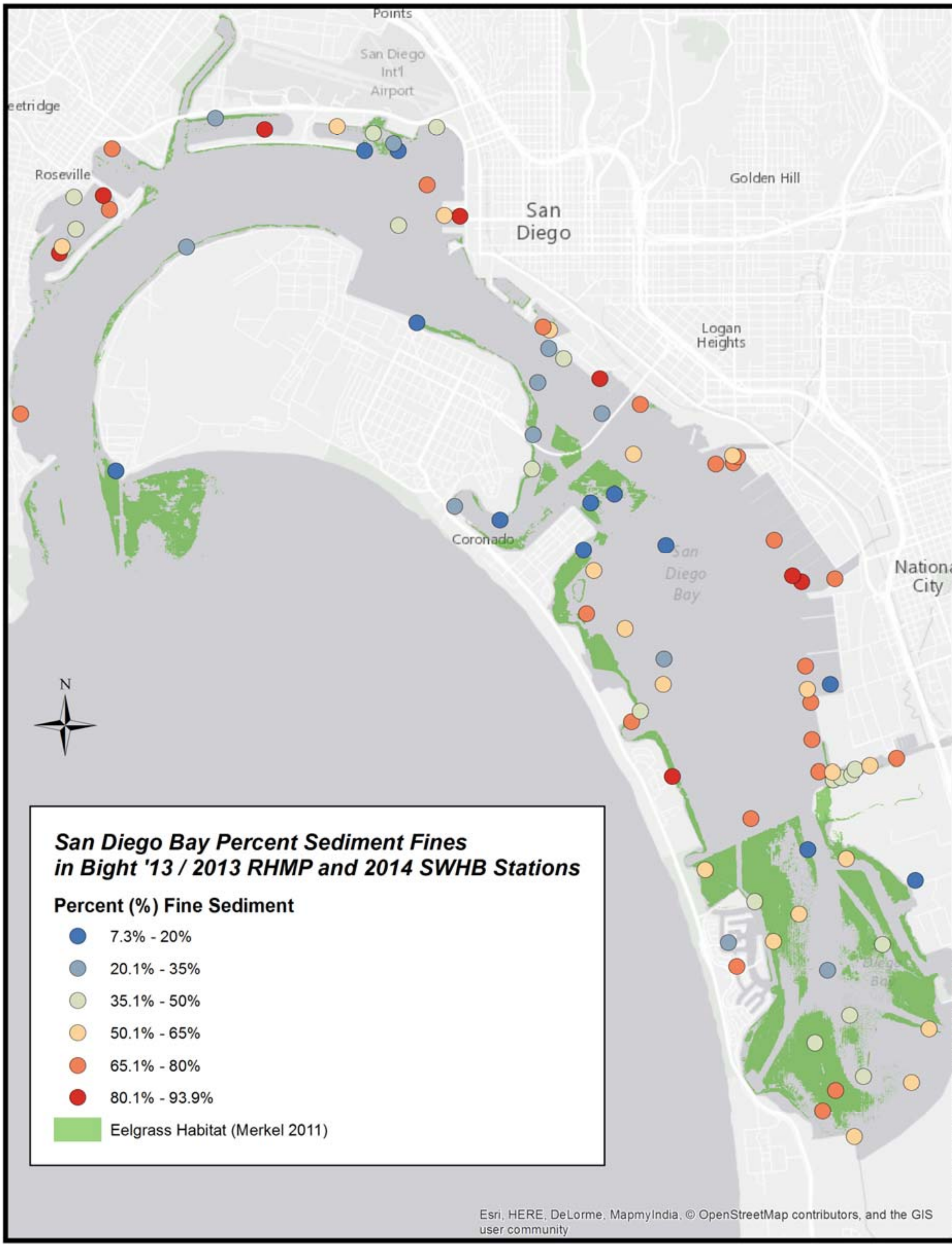

Figure 3-5. Spatial Assessment of Percent Fines in Sediments for Bight ’13/RHMP and the SWHB Study

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3.4 Tissue Contaminants - Overall Summary

Results for tissue bioaccumulation are illustrated in Figure 3-6 using box plots, which show the median, interquartile range (25^{th} to 75^{th} percentile), and individual data points for all San Diego Bay data combined. These plots include results for bird eggs which are reported separately in a final report being prepared by SCCWRP and USFWS at the time of this publication (Bay et al., in prep, 2016).

Tissue chemistry results collectively for all of San Diego Bay showed that biomagnification among food web components was evident for all major contaminant types evaluated (Figure 3-6). A more detailed graphical summary by site with fish divided into a predatory species group[2] and forage species group[3] is provided for reference in Appendix E. A graphical summary of total PCB, DDT, and mercury concentrations among individual fish species is also provided in Appendix E. Relative to the other sample types, predatory fish had the highest mean concentration of total PCBs, total DDTs, and total chlordanes. Mercury concentrations in fish tissue were similar to those in polychaetes, but elevated relative to that in mollusks and crustacea. Similar patterns were evident for most contaminant types, with the lowest concentrations occurring in the lowest trophic levels of plankton and benthic infauna (crustaceans, mollusks, polychaetes), and intermediate contaminant levels present in forage fish. Total PBDEs did not follow this pattern, however, with fish having overall lower mean concentrations than benthic infauna (especially crustaceans) and plankton. PBDE concentrations overall displayed a decrease across trophic levels until birds, where concentrations then increased. Selenium also showed elevated concentrations in lower trophic levels; with the mean concentration in fish tissues generally less than that for benthic infauna, and especially polychaetes.

The greatest bioaccumulation potential from sediment was observed for PCBs and DDTs, where all food web components had median concentrations above bay-wide sediment means. For chlordanes, benthic infauna and plankton did not show much bioaccumulation relative to sediment, but the lack of detectable concentrations in many samples may have obscured some of these relationships. Median tissue mercury concentrations were below sediment levels for all trophic levels, likely reflecting a relatively low influence of local sediment mercury on tissue levels. Most sediment mercury near the surface will be present in the inorganic form while methylated forms of mercury more prevalent in deeper anoxic sediments are those which are bioavailable.

Across all sites, spotted sand bass had the greatest maximum and median measured concentration of total PCBs. A single round ray sample was found to have a PCB concentration that exceeded the median for all other fish species tested though these results represent only a single data point from five composited fish. The greatest median total DDT concentrations were found in deepbody anchovy tissue, followed by shiner surf perch, black perch, and barred sand

[2] Predatory fish species included California halibut, barred sand bass, spotted sand bass, and round stingrays.

[3] Foraging fish species included anchovies (deepbody and slough), topsmelt, perch (black and shiner), California killifish, and goby species.

bass all with very similar median concentrations. Median mercury concentrations were highest across polychaete and spotted sand bass tissues, followed by the barred sand bass. The single round ray composite sample was found to have a mercury concentration that exceeded the median for all other fish species tested.

Across sites and species, total PCBs and total percent lipids exhibited distinct positive relationships, while total DDTs exhibited a weaker relationship to total percent lipids. Relationships between lipid concentrations and bioaccumulation of COPCs is presented in Appendix E for reference.

3.4.1 Total PCBs

Sediment

Total PCB concentrations in sediments ranged from non-detectable (Stations B13-6068 and B13-8087, both in central San Diego Bay) to over 685 ng/g (Station B13-8090 in the industrial/port stratum of central San Diego Bay). The average sediment concentration of total PCBs across San Diego Bay stations exceeded the ER-L screening value of 22.7 ng/g by roughly 20-percent at 27.3 ng/g. The majority of individual stations that exceeded the ER-L screening level were within industrial/port, marina, and freshwater-influenced areas.

Plankton and Benthic Infauna

Total PCBs in plankton and benthic infauna were mostly similar in both concentrations and spatial distribution (Figure 3-7a, 3-7b). Overall, relatively higher concentrations were found in plankton and invertebrate tissues collected in central San Diego Bay, where the highest tissue concentrations were found along the western-most shoreline (SWHB-01 and SWHB-10). All sediment sampling stations co-located with tissue collections in central San Diego Bay had total PCB concentrations below the ER-L. Of the three invertebrate groups, the greatest concentrations of PCBs were observed in polychaetes; with total PCBs concentrations in this class of infauna nearly three times that of mean tissue concentrations in mollusks, and twice that in plankton. In general, spatial patterns of PCBs in plankton and the different benthic infauna followed similar spatial patterns, with some notable exceptions (e.g. low PCB concentrations in mollusks in north San Diego Bay relative to the patterns observed for other species). Total PCBs observed in crustaceans were also greatest in north San Diego Bay (B13-8109, B13-8118, and B13-8122). Two RHMP sampling stations and one SWHB sampling station within this area showed total PCB concentrations in the sediment to exceed the ER-L value. These stations were all located in the immediate vicinity of the shoreline. Stations farther from the shoreline displayed sediment concentrations below the ER-L.

Fish

Forage fish tissue generally showed the highest concentrations of total PCBs in central San Diego Bay, as well as at a single sampling station in north San Diego Bay (Site SWHB-27 near East Harbor Island) (Figure 3-7c). This result coincides with the areas associated with elevated tissue concentrations in plankton, polychaetes, and mollusks in central San Diego Bay, and crustacea in north San Diego Bay. The mean total PCB tissue concentrations for forage fish in San Diego Bay were approximately 50 percent greater than the mean concentration in polychaetes, and four times greater than the mean concentrations found in mollusk tissue in San Diego Bay.

Of all species groups tested, predatory fish had the highest mean total PCB concentrations, with approximately 15 percent greater mean tissue concentrations than that found in forage fish (Figure 3-7d).

Risk Assessment

The concentrations of PCBs in tissues was compared to several screening level guidelines based on both human health and wildlife risk as follows:

- California OEHHA Fish Consumption Advisory Tissue Levels (ATLs): 21 to 42 ng/g (ppb) wet weight (no more than 3 servings per week), and > 120 ng/g (no consumption).
- Oregon DEQ (2007): Lowest ATL for applicable wildlife (880 ng/g wet weight for mammals); ATL for humans (4.7 ng/g wet wt. - general/ recreational); and the Critical Tissue Level (CTL) in fish, shellfish, or other saltwater aquatic organisms (930 ng/g wet wt.). Reported as total Aroclors.
- U.S. Fish and Wildlife - Tissue concentration screening values for San Diego Bay (Zeeman 2007): 80 to 150 ng/g dry weight[4] for a No Observed Effect Concentration (NOEC) to fish.
- U.S. Fish and Wildlife - Initial wildlife risk-based screening levels for contaminants in tissue of aquatic biota in San Diego Bay (Zeeman, draft June 3, 2016): 110 to 566 ng/g wet wt. NOEC values to birds[5] from consuming invertebrates or fish; and 1,556 to 7,987 ng/g wet wt. Lowest Observed Effect Concentration (LOEC) values to birds from consuming invertebrates or fish.
- State of Washington DMMP: Target Tissue Level (TTL) to protect wildlife and human health from ocean disposal of dredged material: 750 ng/g wet wt. based on total Aroclor in clam or worm tissue following a 45-day laboratory bioaccumulation exposure.
- SWRCB TMDL for PCBs in San Francisco Bay: 10 ng/g wet weight fish tissue to protect both wildlife and human health (as congeners or Aroclor mixtures).

The primary driver of risk from PCB exposure is related to human health, with generally much lower screening values for fish consumption than that for wildlife risk. Concentrations of total PCBs in all fish tissue samples exceeded the OEHHA human health ATL of 21 ppb, the TMDL criterion of 10 ppb for San Francisco Bay, and the Oregon DEQ ATL value for the protection of human health (4.7 ppb). Mean values in fish species (185 ng/g in forage fish and 216 ng/g in

[4] Note that dry weight values are presented by Zeeman (2004) as opposed to wet weight concentrations reported herein and among other referenced studies. Dry weight values for data reported herein are provided for comparison purposes in Appendix B.

[5] Includes the surf scooter, California least tern, Caspian tern, Double-crested cormorant, and the Western gull. Prey item tissue screening-level NOEC and LOEC values for the protection of these bird species is provided in Appendix K, along with the associated references cited for the values reported.

predator fish) also exceeded the OEHHA no consumption guideline of 120 ppb. Though concentrations of total PCBs in the infauna and plankton were lower than that in fish species, many still exceeded the various criteria available for the protection of human health.

With regard to wildlife risk, concentrations of PCBs in fish and many of the infauna and plankton samples exceeded a dry weight NOEC value of 80 ng/g for fish species and a Threshold Effect level (TEL) of 22 ng/g for benthic invertebrates reported by Zeeman (2004), the 10 ng/g TMDL criteria for San Francisco Bay, as well as prey item wet weight NOEC values between 110 and 566 ng/g for the protection of bird species. However, measured tissue concentrations for all aquatic species in San Diego Bay (maximum of 571 ng/g measured in a spotted sand bass collected at Site SWHB-01 in central San Diego Bay) were below all wet weight LOEC values reported by Zeeman (2016 draft) for the protection of bird species, the Oregon DEQ CTL wildlife protection screening value of 930 ng/g, and the State of Washington DMMP screening value of 750 ng/g.

3.4.2 Total DDTs

Sediment

Total DDT concentrations were non-detectable in most sediment samples collected from San Diego Bay. Stations with elevated sediment concentrations of total DDTs tended to coincide with areas influenced by freshwater inputs, such as at river mouths or within close proximity of storm drains. The mean concentration of total DDTs in San Diego Bay was 1.9 ng/g, which exceeds the ER-L screening value for this class of compounds, but is well below the ER-M value of 46.1 ng/g. Between the 2013 RHMP and 2014 SWHB, only one station exceeded the ER-M screening value (Station B13-8500, located next to a 48-inch storm drain within Laurel Hawthorn Embayment in north San Diego Bay).

Plankton and Benthic infauna

Total DDTs measured in plankton tissue showed elevated concentrations from trawls performed in north San Diego Bay (SWHB-26 and SWHB-27) and south San Diego Bay (SWHB-21 and SWHB-15). Station SWHB-15 showed the highest concentration of DDTs in plankton tissue at nearly 25 ng/g (Figure 3-8a).

There was little evidence of trends among the three types of infauna for tissue concentrations of total DDTs. Polychaetes showed relatively higher concentrations of total DDTs in central San Diego Bay, though the highest concentration was found in polychaete tissue collected from B13-8029 in south San Diego Bay (in the mouth of the Sweetwater Channel). The highest DDT concentration for crustaceans was observed at Station B13-8109 in north San Diego Bay. Of the three infaunal groups, mollusks had the single highest concentration of total DDTs at Station SWHB-30 (33 ng/g), located at the entrance of San Diego Bay, however, mean tissue concentrations were relatively consistent for each of the three groups, ranging from 6.0 ng/g in crustaceans to 7.1 ng/g in polychaetes (Figure 3-8b).

Fish

Total DDT concentrations in fish tissue were generally about ten-fold lower than PCBs. Of the forage fish, relatively higher concentrations of DDTs were observed in anchovies (both deepbody and slough) and shiner perch. The single highest concentration was found in deepbody anchovy tissue (42.7 ng/g) collected from B13-8052 in central San Diego Bay. This is nearly four times greater than the mean concentration value of 11.3 ng/g for forage fish collected in San Diego Bay (Figure 3-8c).

Predatory fish showed relative elevated concentrations of DDTs in north San Diego Bay stations. This was primarily driven by two samples – a single barred sand bass caught at Station B13-8118 (40.3 ng/g) and a single California halibut caught at Station B13-8122 (37.7 ng/g) (Figure 3-8d). The mean concentration of DDTs in predatory fish tissue was very similar to forage fish tissues at 12.3 ng/g.

Risk Assessment

The concentrations of DDTs in tissues was compared to several screening level guidelines based on both human health and wildlife risk as follows:

- OEHHA Fish Consumption ATLs: 520 to 1,000 ng/g (ppb) wet weight (no more than 3 servings per week), and > 2100 ng/g (no consumption).
- Oregon DEQ (2007): Lowest ATL for applicable wildlife (48 ng/g wet weight for osprey); ATL for humans (27 ng/g wet wt. - general/ recreational); and the Critical Tissue Level (CTL) in fish, shellfish, or other saltwater aquatic organisms (54 ng/g wet wt.). Reported as total 4’4’-DDT, 4’4’-DDE, or 4’4-DDD individually.
- U.S. Fish and Wildlife - Initial wildlife risk-based screening levels for contaminants in tissue of aquatic biota in San Diego Bay (Zeeman, draft June 3, 2016): 11 to 57 ng/g wet wt. NOEC values to birds from consuming invertebrates or fish; and 33 to 170 ng/g wet wt. LOEC values to birds from consuming invertebrates or fish.
- State of Washington DMMP: Target Tissue Level (TTL) to protect wildlife and human health from ocean disposal of dredged material: 500 ng/g wet wt. based on total Aroclors in clam or worm tissue following a 45-day laboratory bioaccumulation exposure.

With just a few exceptions concentrations of total DDT were below screening criteria for the protection of human health. A total of six tissue samples with total DDT concentrations ranging from 38 to 46 ppb exceeded the Oregon DEQ human health ATL of 27 ng/g. Five of these tissues were collected from central San Diego Bay including three deepbody anchovy samples from Site B13-8052, a barred sand bass from Site B13-8118 and a California halibut from Site B13-8122; and one tissue sample of slough anchovies was collected in north San Diego Bay (Site SWHB-15).

Concentrations of total DDTs in tissue samples from all species in San Diego Bay fell below all of the screening criteria listed above for risk to wildlife by the Oregon DEQ and State of WA DMMP. A number of samples across taxa and regions exceeded the screening level prey tissue NOEC values of 11 to 57 ng/g for the protection of bird species, but only the five tissues described above exceeded reported prey tissue LOEC values for the protection of birds (Zeeman 2016 draft).

3.4.3 Mercury

Sediment

Sediment mercury concentrations were elevated throughout San Diego Bay. The mean sediment concentration among all RHMP and SWHB sample locations was over twice the ER-L screening value of 150 ng/g at 354 ng/g. North San Diego Bay had seven stations that exceeded the ER-M of 710 ng/g; these stations were located primarily within marina areas (Figure 3-4). Concentrations of mercury at the 30 sites collected shallow regions assessed during the SWHB study in 2014 had a much lower mean concentration of 131 ng/g.

Plankton and Benthic Infauna

Plankton tissue mercury concentrations ranged from 5.55 ng/g at Station SWHB-30 (located in the mouth of San Diego Bay) to 72.1 ng/g at Station SWHB-01 (central San Diego Bay) (Figure 3-9a). The mean concentration of mercury in plankton tissue for all SWHB stations was 25.1 ng/g, which is well below the mean sediment concentration of 354 ng/g.

Crustaceans and mollusks both had overall lower concentrations of mercury relative to polychaetes. The mean tissue concentrations for all stations in San Diego Bay were 31.1 ng/g and 40.5 ng/g, respectively. Concentrations of total mercury in polychaete tissues were generally greater throughout San Diego Bay, with an average of 99.1 ng/g (Figure 3-9b). Relatively elevated mercury concentrations were present specifically in central San Diego Bay Stations SWHB-01 and B13-8060 (polychaete tissue mercury concentrations were 429 ng/g and 236 ng/g, respectively). It is possible that elevated concentrations are due to the presence of sediment in the polychaete intestinal tube. Most of the polychaetes in the samples were likely to be sediment deposit feeders that live within a tube partially constructed of sediment. Additionally, the relatively small size of the polychaetes may have increased the occurrence of contamination of the sample with sediment containing higher mercury concentrations.

Fish

Relatively elevated concentrations of mercury in forage fish tissues were identified in central San Diego Bay (Figure 3-9c), however overall concentrations were low. The mean tissue concentration of forage fish tissue was 31.0 ng/g, which is similar to levels observed in plankton, crustaceans, and mollusks. The greatest concentration of mercury observed in forage fish was in tissue from the deepbody anchovy from RHMP Station B13-8052[6] in central San Diego Bay (107 ng/g).

Mercury concentrations of predatory fish tissues were overall greater than concentrations observed in forage fish (Figure 3-9d). Concentrations ranged from 22.9 ng/g (California halibut caught at Station SWHB-21 in south San Diego Bay) to 239 ng/g (also a California halibut,

[6] Three replicates of deepbody anchovy tissue were analyzed at this station for QA purposes. The mean value of the three replicates represented the station concentration for deepbody anchovies.

caught at Station SWHB-40 in central San Diego Bay). The mean tissue concentration for all stations was 69.8 ng/g, which is over twice the average concentration of forage fish.

Risk Assessment

The concentrations of total mercury in tissues was compared to several screening level guidelines based on both human health and wildlife risk as follows:

- OEHHA Fish Consumption ATLs: No more than 3 servings per week: 70 to 150 ng/g wet weight (women aged 18-45 years and children 1-17 years), and 220 to 440 ng/g (women > 45 years of age and men). No consumption: > 440 ng/g wet weight (women aged 18-45 years and children 1-17 years), and > 1,310 ng/g (women > 45 years of age and men).
- Oregon DEQ (2007): Lowest ATL for applicable wildlife (74 ng/g wet weight for birds); ATL for humans (400 ng/g wet wt. - general/ recreational); and the Critical Tissue Level (CTL) in fish, shellfish, or other saltwater aquatic organisms (180 ng/g wet wt.). Reported as either total inorganic mercury or methyl mercury.
- U.S. Fish and Wildlife - Screening values for San Diego Bay (Zeeman 2007): < 120 ng/g dry weight NOEC value for fish.
- U.S. Fish and Wildlife - Initial wildlife risk-based screening levels for contaminants in tissue of aquatic biota San Diego Bay (Zeeman, draft June 3, 2016): 4.9 to 25.2 ng/g wet wt. NOEC values to birds from consuming invertebrates or fish; and 12.3 to 62.9 ng/g (most sensitive) or 221 to 1132 ng/g (mid-range) wet wt. LOEC values to birds from consuming invertebrates or fish.
- State of Washington DMMP: Target Tissue Level (TTL) to protect wildlife and human health from ocean disposal of dredged material: 1,000 ng/g wet wt. based on total mercury in clam or worm tissue following a 45-day laboratory bioaccumulation exposure.

Concentrations of total mercury in tissue samples from all species in San Diego Bay were below all of the screening criteria above for risk to human health for women > 45 years in age and men > 18 years of age. A single tissue sample from a California halibut collected from site SWHB-40 in central San Diego Bay had a tissue concentration (239 ng/g) that exceeded the OEHHA three servings/week threshold of 220 ng/g for humans regardless of age or sex. Excluding the single halibut from SWHB-40, a total of 14 fish tissue samples had total mercury concentrations that exceeded the 3 servings/week criterion of 70 ng/g for women < 45 years in age and children less than 17 years old. Of these, 10 were from either spotted bay bass or barred sand bass located throughout the bay, one was from a round sting ray collected from south San Diego Bay (B13-8017), and three were deepbody anchovy samples collected from central San Diego Bay at Site B13-8052. The mean tissue concentration of mercury in predatory fish was equivalent to the 70 ng/g OEHAA human health criterion for women aged 18-45 years and children 1-17 years; no more than 3-servings per week. The mean value for forage fish (31 ng/g) was less than all human health criteria

No fish tissue samples exceeded the Oregon DEQ human health risk value of 400 ng/g or the State of Washington DMMP criterion of 1,000 ng/g.

Concentrations of mercury in tissue samples exceeded a number of mercury screening level values for the protection of wildlife (ranging from < 120 to 180 ng/g), published by Zeeman (2007) and Oregon DEQ (2007); particularly in a few polychaete samples from central San Diego Bay, and spotted bay bass throughout the bay as described above. Mean concentrations for all species or species groups were however all less than these values. When compared to the draft wildlife screening values summarized by Zeeman (2016), many individual and average tissue concentrations throughout the bay exceed NOEC and LOEC values for the most sensitive bird species, but are less than all of the LOEC values based on mid-range sensitive bird species.

3.4.4 Selenium

Sediment

Selenium concentrations ranged from less than the reporting limit of 0.05 micrograms per gram (µg/g) to 0.62 µg/g. The mean selenium concentration for all stations in San Diego Bay was 0.23 µg/g. There are no ER-L or ER-M screening values for selenium concentrations in sediment.

Plankton and Benthic Infauna

With the exception of plankton tissue, tissue concentrations of selenium across all species groups (including fish) were generally greater than the mean selenium sediment concentration measured in San Diego Bay. The highest concentrations were observed in invertebrates; the mean concentration of selenium found in crustaceans and mollusks were over twice the mean concentration found in sediment (0.50 µg/g and 0.53 µg/g, respectively), and the mean selenium concentration in polychaetes were about five times the sediment mean (1.3 µg/g). The greatest single concentration value of selenium was found in polychaete tissue from Station B13-8122 in north San Diego Bay, which was over tenfold the mean sediment concentration (2.6 µg/g). A distinct overall spatial pattern was not apparent for selenium tissue concentrations in plankton or infauna.

Fish

As mentioned, mean concentrations of selenium in fish tissue were higher than the mean sediment concentration. Predatory fish had relatively elevated selenium concentrations, as the mean selenium concentration among all predatory fish (0.22 µg/g) was nearly twice the concentration observed in sediment. The maximum concentration was found in round ray tissue from Station B13-8017 (1.5 µg/g) with the remaining predatory fish concentrations ranging from 0.26 µg/g to 0.53 µg/g.

Forage fish had relatively lower selenium concentrations compared to predatory fish. The mean selenium concentration in forage fish tissue was approximately 0.31 µg/g, which is about 35 percent greater than the mean concentration found in sediment. The maximum tissue concentration was not much greater than the mean at 0.37 µg/g (observed in black perch tissue at Station SWHB-26 in north San Diego Bay).

As with plankton and infauna a distinct overall spatial pattern was not apparent for selenium tissue concentrations in fish species.

Risk Assessment

The concentrations of selenium in tissues was compared to several screening level guidelines based on both human health and wildlife risk as follows:

- OEHHA Fish Consumption Advisory Tissue Levels (ATLs): 2.5 to 4.9 µg/g (ppm) wet weight (no more than 3 servings per week), and > 15 µg/g (no consumption).
- Oregon DEQ (2007): Lowest ATL for applicable wildlife (0.036 µg/g wet weight for mammals and 0.23 µg/g wet weight for individual birds); ATL for humans (20 µg/g wet wt. - general/ recreational); and the Critical Tissue Level (CTL) in fish, shellfish, or other saltwater aquatic organisms (0.34 µg/g wet wt.).
- State of Washington DMMP: Target Tissue Level (TTL) to protect wildlife and human health from ocean disposal of dredged material: 3 µg/g wet wt. in clam or worm tissue following a 45-day laboratory bioaccumulation exposure.
- SWRCB TMDL for selenium in San Francisco Bay: 8.0 µg/g dry weight whole body fish tissue or 11.3 µg/g dry weight mussel tissue to protect both wildlife and human health.

Concentrations of selenium in tissue samples from all fish species in San Diego Bay were below all available criteria for the protection of human health. Only a single polychaete sample (2.6 µg/g selenium) from north San Diego Bay exceeded the most conservative human health risk value of 2.5 µg/g for this chemical.

No tissue samples had dry weight concentrations of selenium exceeding estimates for the protection of wildlife in San Francisco Bay based on the TMDL for this water body (even after correcting for moisture content), but quite a few samples exceeded Oregon DEQ ATLs for the protection of birds and mammals, as well as the Oregon DEQ CTL value for fish, shellfish, or other aquatic organisms. Applicability of selenium ATL and CTL values derived by the Oregon DEQ to species found in San Diego Bay is uncertain at this time without further investigation.

3.4.5 Total Chlordanes

Sediment

Total chlordane concentrations in sediment were relatively low throughout stations in San Diego Bay. The mean concentration of all stations was 0.86 ng/g. This concentration value was driven primarily by three stations, all of which are in freshwater-influenced areas. These three stations (B13-8075, B13-8077, and B13-8500) had concentrations that exceeded the ER-M screening value of 6.0 ng/g for total chlordanes. Ten stations exceeded the ER-L of 0.5 ng/g, and the majority of stations in San Diego Bay had total chlordane sediment concentrations that were non-detectable (<0.05 ng/g).

Plankton and Benthic Infauna

Total chlordane concentrations found in plankton tissues were relatively low. The majority of samples had non-detectable concentrations. The greatest concentration was found in plankton tissue from Station SWHB-26 (1.3 ng/g), in north San Diego Bay. Crustacean and mollusk tissue concentrations were also relatively low; both concentration means were lower than the mean sediment concentration. Polychaete tissue concentrations were elevated relative to crustacea and mollusk tissue. The mean concentration in polychaete tissues was 4.4 ng/g; this mean was driven by tissue collected at Station B13-8060 in central San Diego Bay, with a reported concentration 62 ng/g. The remaining polychaete tissue concentrations ranged from non-detectable (< 0.05 ng/g) to 4.6 ng/g.

Fish

The mean concentration of total chlordane (approximately 1.5 ng/g) found in forage fish tissue was elevated in comparison to the means of sediment, plankton, crustaceans, and mollusks, as well as the majority of individual tissue concentrations of polychaetes. Total chlordane concentrations in forage fish ranged from 0.03 ng/g (shiner perch issue from Station SWHB-27 in north San Diego Bay) to 7.7 ng/g (shiner perch tissue from Station SWHB-27 in north San Diego Bay). Predatory fish with a mean total chlordane tissue concentration of 1.9 ng/g had elevated concentrations of approximately 30-percent greater than the mean concentration in forage fish. Total chlordane concentrations ranged from non-detect (found in Stations B13-8020 [barred sand bass] and SWHB-30 [California halibut]) to 10 ng/g (found in round stingray tissue from Station B13-8017 in south San Diego Bay).

As with selenium, a distinct overall spatial pattern was not apparent for chlordane in tissue concentrations for all species.

Risk Assessment

The concentrations of total chlordanes in tissues was compared to several screening level guidelines based on both human health and wildlife risk as follows:

- OEHHA Fish Consumption: 190 to 280 ng/g wet weight (no more than 3 servings per week), and > 560 ng/g (no consumption).
- Oregon DEQ (2007): Lowest Advisory Tissue Levels (ATLs) for applicable wildlife (1,200 ng/g wet weight for birds and 3,300 ng/g wet wt. for mammals); ATL for humans (27 ng/g wet wt. - general/ recreational); and the Critical Tissue Level (CTL) in fish, shellfish, or other saltwater aquatic organisms (56 ng/g wet wt.).
- State of Washington DMMP: Target Tissue Level (TTL) to protect wildlife and human health from ocean disposal of dredged material: 300 ng/g wet wt. based on total chlordanes in clam or worm tissue following a 45-day laboratory bioaccumulation exposure.
- U.S. Fish and Wildlife - Initial wildlife risk-based screening levels for contaminants in tissue of aquatic biota San Diego Bay (Zeeman, draft June 3, 2016): 196 to 1,006 ng/g wet wt. NOEC values to birds from consuming invertebrates or fish; and 8,578 to 44,025 ng/g wet wt. LOEC values to birds from consuming invertebrates or fish.

Concentrations of total chlordanes in tissue samples from all fish species in San Diego Bay were below all available criteria for the protection of human health. Only one tissue sample (polychaetes from Site B13-8060 in central San Diego Bay) had a concentration (61.6 ng/g) in excess of a wildlife threshold value (Oregon DEQ CTL of 56 ng/g). This concentration also exceeded the Oregon DEQ human health ATL of 27 ng/g, but was well below the most conservative OEHHA fish consumption guideline values. No concentrations of chlordane in tissues exceeded the NOEC and LOEC prey item threshold values for the protection of bird species summarized by U.S. Fish and Wildlife (Zeeman, 2016 draft).

3.4.6 PBDEs

Sediment

The mean total PBDE concentration of 5.1 ng/g among stations in San Diego Bay was relatively low, however, individual station concentrations varied greatly. Sediment concentrations ranged from non-detect (< 0.05 ng/g) to 58 ng/g. Relatively elevated concentrations of PBDEs were observed at stations closer to freshwater-influences. There are no threshold values currently set for PBDEs. However, PBDEs have recently been labeled as a “chemical of emerging concern” (Kimbrough et al., 2009). During a 2012 study of PBDE concentrations in the southern California Bight, the area-weighted geometric mean total PBDE concentration was found to be 12 ng/g within embayments (Dodder et al., 2012). Thirteen stations in this study had concentrations at or above this value.

Plankton and Benthic Infauna

Relatively greater concentrations of total PBDEs were observed in lower trophic levels during this study. Plankton tissues ranged from 1.9 ng/g (Station SWHB-22 in south San Diego Bay) to 108 ng/g (Station SDC1 in central San Diego Bay). The mean concentration in San Diego Bay was approximately 18 ng/g. Invertebrate concentrations were slightly lower. The mean concertation in mollusk tissues was 1.4 ng/g, 6.0 ng/g in polychaete tissues, and approximately 11 ng/g in crustacean tissues. The value for crustacean tissue was primarily driven by Station SWHB-21 in south San Diego Bay with a tissue concentration of 99 ng/g.

Fish

The mean concentration of total PBDEs found in forage fish was similar to mean sediment concentrations at 5.1 ng/g. The maximum concentration was found in arrow goby tissue at Station SD2/3 in south San Diego Bay (20 ng/g). Predatory fish had overall lower relative concentrations; the mean concentration was 2.2 ng/g. The highest tissue concentration among predatory fish was found in the round ray collected at Station B13-8017 in south San Diego Bay.

Overall, concentrations of PBDEs in tissues from all species were greatest in the central and south regions of San Diego Bay though a distinct consistent pattern was not observed as with selenium and chlordanes.

Risk Assessment

There is currently a lack of data in the literature to establish a meaningful risk of PBDE exposure in fish tissue to human health. The concentrations of total PBDEs in tissues were only compared to screening levels based on wildlife risk as follows:

- U.S. Fish and Wildlife - Initial wildlife risk-based screening levels for contaminants in tissue of aquatic biota San Diego Bay (Zeeman, draft June 3, 2016): 12 to 60 ng/g wet wt. NOEC values to birds from consuming invertebrates or fish; and 118 to 604 ng/g wet wt. LOEC values to birds from consuming invertebrates or fish.

Concentrations of total PBDEs exceeded the lowest NOEC value of 12 ng/g for the protection of the California least tern in four plankton samples, a single crustacean sample, a single polychaete sample, and five forage fish composite samples (northern anchovy, arrow goby, shiner perch, and two topsmelt samples). Only two of the samples, the crustacean sample from Site SWHB-21 in south San Diego Bay, and a plankton sample from Site SDC1 in central San Diego Bay had total PBDE concentrations that exceeded NOEC values between 12 and 60 ng/g for the protection of other bird species. No tissue concentrations exceeded the lowest LOEC value of 118 ng/g.

Overall, greatest tissue concentrations of PBDEs were located in the central and southern portions of the bay, though clear trends among locations and species are not readily apparent.

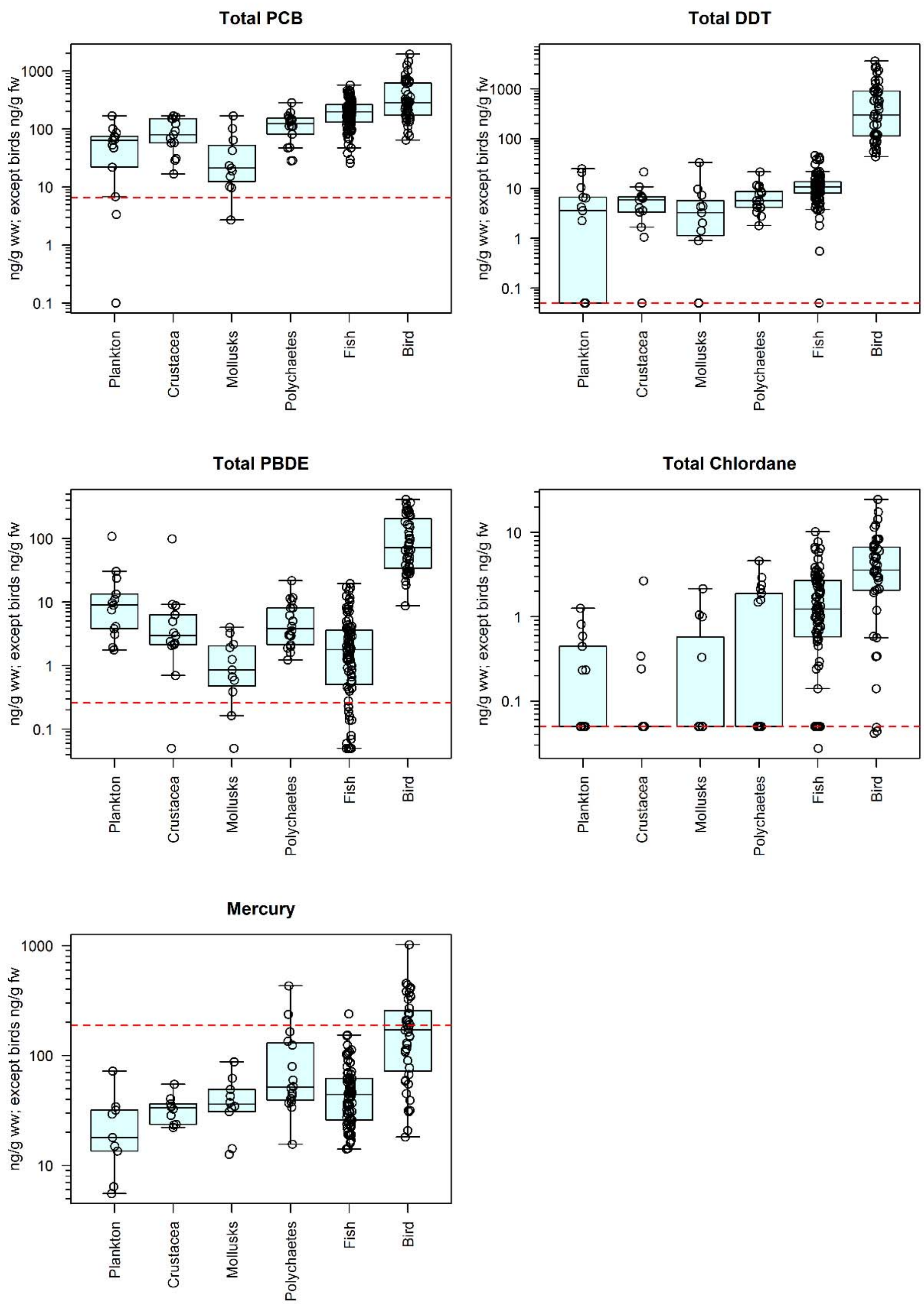

Figure 3-6. Summary of Select Tissue COPC Data for all of San Diego Bay (Bight'13/RHMP and SWHB Studies)

The median is represented by the horizontal line, the box shows the interquartile range (IQR), and the whiskers show potential outliers and extend to the farthest data point that is <1.5 x IQR from the box. Circles show individual data values. Dashed lines indicate average contaminant concentrations in sediment (dry weight basis).

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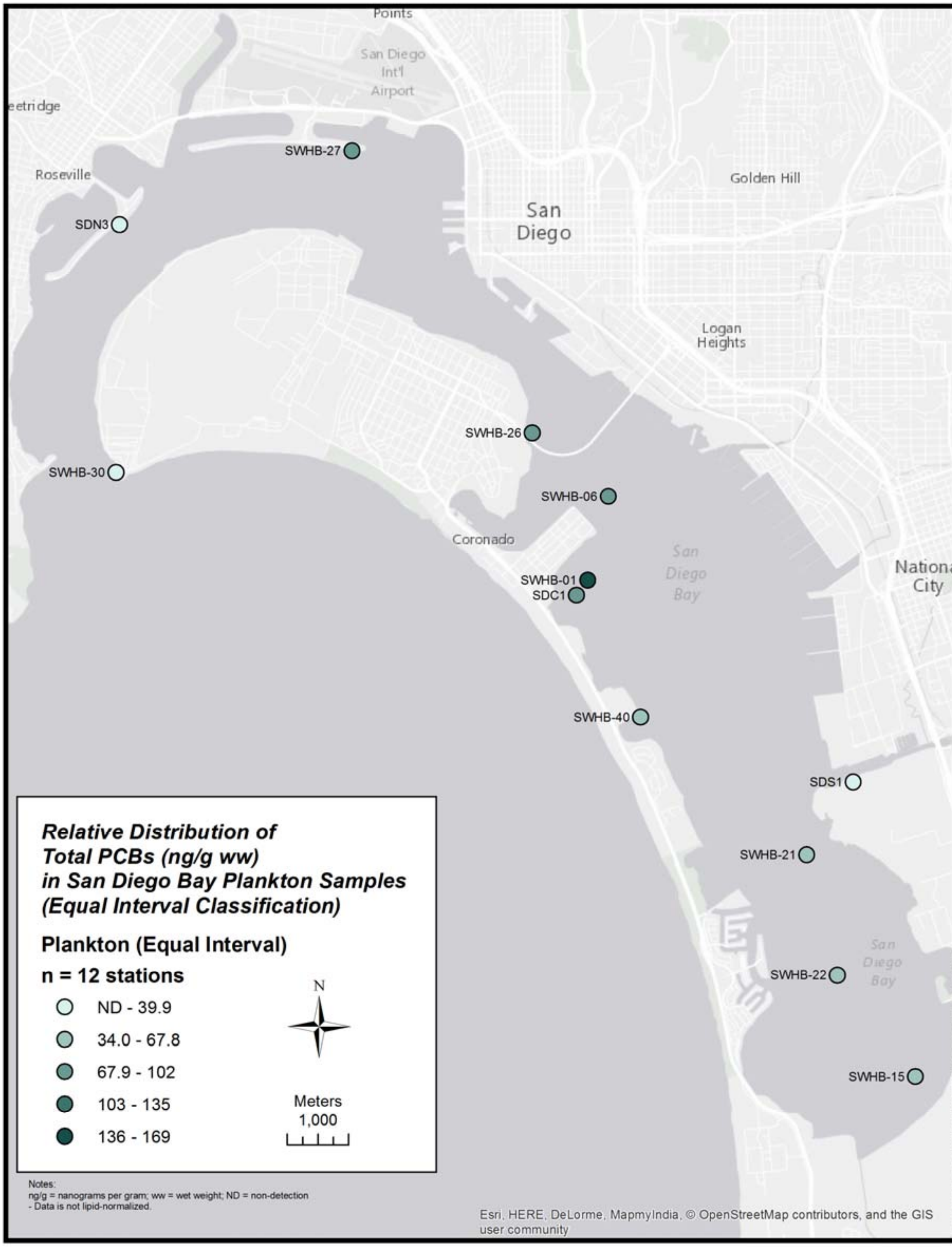

Figure 3-7a. Spatial assessment of total PCBs in tissues for the Bight '13/RHMP and SWHB studies – Plankton

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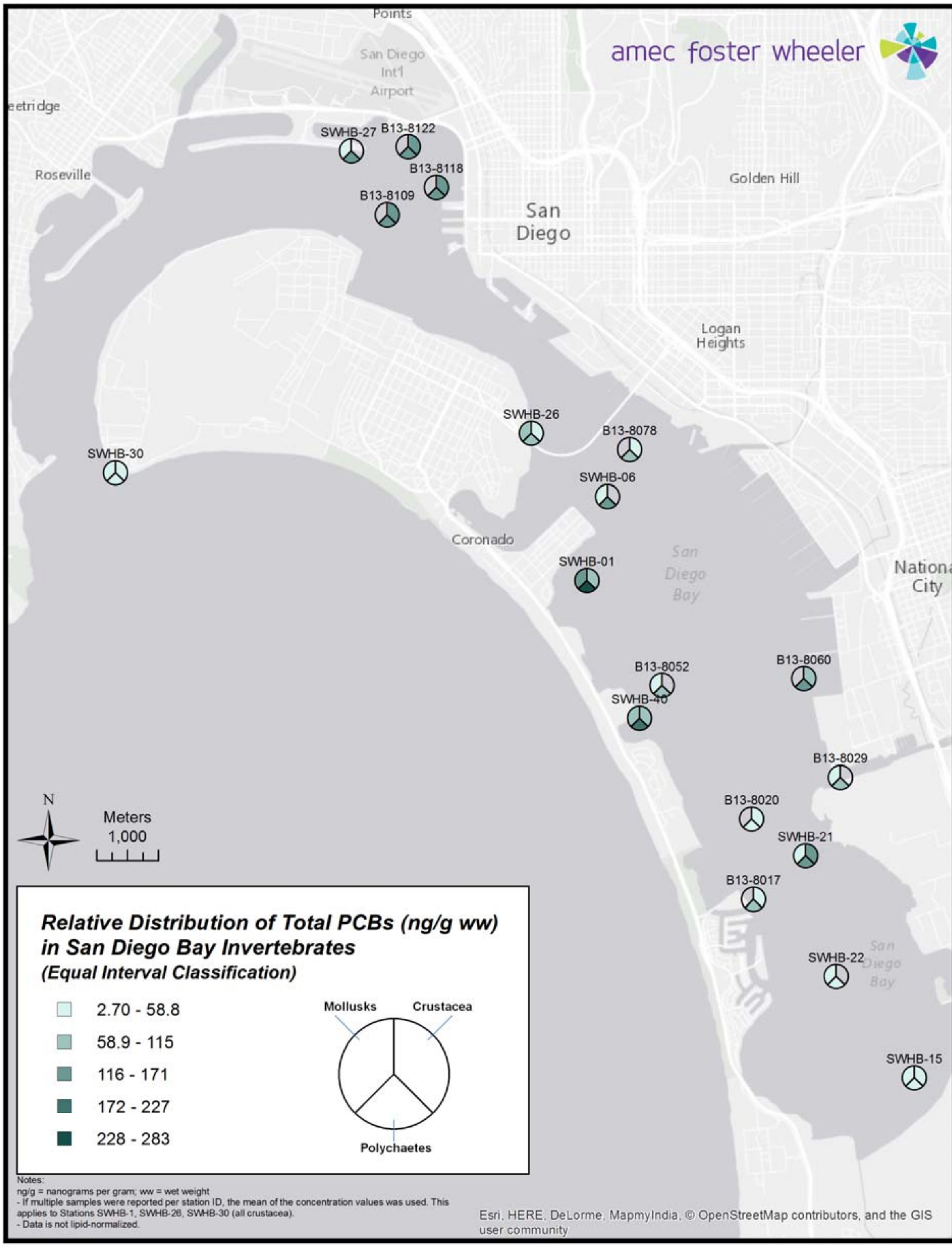

Figure 3-7b. Spatial assessment of total PCBs in tissues for the Bight '13/RHMP and SWHB studies – Invertebrates

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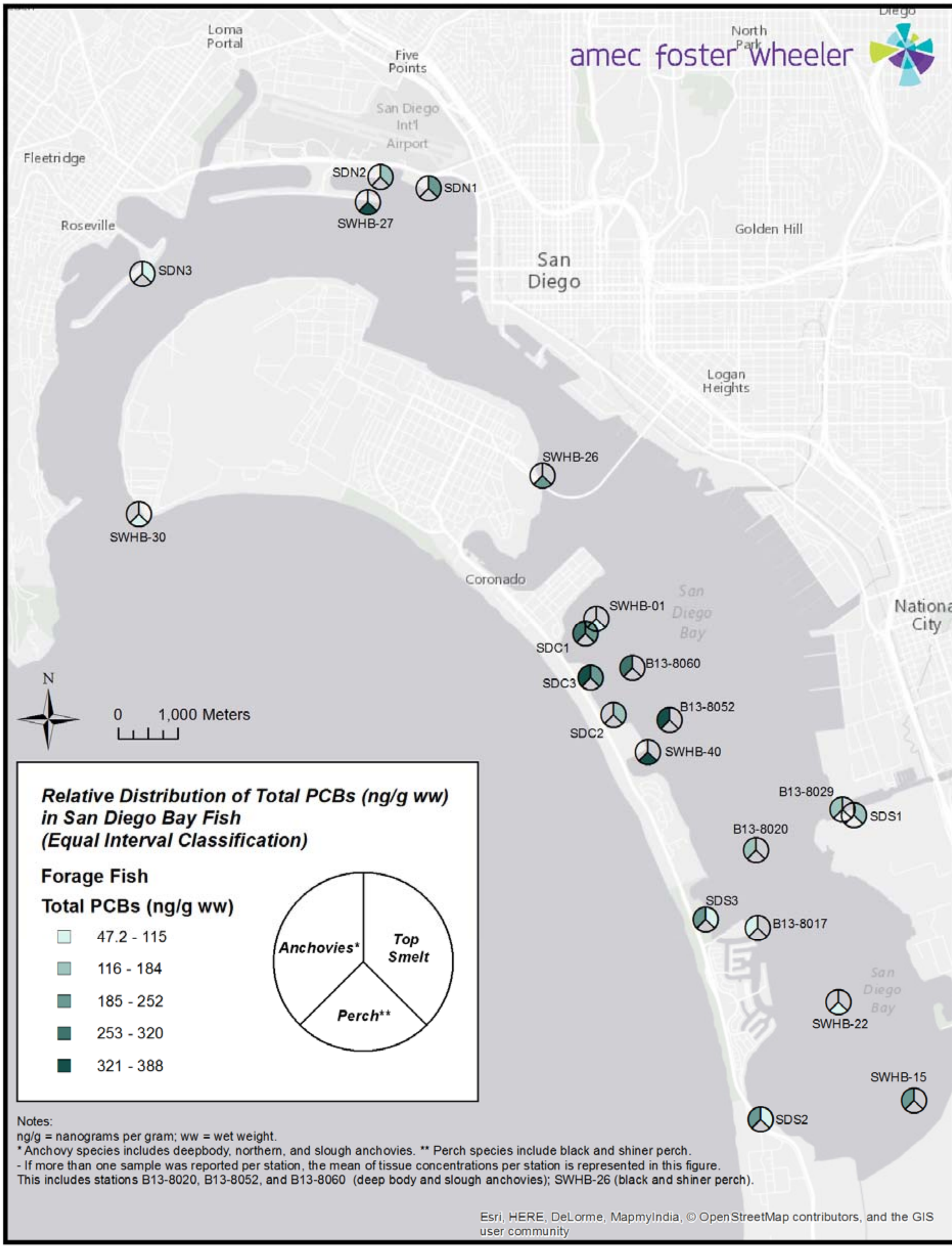

Figure 3-7c. Spatial assessment of total PCBs in tissues for the Bight '13/RHMP and SWHB studies – Forage fish

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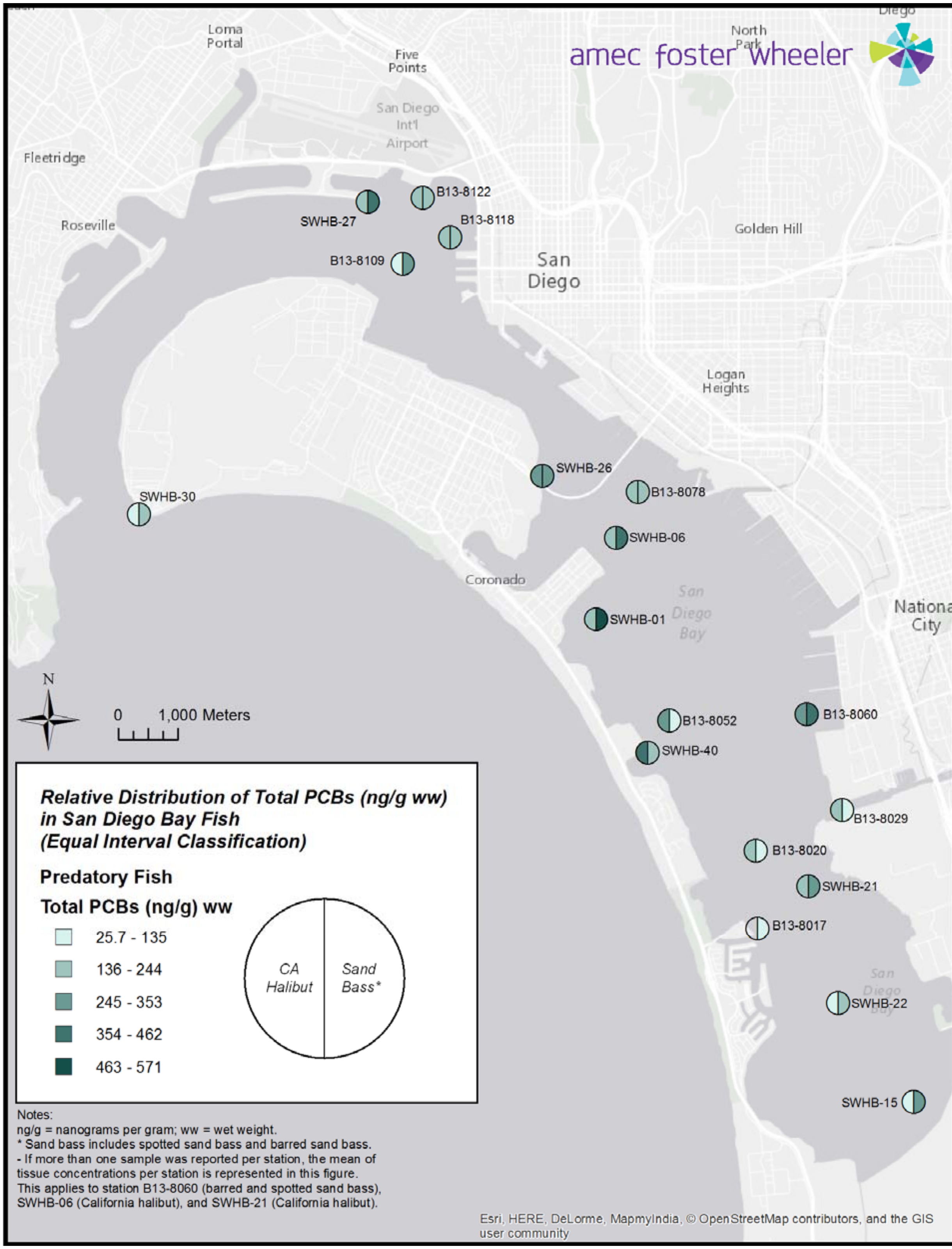

Figure 3-7d. Spatial assessment of total PCBs in tissues for the Bight '13/RHMP and SWHB studies – Predatory fish

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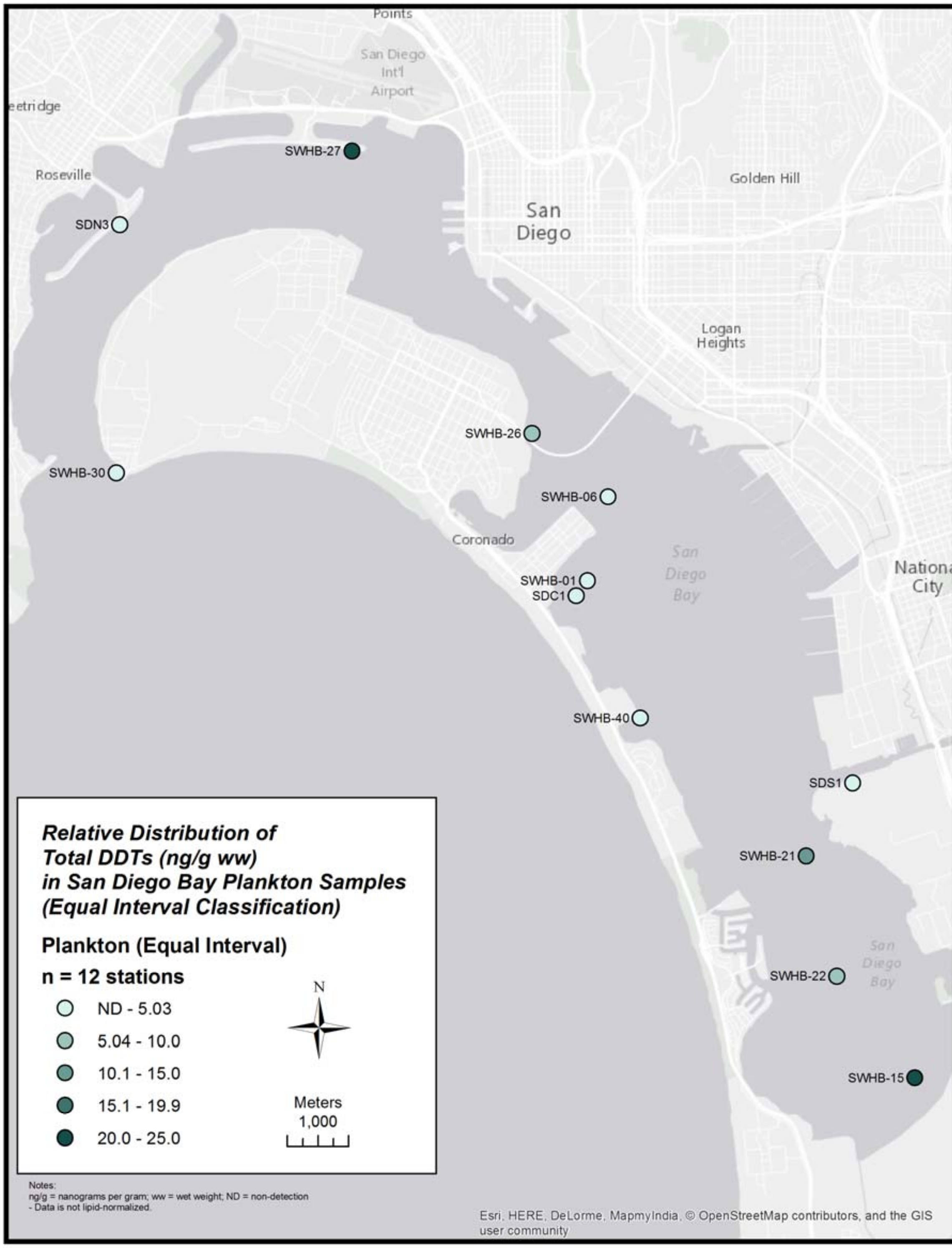

Figure 3-8a. Spatial Assessment of Total DDTs in Tissues for Bight '13/RHMP and the SWHB Study – Plankton

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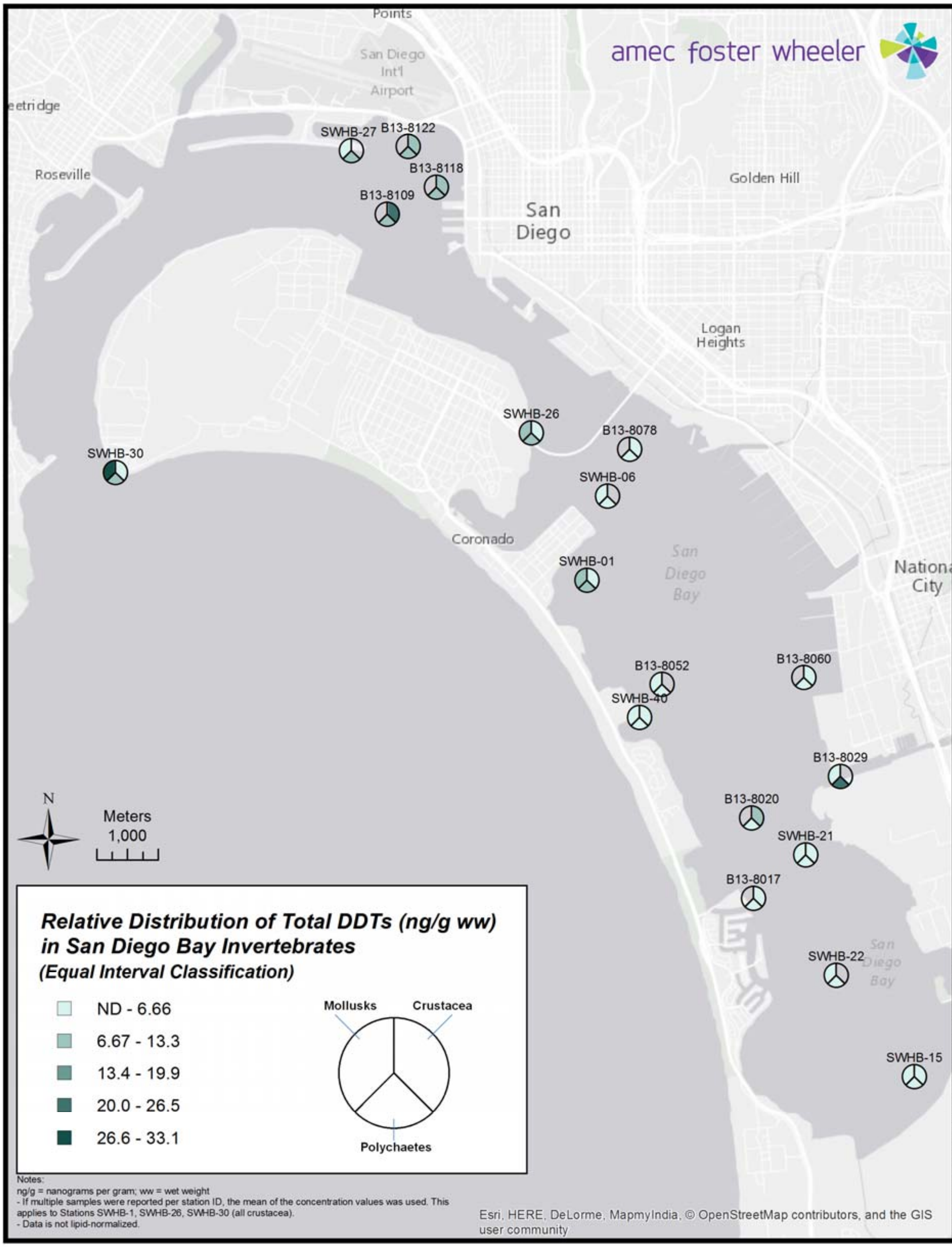

Figure 3-8b. Spatial Assessment of Total DDTs in Tissues for Bight '13/RHMP and the SWHB Study – Invertebrates

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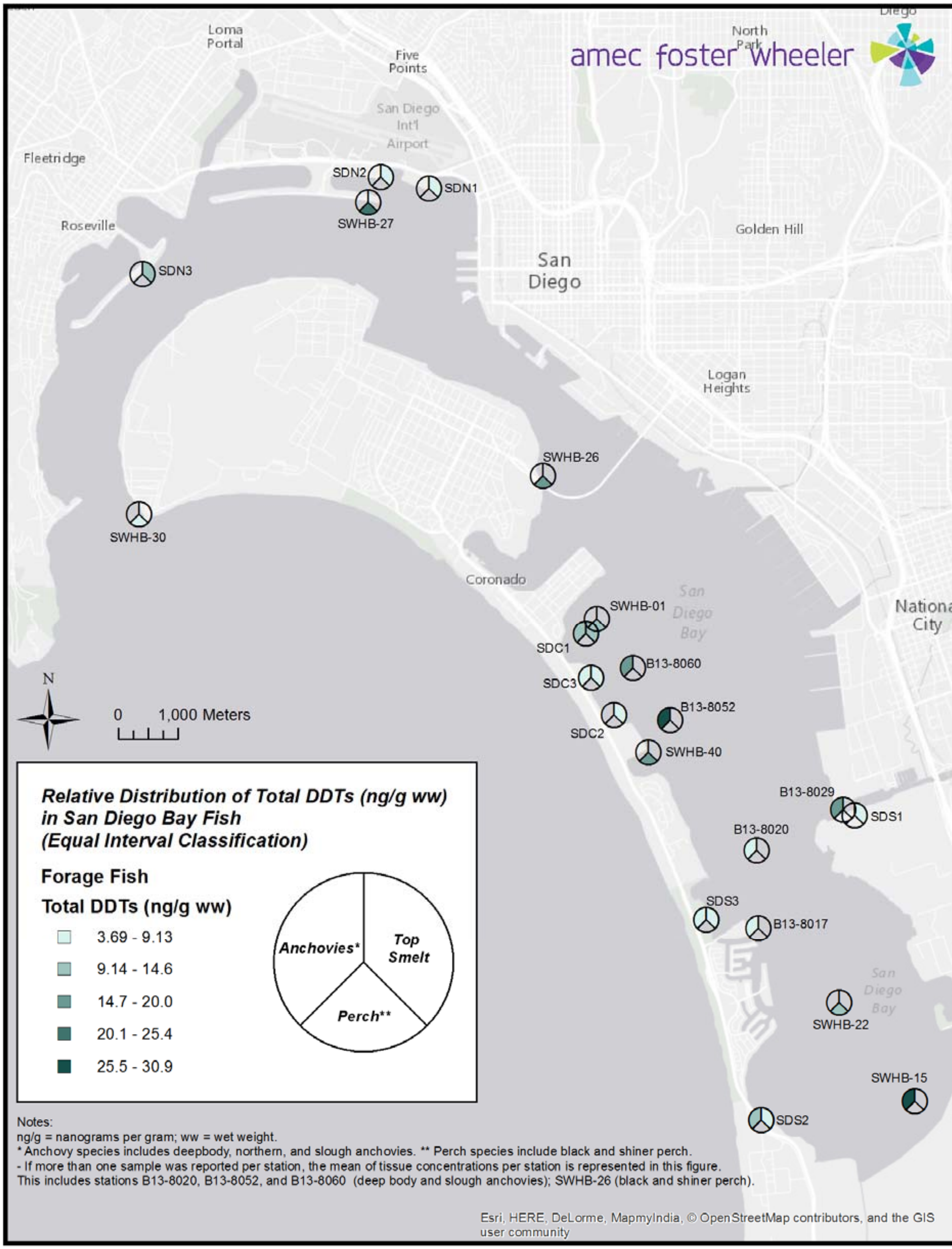

Figure 3-8c. Spatial Assessment of Total DDTs in Tissues for Bight '13/RHMP and the SWHB Study – Forage Fish

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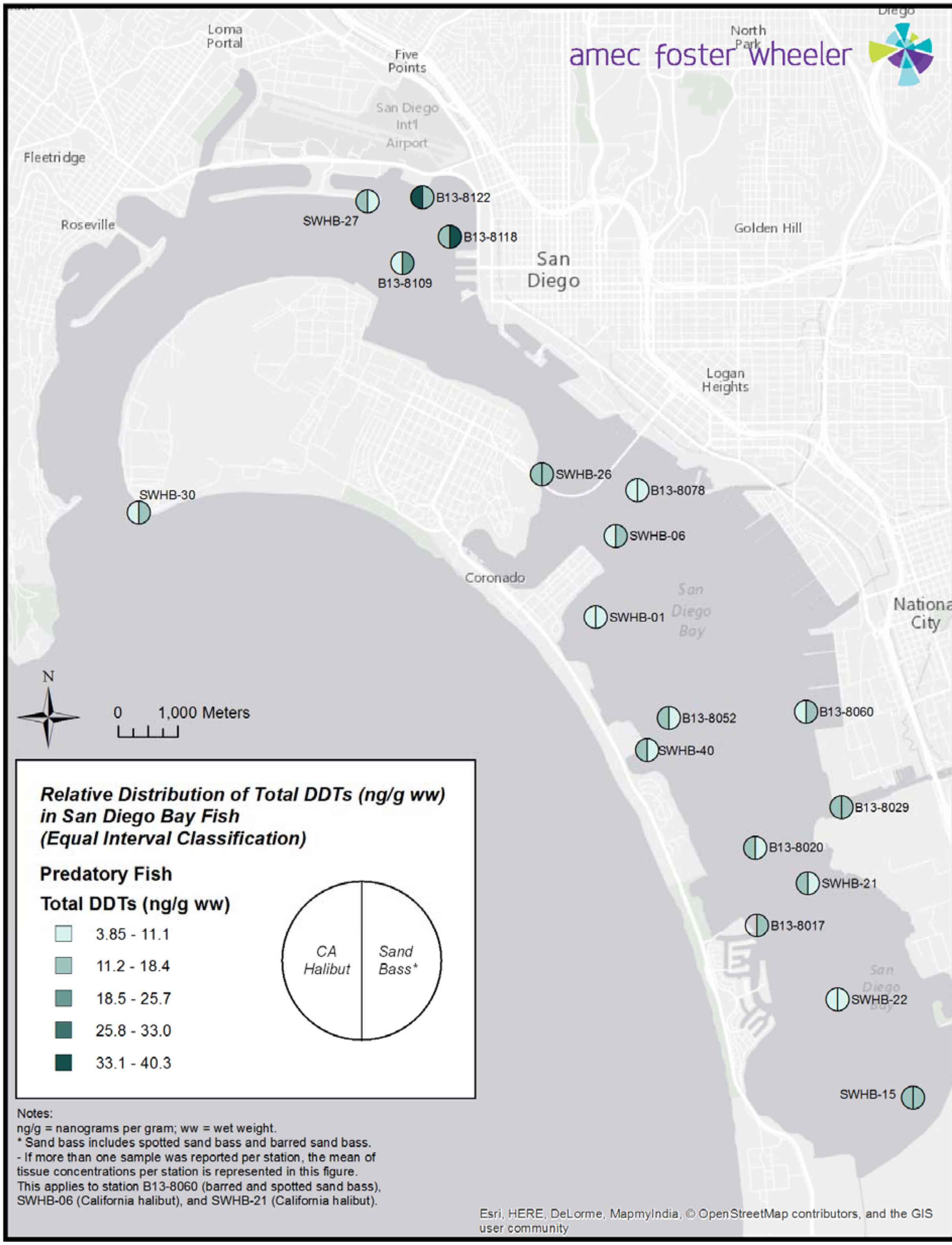

Figure 3-8d. Spatial Assessment of Total DDTs in Tissues for Bight '13/RHMP and the SWHB Study – Predatory Fish

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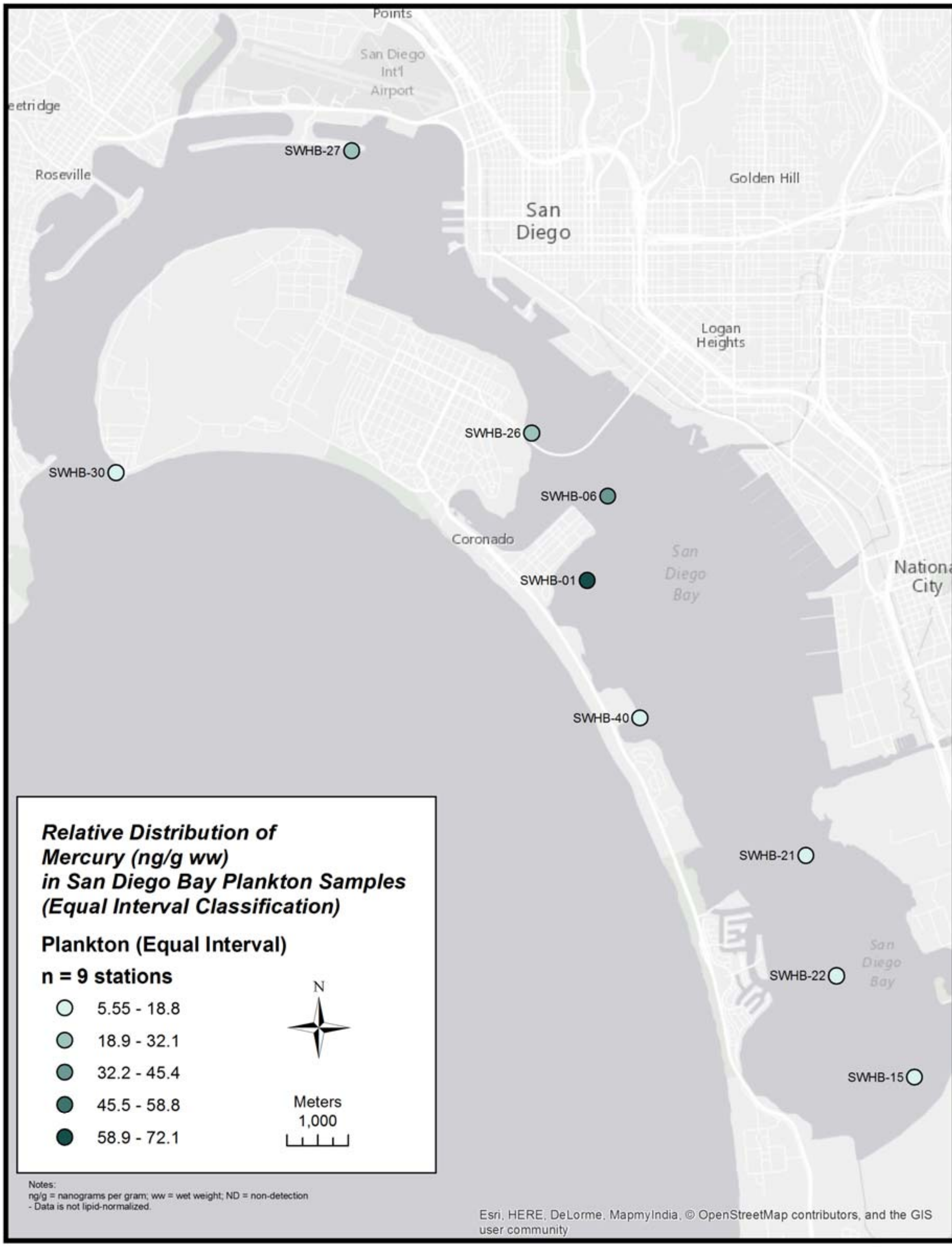

Figure 3-9a. Spatial Assessment of Total Mercury in Tissues for Bight '13/RHMP and the SWHB Study – Plankton

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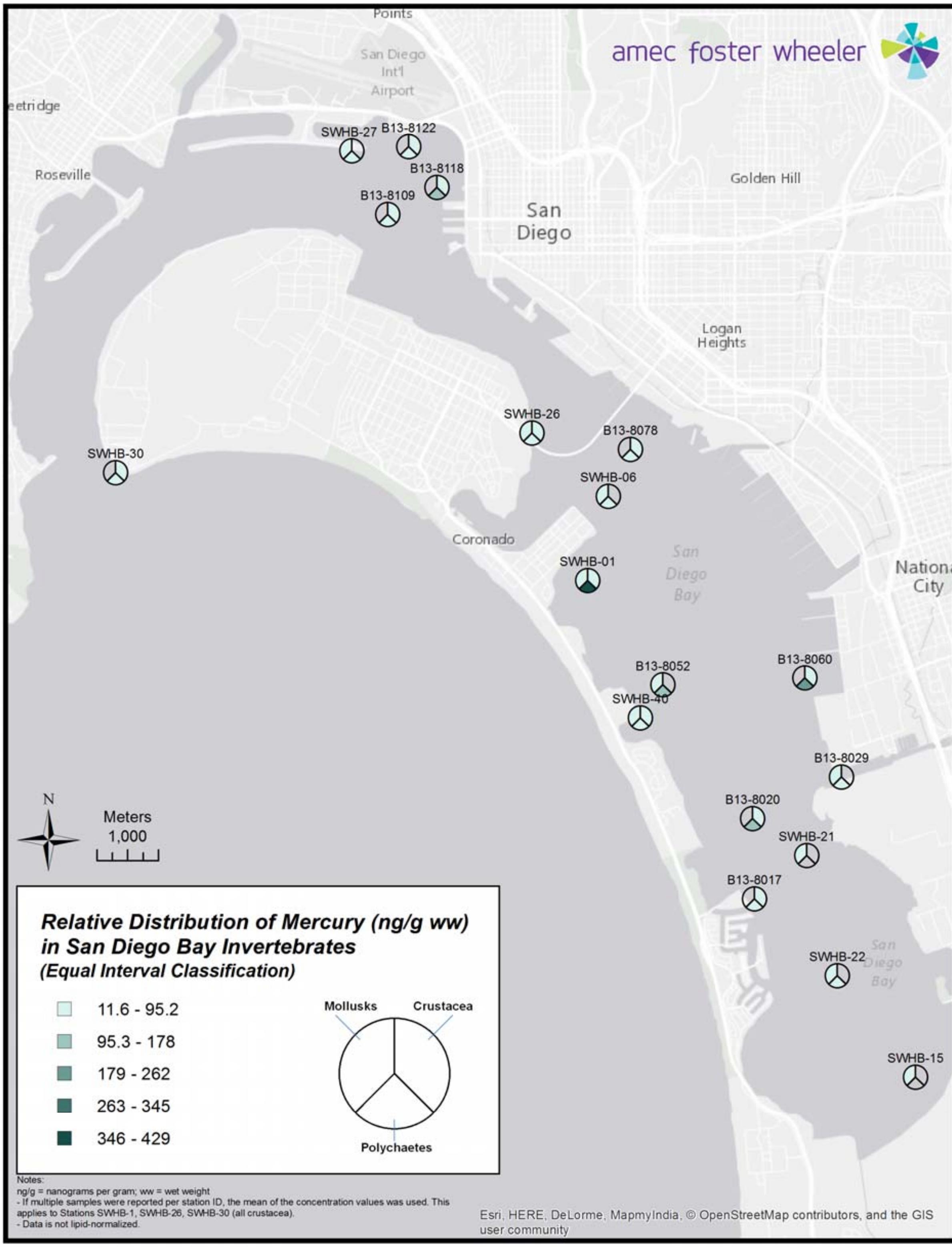

Figure 3-9b. Spatial Assessment of Total Mercury in Tissues for Bight '13/RHMP and the SWHB Study – Invertebrates

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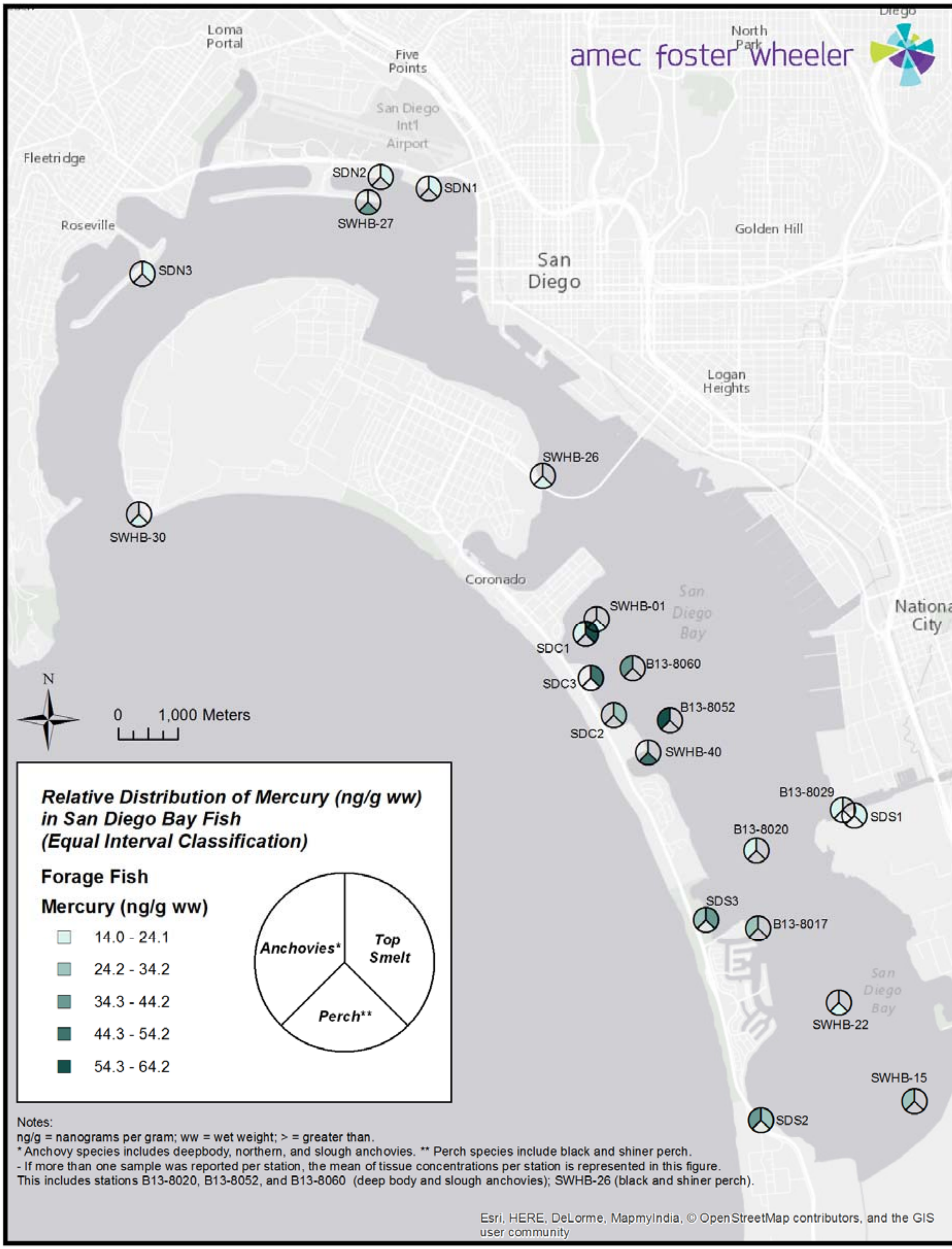

Figure 3-9c. Spatial Assessment of Total Mercury in Tissues for Bight '13/RHMP and the SWHB Study – Forage Fish

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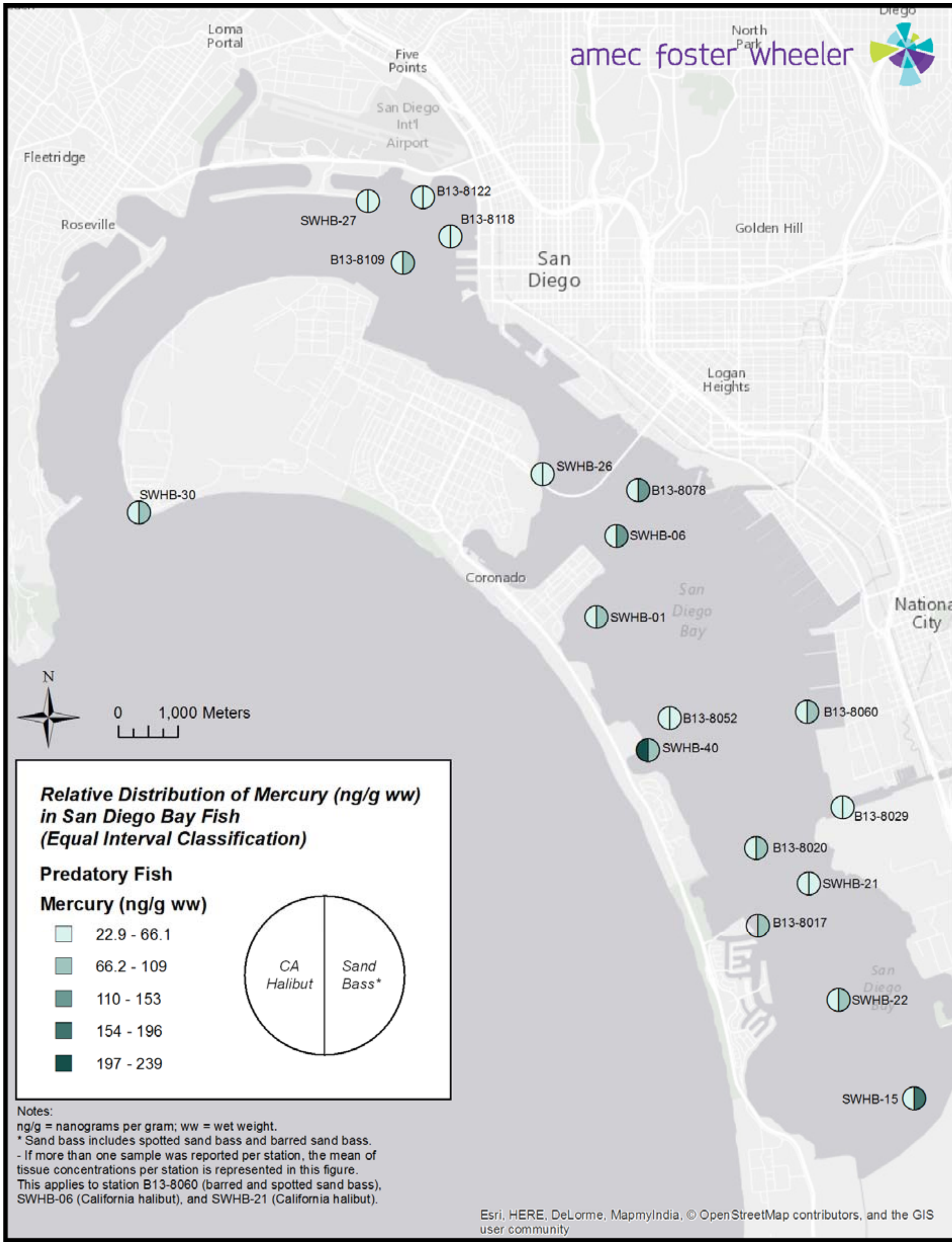

Figure 3-9d. Spatial Assessment of Total Mercury in Tissues for Bight '13/RHMP and the SWHB Study – Predatory Fish

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3.5 Tissue Contaminant Concentrations - Individual Site Assessment

A graphical summary of tissue concentration data for major invertebrate classes (polychaetes, crustacea, mollusks, and plankton), and individual fish species at each sampling location is provided in Appendix E for total PCBs, total DDTs, and mercury. A few examples for each of these three COPCs is provided below in Figure 3-10a and 3-10b. For total PCBs, tissue concentrations were also normalized for lipid content and displayed for comparison purposes. Similar data was presented in the associated report by SCCWRP without lipid normalizing (Bay et al., 2016 draft), however sites were combined by region (north, central, and south San Diego Bay) for that assessment.

In general, chemical concentrations of PCBs and DDTs increased with increasing trophic levels, however a variety of patterns were observed that did not always match this trend. As an example, total PCBs in tissues collected from Site SWHB-27 located in north San Diego Bay near the east edge of Harbor Island showed a consistent trend of increasing concentrations from invertebrates and plankton to shiner perch and spotted bay bass. Concentrations of PCBs in California halibut, however, were generally lower than other top predators bay-wide, likely due to their lower lipid content, fast growth rates, and tendency to move in and out of the bay as they mature. When normalizing for lipids, the concentration of PCBs in California halibut are often more similar to that for spotted bay bass as shown in Figure 3-10a. Note that concentrations of PCBs were also elevated in sediments at Site SWHB-27 relative to all other locations where tissue was collected.

As a comparison, PCB tissue data for Site SWHB-15, located in the far southern portion of San Diego Bay is also presented in Figure 3-10a. Sediment concentrations of PCBs are low at this site, but a similar less pronounced trend in bioaccumulation among trophic levels is still noted.

In general, DDTs tended to show more variable bioaccumulation patterns among trophic levels than PCBs as shown in Figure 3-10b for Sites B13-8020 located in south San Diego Bay and B13-8109 located in north San Diego Bay. In this case crustacea had the greatest concentrations of DDT at Site B13-8109, and nearly the greatest concentrations at Site B13-8020, comparable to that in California halibut.

A rather interesting observation was the concentrations of PCBs and DDTs in the plankton, which were often similar to or greater than that in other invertebrates and some fish species. This would likely explain the elevated concentrations often observed in associated planktivores; anchovy and shiner perch in particular. Also of note is that elevated concentrations of PCBs and DDTs were observed in plankton and other species at locations with sediments that appear relatively clean. This is not too surprising given the mobility of species in the water column which may have had exposure to elevated concentrations elsewhere.

Mercury concentrations failed to show a consistent pattern of bioaccumulation among trophic levels at individual locations. Concentrations were generally similar with a few inconsistent outliers such as that observed in polychaetes relative to other species at Site B13-8020 as shown in Figure 3-10b. Collectively when data were combined by region (north, central, and south), an increasing concentration trend was more evident for mercury (See Figure 3-6).

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Total PCBs

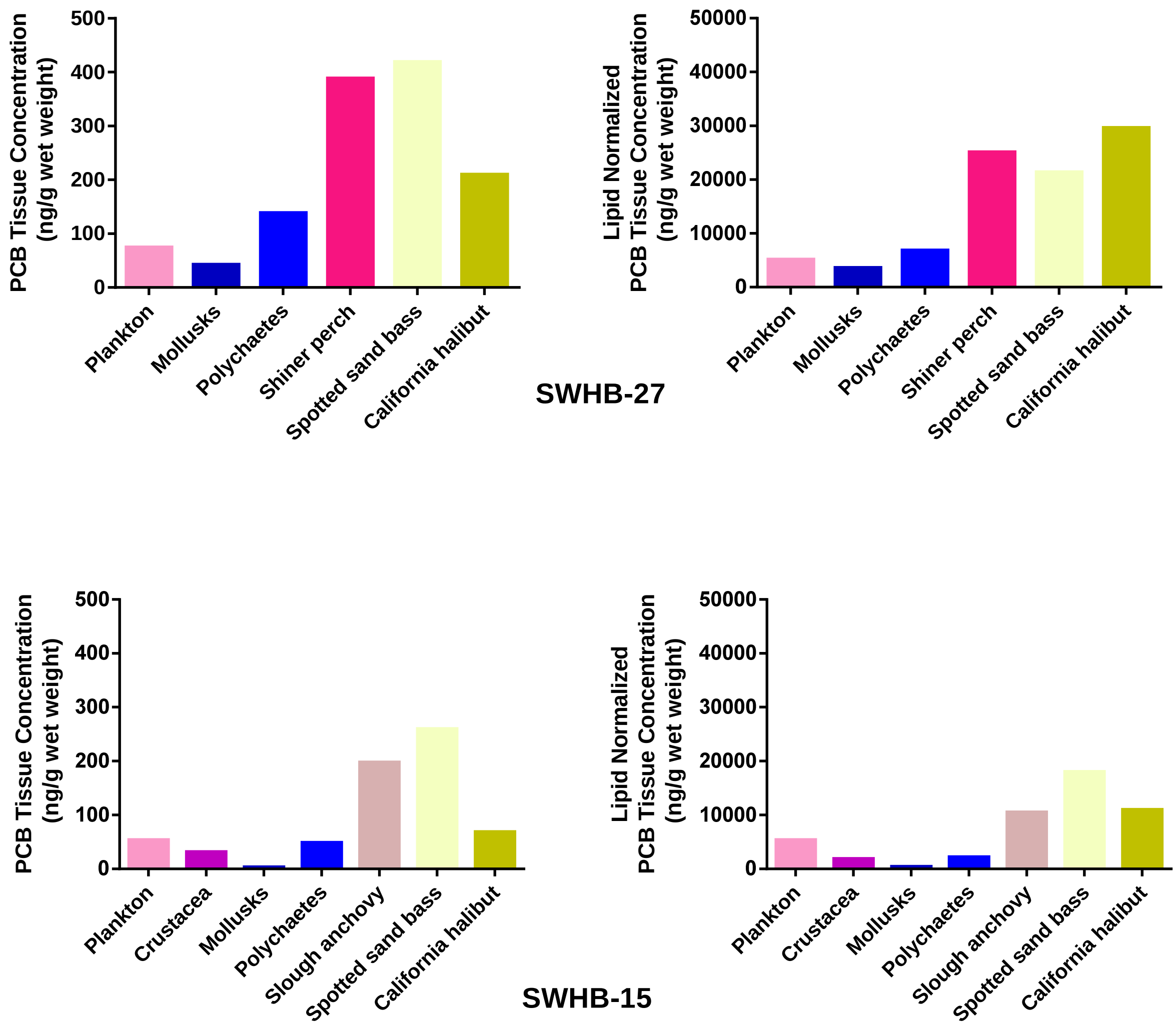

Figure 3-10a. Individual Site Assessment Example of Bioaccumulation Among Aquatic Species Trophic Levels and Associated Sediment Concentrations – Total PCBs

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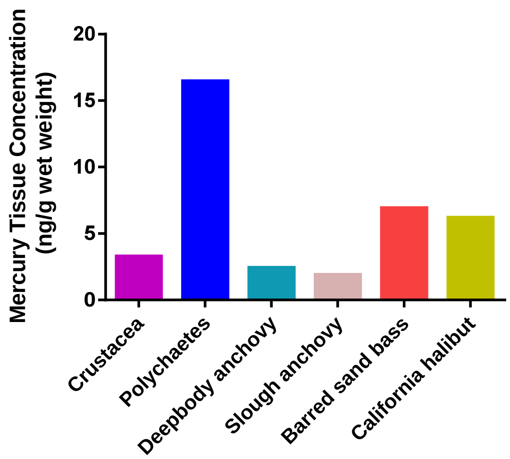
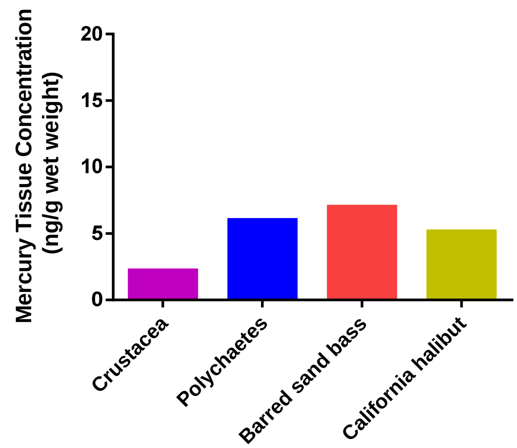
Total Mercury

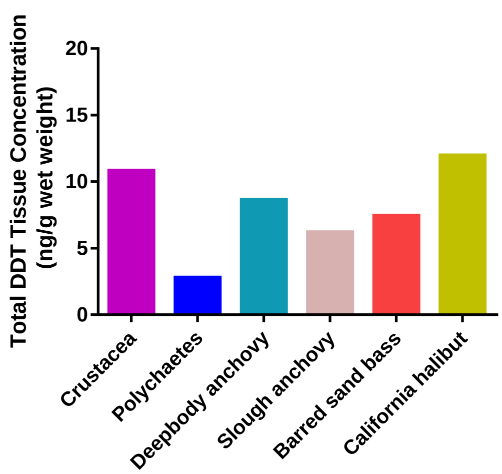


B13-8020

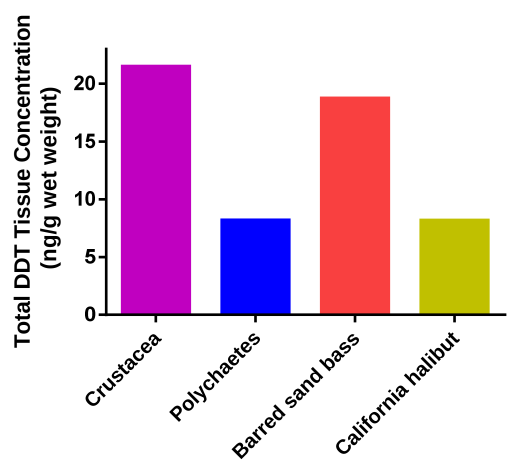


B13-8109

Total DDTs



B13-8020



B13-8109

Figure 3-10b. Individual Site Assessment Example of Bioaccumulation Among Aquatic Species Trophic Levels and Associated Sediment Concentrations – DDT and Mercury

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3.6 Statistical Relationships Between COPCs in Tissues and Associated Sediments

Linear regression analyses were performed to assess the strength of relationship between COPCs in the sediment and associated concentrations in organism tissues in each trophic level at the same location where tissues were collected. Such relationships are important with regard to identifying exposure pathways and potential remedial activities if deemed necessary. These relationships are also key with regard to application and use of the indirect effects Sediment Quality Objective Decision Support Tool (DST) being developed for the State of California. A series of regression plots for total PCBs and mercury are provided in Figures 3-11a-c. These two COPCs were selected for this exercise based on the greatest ecological and human health risk levels identified for these two bioaccumulative compounds as described in Section 3.4. Regression analyses for the other bioaccumulative COPCs are recommended as a follow-up exercise.

Results for both total PCBs and mercury show very little or no relationship between sediment concentrations and associated tissue concentrations. Only one relationship for total PCBs in mollusk tissue showed a significant relation to sediment concentrations, primarily due to a single sample result on the high end. This is somewhat surprising for the infauna in particular which live directly within the sediments that were analyzed. A few observations and hypotheses may help explain the lack of relationships including the following:

1) The locations selected for tissue collections in both 2013 and 2014 were generally away from the shorelines, industrial activity, other potential obstructions, and were not located within confined locations such as marinas. As a result, those locations sampled for tissues generally had low chemical concentrations in the sediments relative to that observed within San Diego Bay at a number of other sites located within the industrial/port or marina strata. Fish and plankton very likely may have had exposure elsewhere before capture during the Bight 13/RHMP and SWHB sampling efforts.

2) Sediments are routinely disturbed from boating activity, wind, and currents in San Diego Bay. Substantial plumes can in fact be observed behind large ships in San Diego Bay from Google Earth™ satellite images. The potential transport of fine particles from areas with elevated chemical concentrations to surficial sediments elsewhere may explain elevated concentrations in some of the infauna found that will often feed right at the sediment/water interface.

3) Many zooplankton species (e.g. copepods) have resting spore stages that settle and reside in the sediments over seasonal cycles. The potential transfer of contaminants from resting stages in the sediments to life stages inhabiting surface waters is unknown at this time, but is a potential explanation for some of the patterns observed in San Diego Bay.

4) Small scale spatial variability in sediment characteristics was noted through both field observations and measures of TOC and grain size throughout San Diego Bay. Patchy eelgrass beds, fine or sandy deposits, and other physical characteristics may have a significant effect on contaminant bioavailability and transport that may not be captured effectively at the spatial scale assessed. For example, sediment samples for chemical

analysis and tissue collections were collected from multiple grabs at a given location and trawls were performed over a relatively large area within the same vicinity. Differing chemical and physical characteristics between grab samples in the same vicinity has the potential to confound relationships observed and estimates of exposure/bioavailability in situ.

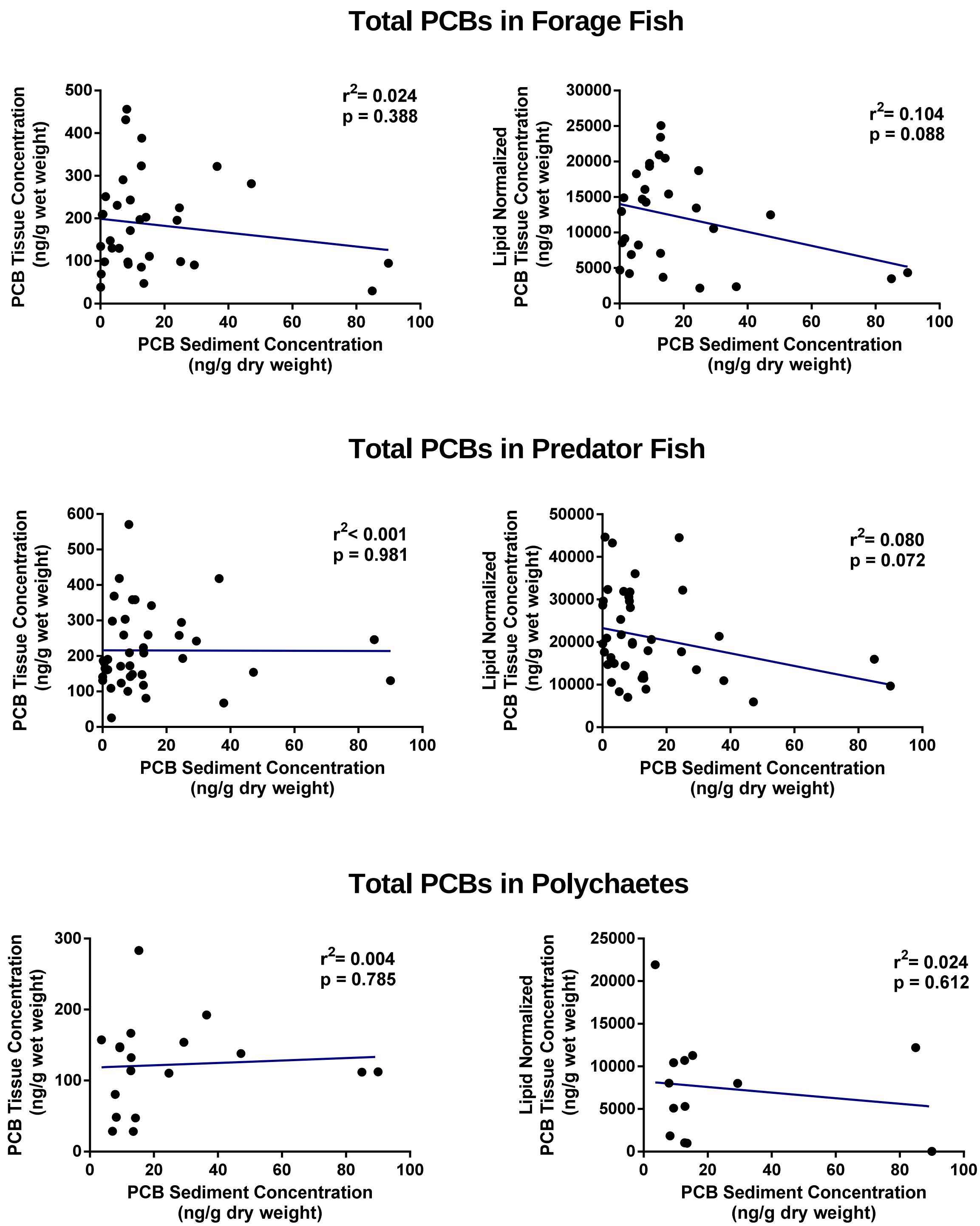

Figure 3-11a. Correlations Between Measured Sediment and Tissue Concentrations - Total PCBs in Fish and Polychaetes

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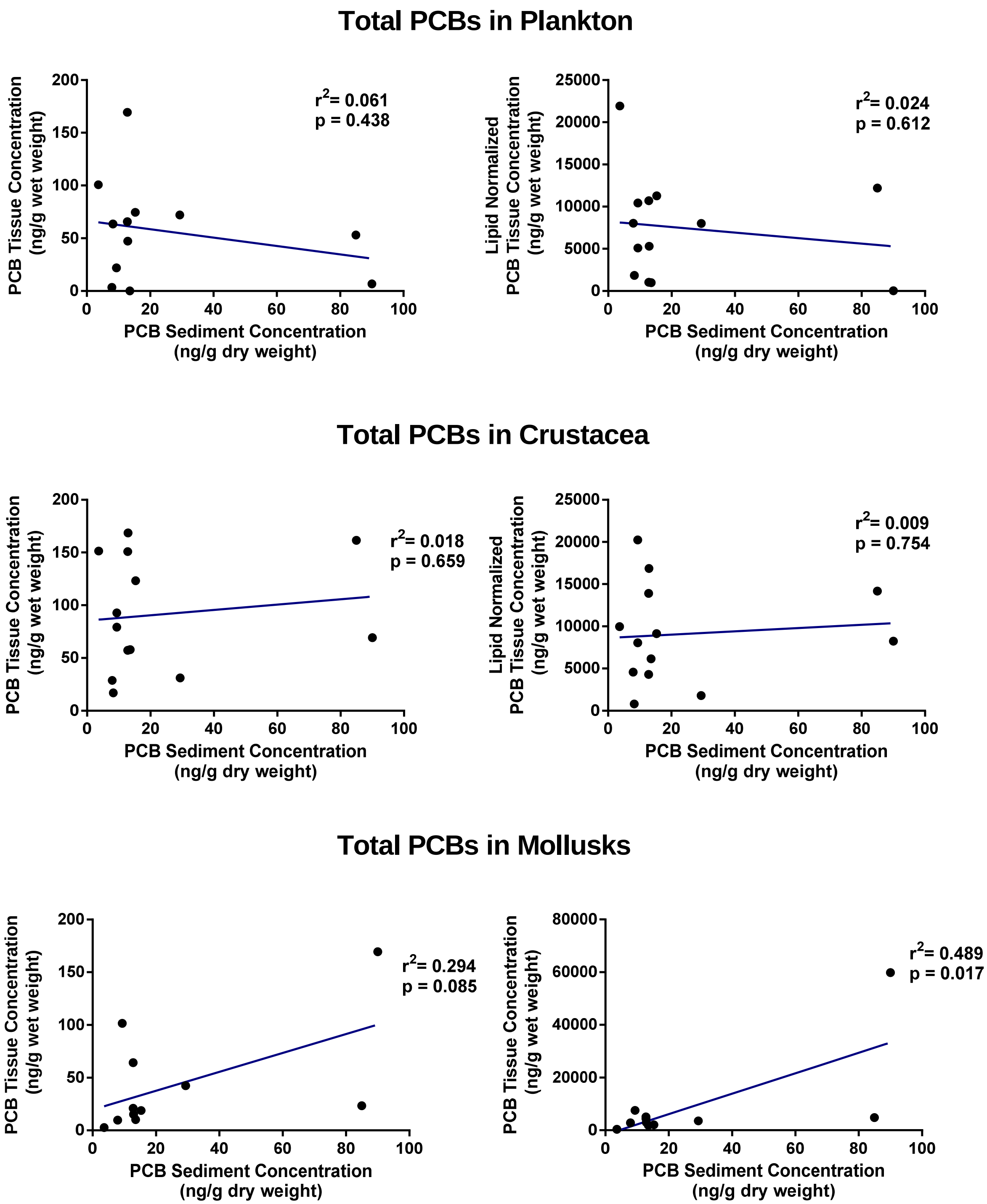

Figure 3-11b. Correlations Between Measured Sediment and Tissue Concentrations – Total PCBs in Plankton, Crustacea, and Mollusks

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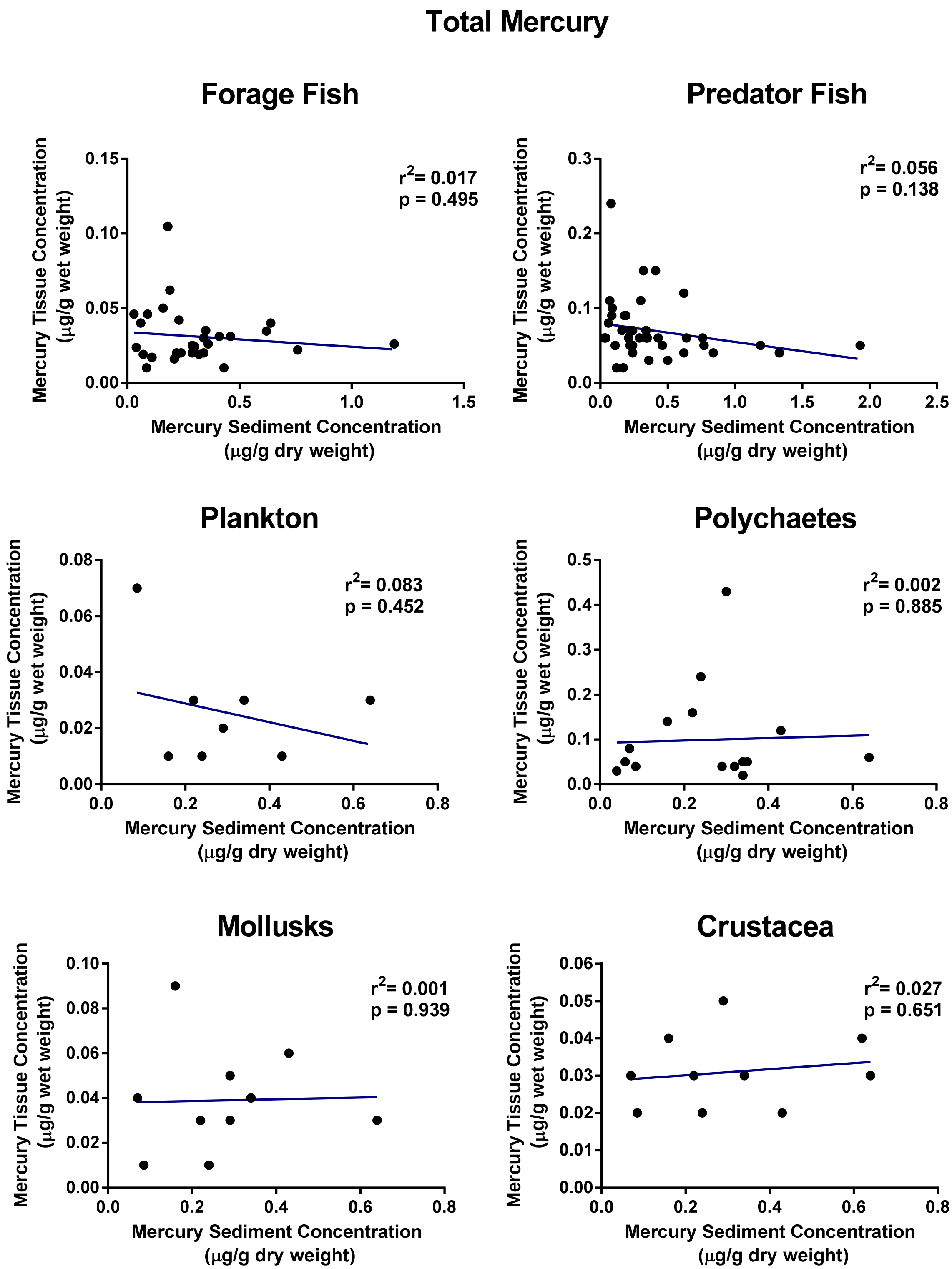

Figure 3-11c. Correlations Between Measured Sediment and Tissue Concentrations – Total Mercury in All Species

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3.7 Bioaccumulation Factors

An evaluation of biota-sediment accumulation factors (BSAFs) provides a direct means to assess the exposure pathways relationship between aquatic species and local sediments. In the summary by Bay et al. (2016 draft) BSAF values were compared among the three regions of the bay collectively (north, central, and south). This recognizes that many species are highly mobile, particularly fish, and thus tissue concentrations will reflect an exposure to a range of sediment contaminants reflective of their home range. For benthic infauna, however, one would expect a stronger relationship with those sediments that they are in direct contact with given their limited mobility. For the exercise presented herein all BSAFs are calculated and reported on an individual site basis without averaging sediment concentrations over larger areas. Overall, patterns in BSAFs among species and taxonomic groups are similar to those described for chemical concentrations, as the values are calculated using the same concentration values expressed on a wet weight basis. However, calculation of BSAFs facilitates comparison of bioaccumulation across different contaminant types as the results are normalized to the sediment concentration.

BSAFs for infauna (crustacea, mollusks, and polychaetes), fish, and plankton are presented in Figures 3-12a-c for total PCBs, DDTs, and mercury. Graphs are provided side-by-side for both raw (untransformed) concentration data and data that was normalized for lipid concentrations (tissues), and total organic carbon content (sediments). Concentrations of lipophilic contaminants such as PCBs, DDTs, and mercury in biota are frequently corrected for variation in tissue lipid content, and sediments corrected for variation in organic carbon prior to evaluating bioaccumulation potential from sediments (Hebert and Keenleyside, 1995). These corrections reduce variation that may be associated with these factors as non-polar organic compounds have a strong affinity for lipids and organic compounds. This normalization approach is desirable when contaminant concentration varies in direct proportion to lipid content. However, when such a relationship does not exist, erroneous conclusions may be reached. A review of the tissue and sediment data for Bight ’13/RHMP and the SWHB study combined does find a general (often statistically significant) relationship between contaminant concentrations and both lipid and TOC concentrations, though there is also some scatter among the data that varies among chemicals and species groups. Regression plots showing relationships between lipid content and COPCs (total PCBs, total DDTs, and mercury) for various species groupings are presented in Appendix E for reference. It should be noted that a majority of the stations had non-detect values for total DDTs in the sediments, thus tissues were compared to ½ the MDL in these cases (0.025 ng/g). PCBs and mercury were detected in all sediment samples evaluated.

3.7.1 Benthic infauna

Among benthic invertebrates, BSAFs were highest for DDTs, where tissue concentrations ranged from less than 1 to 1324 times greater than associated sediments at a given location. Infauna also had relatively high BSAFs for PCBs, ranging from 1 to 70.

Mercury BSAFs values for benthic invertebrates were less than 1 at all but three locations. Maximum BSAF values of 1.3 were observed in polychaetes from Sites SWHB 01 and 06 in central San Diego Bay. At one location with the lowest mercury concentration in the sediments

(SWHB-30 near the mouth of the bay), BSAF values ranged from 1.5 in plankton to 4.0 in polychaetes.

BSAF values for DDT and mercury were similar among taxonomic groups of infauna, with no apparent trend. There was an apparent trend in PCB BSAFs among taxa, with mollusks having BSAFs that were approximately one third of those calculated for polychaetes or crustaceans.

Regional trends for infauna BSAFs were evident only for DDTs. Infauna in the central and north regions had DDT BSAFs that were approximately three times greater than south infauna. This trend suggests that there are differences in sediment characteristics or other exposure pathways among Bay regions that affect contaminant bioavailability.

In general patterns in BSAFs across species and among regions was similar following normalization of concentrations based on tissue lipid content and sediment TOC. Overall, variability was reduced following normalization as might be expected to reduce the effect of these two factors.

3.7.2 Fish

For DDTs, BSAF values ranged from 13 (California halibut in south San Diego Bay; SWHB-15) to 1,708 (deepbody anchovy in central San Diego Bay; B13-8052). PCB BSAFs ranged from 4.2 (shiner surfperch in north/central bay; SWHB-26) to 255 (spotted sand bass in northern San Diego Bay; SWHB-30). As with infauna, fish BSAFs for mercury were low, less than 1 at all but four locations among all species. A maximum mercury BSAF value of 2.1 was observed in spotted sand bass among three of these locations in central and south bay (SWHB-06, 15, and 40). At one location with the lowest mercury concentration in the sediments (SWHB-30 near the mouth of the bay) BSAF values ranged from 5.8 in black perch to 26 in spotted sand bass.

Fish BSAFs for total PCBs and DDTs were generally two to four-fold higher than invertebrate values for the same site, which is consistent with the higher trophic level of fish. A less pronounced trend was observed for mercury with the exception of elevated BSAFs in spotted bay bass relative to all of other fish and invertebrate species.

Regional variation in fish BSAFs was also observed for DDTs and PCBs. Fish collected from the central Bay tended to have higher BSAFs for both compound groups, with values approximately two to three times higher than fish in the other regions. The lowest BSAFs for DDT were usually noted for fish in south bay, while fish in the northern portion of the bay usually had the lowest BSAFs for PCBs. Regional variations in BSAFs for mercury were less pronounced. The location closest to the entrance of San Diego Bay (SWHB-30) had the lowest mercury concentration and thus the greatest BSAFs for this chemical given the relatively consistent concentrations of mercury in tissues across taxa.

Consistent with results for infauna, patterns in BSAFs across species and among regions was generally similar following normalization of concentrations based on tissue lipid content and sediment TOC. Overall, variability within fish species was also reduced following normalization, particularly for PCBs and mercury.

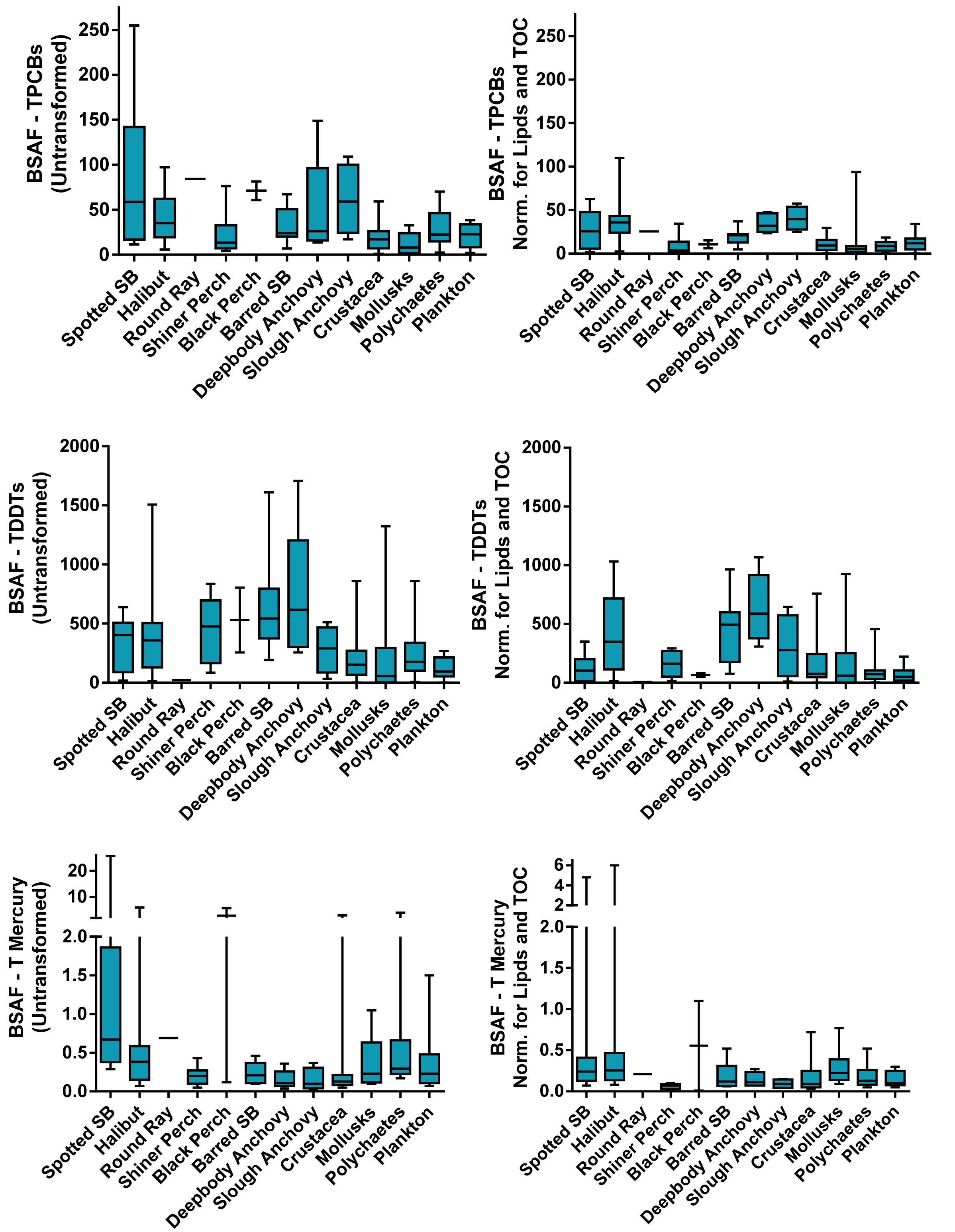

Figure 3-12. Biota to Sediment Accumulation Factors for Total PCBs, DDTs, and Mercury

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3.8 Data Quality Assurance/Quality Control

3.8.1 Field Activities

All field-related activities met QA/QC requirements as set for forth in the project-specific QA/QC Plan for fish and invertebrates (Amec Foster Wheeler, 2014b), plankton (Amec Foster Wheeler, 2014c), and the regional Bight monitoring methods outlined in the Bight '13 QA Manual (SCCWRP, 2013c) and detailed in Section 2.3. This included the calibration and collection of data from portable field meters used to measure field water quality parameters, field sample documentation, electronic capture of data, vessel positioning and collection of sediment samples all within a 100-m radius of the target locations, and all trawl-related activities.

3.8.2 Analytical Chemistry

The following QA/QC review applies only to sediment and tissue data collected for the SWHB study. A complete QA/QC review of sediment data collected during the RHMP, including a 10% Level IV third party review by LDC, is provided in the associated report for this separate effort (Stransky et al., 2016). A 10% Level IV QA/QC review of tissue data collected during the RHMP in 2013 has also been completed, but a written summary is not available at the time of this report. As with the SWHB data, results were deemed 100% usable. It is anticipated that this summary will be completed and available as part of a separate report by the end of 2016 for all RHMP embayments: Dana Point Harbor, Oceanside Harbor, Mission Bay, and San Diego Bay.

3.8.2.1 Introduction and Background – Data Review and Validation Summary

As part of the SWHB effort, 30 sediment and 65 tissue samples were collected in addition to 9 water samples, consisting of 1 field blank and 1 equipment blank. Fish and infauna tissue samples were collected between April 15 and April 23, 2014; sediment samples were collected between April 08 and April 18, 2014; and water samples and plankton tissues were collected between May 7 and May 12, 2014. Amec Foster Wheeler submitted all samples to the primary laboratory, Physis, located in Anaheim, CA. These data supplemented the 59 sediment and water samples, and 55 tissue samples collected during the RHMP as part of Bight '13, and an additional 15 tissue samples collected by MBC as a part of Bight '13.

Samples were collected in accordance with the approved SWHB project-specific QAPP documents (Amec Foster Wheeler, April 2014b) as submitted to the lead agency, the City of San Diego. Samples were analyzed as described in Section 2.2 and the resultant data reviewed against data quality objectives (DQOs) as detailed in the project Quality Assurance Project Plans (Amec Foster Wheeler, 2014b and c). Project DQOs were developed on the basis of SWAMP criteria consistent with the previous 2008 RHMP study (Weston, 2008 and 2010), and related regional monitoring efforts, including the Bight '13 regional monitoring program managed by SCCWRP. No field duplicates or composite replicates were collected for SWHB samples as part of this subset of data. The duplicate precision DQO for this data set is fulfilled using analytical duplicates (including LCS/LCS Dups, MS/MSDs).

3.8.2.2 Test Methods

Physis analyzed the sediment samples for chlorinated pesticides including DDTs, PAHs and PCB congeners were analyzed by EPA 8270D, Pyrethroids and PBDEs by EPA 8270D-NCL and percent solids by SM 2540B. The metals aluminum, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, nickel, selenium, silver and zinc were analyzed by EPA 6020 as was the metalloid phosphorus. Mercury was analyzed by EPA 245.7 and ammonia by SM 4500-NH3 D and chlorinated pesticides PCB congeners, PAHs, and pyrethroid pesticides by EPA Method 8270D. Physis analyzed the tissues samples for Selenium by EPA Method 6020, mercury by EPA Method 7471a, PAHs and PCBs by EPA Method 8270-SIM, Chlorinated Pesticides by EPA 8081 and PBDEs by EPA 8270C NCL, including lipids and percent solids.

3.8.2.3 Data Validation Methodology

Results for these samples underwent a full Tier II data validation by Amec Foster Wheeler consistent with EPA Region 9 protocols to evaluate the usability of the data. The Tier II validation includes review of the quality control results in the laboratory's analytical report and reported on QC summary forms relative to project DQOs. Furthermore, two SDGs, one for tissues and one for sediments, were submitted to LDC for a full Level IV validation equating to 10% of the total number of samples analyzed. Level IV review includes all Tier II validation parameters plus validation of initial and continuing calibration verification, tuning and performance checks, surrogate recoveries, and corresponding QA/QC samples. Physis supplied Level IV data deliverables for two SDGs 1504003-002 for tissues, and 1504003-001for sediments, with both SDGs were subjected to full Level IV validation. These EDDs are included within Appendix J on CD. This data validation has been performed in general accordance with the following protocols:

- Bight, 2013. Southern California Bight 2013 (Bight 13') Regional Marine Monitoring Survey Quality Assurance Project Plan (QAPP), June 13, 2013.
- EPA, 2001. Region 9 Superfund Data Evaluation/Validation Guidance, Version 1, R9QA/006.1, December.
- EPA Contract Laboratory Program (CLP) National Functional Guidelines for Inorganic Superfund Data Review, EPA-540-R-013-001. January 2010
- EPA CLP National Functional Guidelines for Superfund Organic Methods Data Review, EPA-540-R-014-002. June 2008
- EPA SW 846, Third Edition, Test Methods for Evaluating Solid Waste, update 1, July 1992; update IIA, August 1993; update II, September 1994; update IiB, January 1995; update III, December 1996; update IliA, April1998; IIIB, November 2004; Update IV, February 20

The EPA CLP guidelines listed above were written specifically for the CLP, and have been modified for the purposes of these data reviews where they differ from method-specific QC requirements.

3.8.2.4 Data Quality Objectives

DQOs were consistent with the RHMP project-specific QAPP and summarized in Table 7-2 of the Amec Foster Wheeler QAPP (AMEC 2013b) for both sediments and tissues. These include criteria for Precision, Accuracy, Completeness, Comparability and Representativeness (PARCC) and for overall usability. Accuracy was based on acceptance of laboratory derived performance based control limits (±3 standard deviations). Precision limits for laboratory duplicates and matrix spike/matrix spike duplicate pairs are 25% for both sediments and tissues. A default completeness goal of 90% was used, citing no corresponding SWAMP requirement. Because a full Tier II was performed on all samples and a Level IV data validation on 10% of the data, this summary aims to highlight the overall results of both validations and the data usability and is not a comprehensive review of all data qualifications. To ensure data comparability these samples were analyzed using EPA approved laboratory methods by an ELAP accredited laboratory (Physis Laboratories, Inc.). The laboratory also has passed inter-laboratory method calibration studies for the most recent Bight program. Representativeness was ensured by selecting and testing of a broad range of tissue matrices of common species types as determined by input from the bioaccumulation technical work group. In addition, large and small specimen tissues composites were made for select species (e.g., California halibut) to discern possible difference in uptake based on size class are representative.

Of significant note, the whole tissue samples were held at -20 degrees Celsius in excess of 400 days prior to analysis. This is in excess of the maximum one year holding time as recommended under SWAMP (SWRCB, 2008). This delay in testing was due to restrictions in available funding. As a result, all tissues is flagged as estimated, but is considered usable for the intended purpose. The likely data impact is unknown, but considered negligible.

3.8.2.5 Data Usability

The project default completeness DQO for data usability is 90% of any constituent.

Rejected Data

A rejected (“r-flagged”) result is typically due to a significant nonconformance, and the affected data are rendered as unusable. The Tier II validation performed by Amec Foster Wheeler in addition to the Level IV validation performed by LDC indicated no r-qualified results for either sediment or tissues were warranted. Based on these criteria, the data is considered 100 percent usable.

Estimated Data

Both the Tier II and Level IV validation identified a small number of method protocol exceptions that warranted an estimated (“J-flagged”) validation qualifier. Affected data were assigned either a J as estimated but quantifiable or UJ validation code if the constituent was below the method detection limit (non-detects). A summary of flagged data by DQO is provided below. There were no significant trends or specific compounds with systemic bias. A detailed description of the affected constituents, flags, and reason and explanation codes is provided in Appendix J.

3.8.2.6 Precision

All data for both sediment and tissues were well above the data completeness goal for duplicate precision, with the following exceptions;

Sediments

- 0.7% of PAH data was affected for analytical precision (99.3% complete)
- None of the metals, PCBs (congener) or chlorinated pesticides data was flagged (100% complete)

Tissues

- 5.9% of PAH data was affected for analytical precision (93.1% complete)
- 0.3% of chlorinated pesticide data was affected for analytical precision (93.1% complete)
- 1.7% of metals data was affected for analytical precision (98.3% complete)
- 1.1% of PCB congener data was affected for analytical precision (98.9% complete)

3.8.2.7 Accuracy

All data for both sediment and tissues were well above the data completeness goal for spike recovery (e.g., ICV, CCV, LCS, CRM) with the following exceptions;

Sediments

- 0.7% of PAH data was affected for analytical accuracy (99.3% complete)
- None of the metals, PCBs (congener) or chlorinated pesticides data was flagged (100% complete)

Tissues

- 7.0% of PAH data was affected for analytical precision (93.0% complete)
- 2.1 % of chlorinated pesticide data was affected for analytical precision (97.9% complete)
- 11.9% of metals data was affected for analytical precision (88.1% complete)
- 4.5% of PCB congener data was affected for analytical precision (96.5% complete)

The completeness goal for metals was slightly below the 90% DQO (88.1%). All of the accuracy outliers for metals were the result of poor internal standard recovery for Selenium only.

3.8.2.8 Overall Data Quality

With minor exception, the data quality for both sediments and tissues was well above DQO guidelines. All data was considered useable with a 100 percent completeness goal for this objective. Only selenium in tissues showed minor data impact due to variability in internal standard recovery, and flagged as estimated. A limited number of results were flagged as estimated “J-flagged” or UJ flagged (estimated, non-detect) with few if any systematic potential bias. A summary of the likely data implication is provided in Appendix Tables J-1 and J-2.

4.0 CONCLUSIONS AND RECOMMENDATIONS

A number of key observations and recommendations highlighted in the results section are summarized here in conclusion. As data continues to be evaluated with ongoing stakeholder efforts and scientific peer review refined and/or additional conclusions and recommendations are anticipated.

Bioaccumulation Patterns for COPCs

Tissue chemistry results collectively for all of San Diego Bay showed that biomagnification among food web components was evident for most of the major contaminant types evaluated. Relative to the other sample types, predatory fish had the highest mean concentration of total PCBs, total DDTs, and total chlordanes. Mercury concentrations in fish tissue were similar to that in polychaetes, but elevated relative to that in mollusks and crustacea. Similar patterns were evident for most contaminant types, with the lowest concentrations occurring in the lowest trophic levels of plankton and benthic infauna (crustaceans, mollusks, polychaetes), and intermediate contaminant levels present in forage fish. Total PBDEs did not follow this pattern, however, with fish having overall lower mean concentrations than benthic infauna (especially crustaceans) and plankton. Selenium also showed elevated concentrations in lower trophic levels; the mean concentration of fish tissues was substantially less than benthic infauna, particularly that observed in the polychaetes.

The greatest bioaccumulation potential from sediment was observed for PCBs and DDTs, where all food web components had median concentrations above bay-wide sediment means. Benthic infauna and plankton did not show much bioaccumulation of chlordanes relative to sediment, but the lack of detectable concentrations in many samples may have obscured some of these relationships. Median tissue mercury concentrations were below sediment levels for all trophic levels, likely reflecting a relatively low influence of local sediment mercury on tissue levels. Most of sediment mercury is likely present in the inorganic form, while methylated forms of mercury more prevalent in deeper anoxic sediments are the bioavailable form responsible for most of the bioaccumulation.

Across all sites, the round ray had the average highest measured concentrations of total PCBs, followed by the spotted sand bass. Highest average total DDT concentrations were found in slough anchovy tissue, followed by barred sand bass and perch species. Average mercury concentrations were highest across polychaete and spotted sand bass tissues, followed by the barred sand bass. Across sites and species, total PCBs and total percent lipids exhibited distinct positive relationships, while total DDTs exhibited a weaker relationship to total percent lipids.

Relationships Between Sediment COPCs and Associated Tissue Concentrations

Results for both total PCBs and mercury show very little or no relationship between sediment concentrations and tissue concentrations. Only one relationship for total PCBs in mollusk tissue showed a significant relation to sediment concentrations. This is somewhat surprising for the infauna in particular which live directly within the sediments that were analyzed. A few observations and hypotheses may help explain the lack of relationships including the following:

- The locations selected for tissue collections in both 2013 and 2014 were generally away from the shorelines, industrial activity, other potential obstructions, and were not located within confined locations such as marinas. As a result, those locations sampled for tissues generally had low chemical concentrations in the sediments relative to that observed within San Diego Bay at a number of other sites located within the industrial/port or marina strata. Fish and plankton very likely may have had exposure elsewhere before capture during the Bight 13/RHMP and SWHB sampling efforts.
- Sediments are routinely disturbed from boating activity, wind, and currents in San Diego Bay. Substantial plumes can in fact be observed behind large ships in San Diego Bay from Google Earth™ satellite images. The potential transport of fine particles from areas with elevated chemical concentrations to surficial sediments elsewhere may explain elevated concentrations in some of the infauna found that will often feed right at the sediment/water interface.
- Many zooplankton species (e.g. copepods) have resting spore stages that settle and reside in the sediments over seasonal cycles. The potential transfer of contaminants from resting stages in the sediments to life stages inhabiting surface waters is unknown at this time, but a potential explanation for some of the patterns observed in San Diego Bay.
- Small scale spatial variability in sediment characteristics was noted through both field observations and measures of TOC and grain size throughout San Diego Bay. Patchy eelgrass beds, fine or sandy deposits, and other physical characteristics may have a significant effect on contaminant bioavailability and transport that may not be captured effectively at the spatial scale assessed. For example, sediment samples for chemical analysis and tissue collections were collected from multiple grabs at a given location and trawls were performed over a relatively large area within the same vicinity. Differing chemical and physical characteristics between grab samples in the same vicinity has the potential to confound relationships observed.

Risk Assessment

A comparison of measured tissue concentrations in fish and invertebrates in San Diego Bay to various available human health criteria and regulatory-based wildlife tissue residue effects threshold values provided a means to evaluate comparative risk for those bioaccumulative COPCs measured.

<u>PCBs</u>

This assessment found total PCBs to be a primary COPC of concern for both human health risk and potential ecological effects, though to a lesser extent for wildlife. The primary driver of risk from PCB exposure is related to human health due to the much lower screening values for fish consumption than that for wildlife risk. Concentrations of total PCBs in all fish tissue samples exceeded the most conservative OEHHA human health Advisory Tissue Level (ATL), the TMDL criterion for PCBs in San Francisco Bay, and the Oregon DEQ ATL value for the protection of human health. Mean values in several fish species also exceeded the OEHHA no consumption guideline of 120 ppb. Though concentrations of total PCBs in the infauna and plankton were lower than that in fish species, many still exceeded the various criteria available for the protection of human health.

With regard to wildlife risk, concentrations of PCBs in fish and many of the infauna and plankton samples exceeded a dry weight NOEC value of 80 ng/g for fish species and a Threshold Effect level (TEL) of 22 ng/g for benthic invertebrates reported by Zeeman (2004), as well as prey item wet weight NOEC values between 110 and 566 ng/g for the protection of bird species. However, measured tissue concentrations for all aquatic species in San Diego Bay (maximum of 571 ng/g measured in a spotted sand bass collected at Site SWHB-01 in central San Diego Bay) were below all wet weight LOEC values reported by Zeeman (2016 draft) for the protection of bird species, the Oregon DEQ CTL wildlife protection screening value of 930 ng/g, and the State of Washington DMMP screening value of 750 ng/g.

Mercury

Of the bioaccumulative COPCs in San Diego Bay, mercury is considered to be second to PCBs with regard to both human and ecological risk. Regardless, the overall level of risk due to mercury in San Diego Bay appears to be much lower than that for PCBs based on both low tissue concentrations levels overall relative to thresholds of potential concern, as well as the lack of bioavailability observed with concentrations of mercury in tissues generally less than that in the sediments. Concentrations of total mercury in tissue samples from all species in San Diego Bay were below all of the screening criteria above for risk to human health for women greater than 45 years in age and men. Only one sample from a California halibut had a tissue concentration that exceeded the OEHHA three servings/week threshold of 220 ng/g for humans regardless of age or sex. Multiple spotted bay bass composite samples, a single round sting ray composite, and three deepbody anchovy samples had total mercury concentrations that exceeded the 3 servings/week criterion of 70 ng/g for women less than 45 years in age and children less than 17 years old, however no concentrations exceeded OEHHA thresholds for one or fewer servings/week regardless of age or sex. In addition, no fish tissue samples exceeded the Oregon DEQ human health risk value of 400 ng/g or the State of Washington DMMP criterion of 1,000 ng/g.

Concentrations of mercury in tissue samples exceeded a number of mercury screening level values for the protection of wildlife (ranging from < 120 to 180 ng/g), published by Zeeman (2007) and Oregon DEQ (2007); particularly in a few polychaete samples from central San Diego Bay, and spotted bay bass throughout the bay as described above. Mean concentrations for all species or species groups were however all less than these values. When compared to the draft wildlife screening values summarized by Zeeman (2016), many individual and average tissue concentrations throughout the bay exceed NOEC and LOEC values for the most sensitive bird species, but are less than all of the LOEC values based on mid-range sensitive bird species.

DDTs

With just a few exceptions concentrations of total DDTs in tissue samples from all species in San Diego Bay were below screening criteria for the protection of wildlife and human health risk. Risk to both aquatic species and humans from DDTs is thus considered minimal.

Selenium

Concentrations of selenium in tissue samples from all fish species in San Diego Bay were below all available criteria for the protection of human health. Only a single polychaete sample from north San Diego Bay exceeded the most conservative human health risk value of 2.5 µg/g for this chemical. No tissue samples had concentrations of selenium exceeding estimates for the protection of wildlife in San Francisco Bay based on the TMDL for this water body, but quite a few samples exceeded Oregon DEQ ATLs for the protection of birds and mammals, as well as the Oregon DEQ CTL value for fish, shellfish, or other aquatic organisms.

In summary, there is no human health related concern due to selenium in San Diego Bay, but potential effects on aquatic species are uncertain at this time given the wide variation in available threshold effect tissue concentrations cited in this document. A more detailed evaluation of the studies and species used to establish tissue contaminant effects concentrations for the State of Oregon is recommended to see if they are relevant to species found in or around San Diego Bay.

Total Chlordanes

Concentrations of total chlordanes in tissue samples from all fish species in San Diego Bay were below all available criteria for the protection of human health. Only one tissue sample had a concentration slightly in excess of a wildlife threshold value published by the Oregon DEQ. This concentration also exceeded the Oregon DEQ human health ATL of 27 ng/g, but was well below the most conservative OEHHA fish consumption guideline values. The overall low concentrations and limited bioaccumulation of total chlordanes results in a limited human health and ecological risk due to this class of compounds in San Diego Bay.

PBDEs

There is currently a lack of data in the literature to establish a meaningful risk of PBDE exposure to human health, and only limited data to establish risk to wildlife specific to San Diego Bay. Concentration appear generally low throughout San Diego Bay sediments and tissues (< 10 to 20 ng/g), with a maximum tissue concentration of 108 ng/g in a plankton sample collected in central San Diego Bay. A total of 11 tissue samples exceeded the lowest reported NOEC value of 12 ng/g for the protection of bird species. No tissue concentrations exceeded the lowest LOEC value of 118 ng/g for the protection of bird species consuming infauna or fish. Limited to no biomagnification from sediments to tissues was observed for PBDEs.

Recommendations

- To better understand the source of bioaccumulative constituents it is recommended that sediment concentrations at multiple sites at varying scales be averaged within different areas of the bay where tissues were collected to see if stronger relationships might be obtained. Many of the locations sampled during Bigh'13/RHMP were not included in the regional assessment of north, central, and southern regions of San Diego Bay in the draft associated report by Bay et al (2016) and this current report only conducted correlations using paired data for single locations.

- Sources of bioaccumulative contaminants may also arrive via other sources such as aerial deposition, runoff, and groundwater influx. A closer look at these ongoing sources may be warranted as well.

- Complete sediment/tissue regression relationships and BSAF calculations for other COPCs: DDTs, chlordanes, selenium, and PBDEs.

- Complete a literature search and database of up to date tissue residue effects data relevant to species found in and around San Diego Bay. This effort is currently in progress by Ms. Katie Zeeman of USFWS. Re-evaluate ecological risk of identified COPCs based on any new values obtained.

- Re-evaluate assumptions provided in the SQO DST in an attempt to increase predictive ability for bioaccumulation of COPCs in San Diego Bay.

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APPENDIX A

TRAWL LOCATION MAPS
(PROVIDED ON CD)

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APPENDIX B

CHEMISTRY SUMMARY TABLES
(PROVIDED ON CD)

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APPENDIX C

CATCH AND BYCATCH DATA TABLES (RHMP AND SWHB) (PROVIDED ON CD)

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APPENDIX D

CATCH AND BYCATCH PHOTO LOGS (RHMP AND SWHB)
(PROVIDED ON CD)

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APPENDIX E

GRAPHICAL AND STATISTICAL ANALYSES
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APPENDIX F

SWHB WATER QUALITY SURFACE INSTRUMENT READINGS (PROVIDED ON CD)

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APPENDIX G

SCANNED FIELD DATA SHEETS
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APPENDIX H

COCS
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APPENDIX I

RAW CHEMISTRY REPORTS
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APPENDIX J

DATA VALIDATION REPORT (LDC)
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APPENDIX K

INITIAL WILDLIFE RISK-BASED SCREENING LEVELS FOR CONTAMINANTS IN TISSUES OF AQUATIC BIOTA IN SAN DIEGO BAY (PROVIDED ON CD)

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