Regional Harbor Monitoring Program

2013

Unified Port of San Diego

January 2016

amec foster wheeler

FINAL
REGIONAL HARBOR MONITORING PROGRAM
2013 REPORT

Submitted to:

Unified Port of San Diego | **City of San Diego** | **City of Oceanside** | **County of Orange**

Submitted by:

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January 2016

Port of San Diego
Agreement Number: 50-2013
Amec Foster Wheeler Project No.: 1315102304

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Prepared for:
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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 the San Diego Regional Harbors. This effort was made possible with generous funding by the RHMP Agencies. Special thanks to the lead agency participants with all of the great ideas and input throughout: Philip Gibbons, Karen Holman, and Paul Maechler of the Port of San Diego, Ruth Kolb of the City of San Diego, Justin Gamble and Mo Lahsaiezadeh of the City of Oceanside, and Stuart Goong and Jian Peng of the County of Orange.

Special thanks as well to all of the exceptional support provided to implement the program and prepare this report: Captain Kenny Neilson and Bob Lohrman of Seaventures for field vessel and sampling support; Mary Tamburro and Jordon Volker of Merkel and Associates for field sampling and infauna sorting support; Adrienne Cibor, Peter Arth, Dr. Howard Bailey, and the rest of the crew at Nautilus Environmental for toxicity testing and associated data analysis support; Mark Baker, Misty Mercier, Rich Gossett and the rest of the crew at Physis Analytical for chemical analysis support; Larry Lovell, Dean Pasko, and Tony Phillips of Dancing Coyote Environmental for infauna taxonomy support; Dr. Allen Burton of the University of Michigan and Dr. Brock Bernstein for technical peer review support, Pei Geng, Linda Rauto, and rest of the crew at Laboratory Data Consultants; and finally Tyler Huff, Jeremy Burns, Kevin Stolzenbach, and Holly Ayala of Amec Foster Wheeler for a wide variety of support in the field, data analyses, and reporting-related efforts.

EXECUTIVE SUMMARY

The Regional Harbor Monitoring Program (RHMP) provides a comprehensive survey of the quality of water, sediments, and aquatic life on a 5-year cycle in four southern California embayments in the San Diego Region: Dana Point Harbor, Oceanside Harbor, Mission Bay, and San Diego Bay. The RHMP was developed by the Unified Port of San Diego, the City of San Diego, the City of Oceanside, and the County of Orange to evaluate status and trends related to a variety of environmental condition indicators, and whether beneficial uses are being attained and protected in the four harbors. The RHMP is coordinated with the larger-scale regional southern California Bight monitoring program managed by the Southern California Coastal Water Research Project (SCCWRP).

The RHMP sampling areas were partitioned into five strata classified as either freshwater-influenced, marina, industrial, deep, and shallow regions for comparative assessments. Sampling was performed at a total of 75 water and sediment quality stations and benthic trawls were performed at 15 locations, with stations positioned according to a stratified random sampling design. Surface water and sediment chemistry, sediment toxicity, and biological community conditions were quantified to determine the overall environmental conditions of the harbors. To evaluate the contributions and spatial distribution of pollutants, concentrations of chemical indicators were compared among strata and among harbors. To determine whether the waters and sediments sustain healthy biota, a weight-of-evidence approach was used that combined the indirect lines of evidence (LOE) (chemistry and toxicity) with the direct LOE (benthic infauna and demersal communities). Lastly, determinations of long-term trends were based on comparisons of the 2013 RHMP findings with historical conditions to evaluate whether conditions are improving or deteriorating over time. The results are discussed in relation to the following three core questions:

1. ***What are the contributions and spatial distributions of inputs of pollutants?***
   Areas of the harbors most closely associated with human uses (i.e., the marina, industrial, and freshwater-influenced strata) tended to have elevated chemical concentrations and greater exceedances of chemical thresholds in surface waters and sediments, as compared with areas that were not closely associated with anthropogenic influences (deep and shallow strata). This tendency was most notably the case for the marina stratum due to consistently elevated levels of copper both in the surface waters and sediments, as well as other metals (e.g., mercury and zinc) and organics in the sediments. The port/industrial stratum, which was located solely along the eastern shore of San Diego Bay, also had elevated concentrations of metals and organics in sediments. The primary elevated contaminants associated with the freshwater-influenced stratum were pesticides (i.e., chlordanes and pyrethroids) as well as zinc.

2. ***Do the waters and sediments in the harbors sustain healthy biota?***
   A majority of the area within the RHMP harbors was found to be supportive of healthy biota, based upon a weight-of-evidence approach that combines physical, chemical, and toxicological LOE with biotic LOE. However, areas directly associated with anthropogenic disturbance and inputs of pollutants tended to have elevated chemistry and conditions that were less supportive of healthy benthic infaunal communities; this tendency was most notably the case for the marinas and port/industrial areas.

Surface water chemistry and physical water quality parameters were largely supportive of healthy biota based on water quality benchmarks. All chemical and physical indicators met water quality objectives and threshold effects levels with the exception of copper, primarily in marinas, and dissolved oxygen in bottom water at a few select stations within the marinas and deep water locations.

Using the recently updated State of California Sediment Quality Objective (SQO) approach to assess direct effects, sediment quality region-wide was also considered to be largely protective of healthy biota with 72 percent (%) of stations classified as either unimpacted or likely unimpacted based on a combined metric that includes sediment chemistry, toxicity, and benthic community lines of evidence (Figure ES-1). Supporting the sediment quality line of evidence using the SQO approach, 80% of stations did not exceed a single more traditional screening level effects-range median (ER-M) value for any analyte. Particularly noteworthy, 84% of the 2013 RHMP sampling stations were classified as nontoxic, with 16% considered to have low toxicity according to the SQO methodology while no sites were moderately or highly toxic. Consistent with the sediment chemistry and toxicity LOEs, the benthic infauna at a majority of sites occurred in most areas at an abundance and diversity indicative of healthy communities. A total of 60% of stations had benthic infaunal communities consistent with reference or low disturbance conditions according to the benthic SQO LOE. The variation in disturbance scores observed among benthic communities was a significant driver for final integrated SQO scores. Multiple factors such as physical disturbance and substrate type, in addition to elevated chemistry likely contribute to impaired benthic communities.

Finally, the demersal fish and invertebrate community was composed of healthy individuals, with a diversity and abundance of species that were consistent with those of prior regional monitoring assessments. The fish communities sampled in the 2013 RHMP were similar to those of prior Bight surveys in terms of the mean number of taxa caught per trawl, whereas the mean abundance and biomass were greater in 2013. Overall, the diversity, abundance, and biomass recorded in both the 2013 RHMP and historical data sets, along with minimal abnormalities, support the premise that regional harbors are capable of supporting healthy fish assemblages.

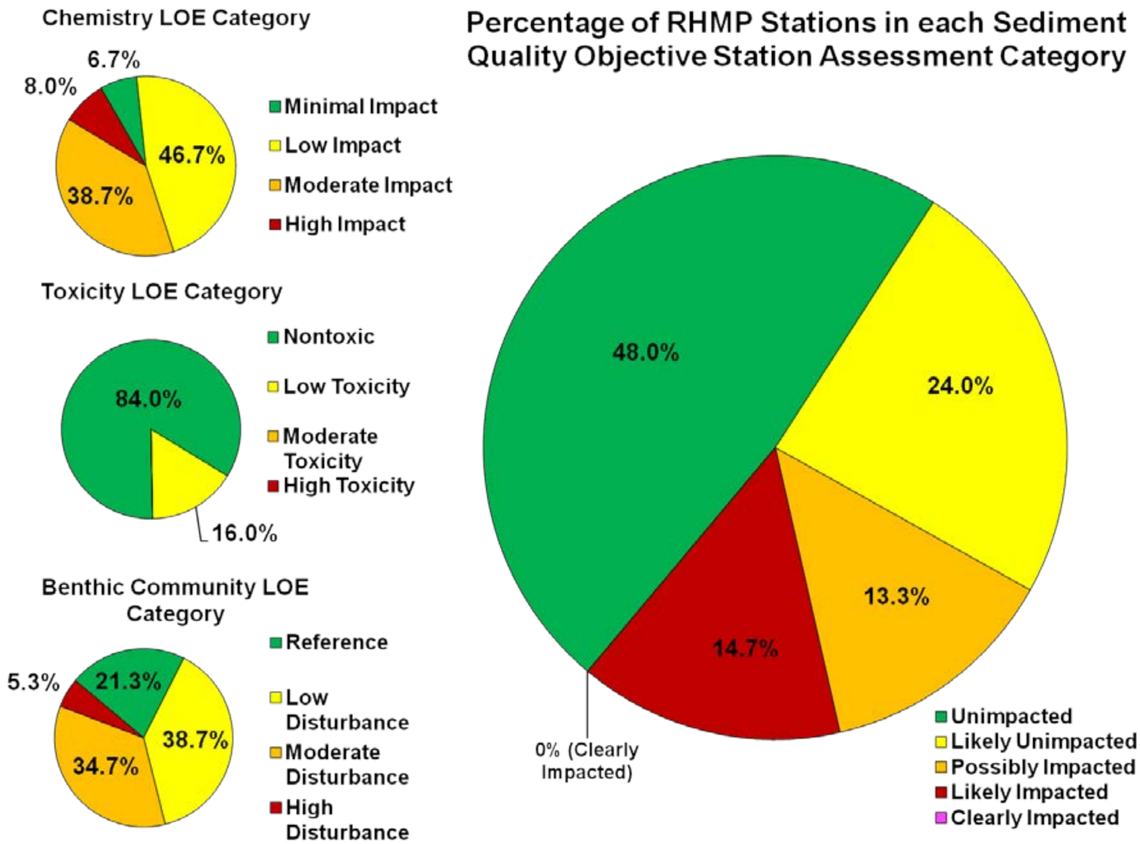

Figure ES-1. Percentage of RHMP Stations in each Sediment Quality Objective LOE and Overall Assessment Categories

3. ***What are the long-term trends in water quality for each harbor?***
   Historical conditions for the 2013 RHMP were determined based on a review of multiple studies completed from 1994 to 2007. RHMP-wide conditions were found to be improving over time based on comparisons of multiple lines of evidence (MLOE), including surface water chemistry, sediment chemistry, sediment toxicity, and benthic infaunal community health. Of the 22 primary and secondary indicators assessed for changes from historical conditions, 16 showed improvement. The remaining six indicators showed no noticeable trends; and no single indicator provided clear evidence of degradation from historical conditions. While this trend was apparent for RHMP-wide conditions, not all areas of the harbors showed improvement over time (e.g., the marina stratum), nor were improvements with time as evident when assessing the subset of stations revisited from prior Bight studies. With regard to long-term trend assessment, it should be noted here that a number of studies used to establish historic thresholds for comparison were targeted non-randomized assessments making direct comparisons with the current randomized approach for RHMP challenging, thus warranting some caution when interpreting these results as a whole. A closer look at results for individual or closely grouped sites that have been revisited over time will provide a more comparable assessment of trends on a refined scale.

In addition to the three core questions addressed in this report, the RHMP also attempts to understand the bioaccumulative transfer of contaminants through the food web. This analysis is currently being conducted in association with the Bight Program. During the 2013 RHMP sampling effort, tissue was collected from fish and invertebrates to measure the degree of trophic transfer of bioaccumulative contaminants from the sediments through the food web. Data analyses are still in progress at the time of this publication. A supplemental report will be prepared in early 2017 that will include methods and a summary of food web bioaccumulation results.

Focused Special Studies

In addition to the food web bioaccumulation effort, the RHMP supported a number of additional new special studies added to the Bight program in 2013. These included (1) an assessment of plastics and other marine debris collected from benthic trawls, sediment cores, and fish stomachs; (2) analysis of contaminants of emerging concern (CECs); (3) bioanalytical screening of Bight ’13 sediment extracts; and (4) an assessment of fish weight, length, and age relationships for California Halibut in southern California. A description of specific methods implemented under the RHMP to support these studies is included in this report. Results for these special studies will be reported at a later date under separate cover by the agencies overseeing these efforts: SCCWRP (Special Studies 1-3), and the California Department of Fish and Wildlife (CDFW) (Special Study 4).

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

LIST OF TABLES

TABLE OF CONTENTS (Cont.)

Page

LIST OF TABLES (Cont.)

TABLE OF CONTENTS (Cont.)

Page

LIST OF FIGURES

TABLE OF CONTENTS (Cont.)

Page

LIST OF FIGURES (Cont.)

TABLE OF CONTENTS (Cont.)

Page

LIST OF FIGURES (Cont.)

TABLE OF CONTENTS (Cont.)

Page

LIST OF FIGURES (Cont.)

TABLE OF CONTENTS (Cont.)

Page

LIST OF FIGURES (Cont.)

TABLE OF CONTENTS (Cont.)

Page

LIST OF FIGURES (Cont.)

TABLE OF CONTENTS (Cont.)

Page

LIST OF FIGURES (Cont.)

TABLE OF CONTENTS (Cont.)

LIST OF APPENDICES (PROVIDED ON CD)

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ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
>	greater than
≥	greater than or equal to
<	less than
µg/g	microgram per gram
µg/kg	micrograms per kilogram
µg/L	microgram per liter
µS/cm	microsiemens per centimeter
µm	micron
µmol/g_{OC}	micromole per gram of organic carbon
%	percent
§	Section
AB 411	California Assembly Bill 411
Amec Foster Wheeler	Amec Foster Wheeler Environment & Infrastructure, Inc.
ANOVA	Analysis of Variance
ASTM	American Society for Testing and Materials
ATL	ambient threshold limit
AVS	acid volatile sulfide
AVS-SEM	acid volatile sulfide-simultaneously extracted metals
Bight	Southern California Bight
Bight ’98	Southern California Bight 1998 Regional Monitoring Study
Bight ’03	Southern California Bight 2003 Regional Monitoring Study
Bight ’08	Southern California Bight 2008 Regional Monitoring Study
Bight ’13	Southern California Bight 2013 Regional Monitoring Study
BPTCP	Bay Protection and Toxic Cleanup Program
BRI	Benthic Response Index
CA	California
CA LRM	California Logistic Regression Model
Cal/EPA	California Environmental Protection Agency
CDFW	California Department of Fish and Wildlife
CEC	contaminant of emerging concern

ACRONYMS AND ABBREVIATIONS (Cont.)

CEDEN	California Environmental Data Exchange Network
CLP	Contract Laboratory Program
cm	centimeter(s)
CSI	Chemical Score Index
CTD	conductivity-temperature-depth profiler
CTR	California Toxics Rule
CTR CCC	California Toxics Rule Criterion Continuous Concentration
CTR CMC	California Toxics Rule Criterion Maximum Concentration
DCE	Dancing Coyote Environmental
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
dGPS	differential Global Positioning System
DGT	diffusive gel technology
DNA	deoxyribonucleic acid
DO	dissolved oxygen
DOC	dissolved organic carbon
DQO	data quality objective
EC_{50}	median effective concentration
EI	ecological index
EPA	United States Environmental Protection Agency
ER-L	effects range–low
ER-M	effects range–median
ESB	equilibrium partitioning sediment benchmark
FeS	iron sulfide
FID	further identification
fOC	fraction of organic carbon
ft	foot or feet
g	gram(s)
GC	gas chromatograph
HPAH	high-molecular-weight PAH

ACRONYMS AND ABBREVIATIONS (Cont.)

IBI	Index of Biotic Integrity
IIRMES	Institute for Integrated Research in Materials, Environments, and Society
km	kilometer(s)
kg	kilogram(s)
km^2	square kilometer(s)
LC_{50}	median lethal concentration
L	liter(s)
LCS	laboratory control sample
LDC	Laboratory Data Consultants, Inc.
LOE	line of evidence
LPAH	low-molecular-weight PAH
LRM	Logistic Regression Method
m	meter(s)
m^2	square meter(s)
MCB	Marine Corps Base
mg/kg	milligram(s) per kilogram
mg/L	milligram(s) per liter
m/sec	meter(s) per second
MBAS	methylene blue active substances
Merkel	Merkel and Associates, Inc.
MDL	Method Detection Limit
MDS	multidimensional scaling
mg	milligram(s)
mg/kg	milligram(s) per kilogram
mL	milliliter(s)
MLLW	mean lower low water
MLOE	multiple lines of evidence
mm	millimeter(s)
MS	mass spectrophotometer
MS	matrix spike
MTBE	methyl-t-butyl ether

ACRONYMS AND ABBREVIATIONS (Cont.)

N	nitrogen
N/A	not applicable
Nautilus	Nautilus Environmental, LLC
NCI	negative chemical ionization
ng/g	nanogram(s) per gram
ng/L	nanogram(s) per liter
NH_4	ammonia
NH_4Cl	ammonium chloride
NIST	National Institute for Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NT	not tested
O&G	oil and grease
oz	ounce(s)
PAHs	polynuclear aromatic hydrocarbons
PBDEs	polybrominated diphenyl ethers
PBMS	performance-based measurement system
PCA	principal components analysis
PCBs	polychlorinated biphenyls
PFC	perfluorinated compound
PFOS	perfluorooctane sulfonate
Physis	Physis Environmental Laboratories, Inc.
P_{MAX}	maximum probability model
Port	Port of San Diego
ppt	parts per trillion
psu	practical salinity unit
PVC	polyvinyl chloride
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
QC	quality control
RBI	Relative Benthic Index

ACRONYMS AND ABBREVIATIONS (Cont.)

RHMP	Regional Harbor Monitoring Program
RIVPACS	River Invertebrate Prediction and Classification System
RL	Reporting Limit
SCAITE	Southern California Association of Ichthyological Taxonomists and Ecologists
SCAMIT	Southern California Association of Marine Invertebrate Taxonomists
SCCWRP	Southern California Coastal Water Research Project
SDG	sample delivery group
SDR	synoptic data review
SDRWQCB	San Diego Regional Water Quality Control Board
SEM	simultaneously extracted metals
SIYB	Shelter Island Yacht Basin
SM	Standard Method
SOP	standard operating procedure
SP	solid-phase (toxicity test)
SQO	sediment quality objective
Sunstar	Sunstar Laboratories, Inc.
SWAMP	Surface Water Ambient Monitoring Program
SWI	sediment-water interface test
SWRCB	State Water Resource Control Board
TMDL	Total Maximum Daily Load
TOC	total organic carbon
TVV	Tandem Van Veen
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
VRG	Vantuna Research Group
Weston	Weston Solutions, Inc.
WQO	water quality objective
∑SEM:AVS	ratio of the sum of SEM to AVS

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1.0 INTRODUCTION

The Regional Harbor Monitoring Program (RHMP) was developed by the Unified Port of San Diego, the City of San Diego, the City of Oceanside, and the County of Orange in response to a July 24, 2003, request by the San Diego Regional Water Quality Control Board (SDRWQCB) under Section (§) 13225 of the California Water Code. The RHMP is a comprehensive survey of the quality of water, sediments, and aquatic life to determine whether beneficial uses are being attained and protected in Dana Point Harbor, Oceanside Harbor, Mission Bay, and San Diego Bay. The RHMP is composed of a core monitoring program and supplementary focused special studies. The initial program was designed to address five major questions posed in the SDRWQCB's request:

1. What are the contributions and spatial distributions of inputs of pollutants?
2. Do the waters and sediments in the harbors support healthy biota?
3. What are the long-term trends in water quality?
4. Are the fish safe to eat?[1]
5. Are the waters safe for human body contact?[1]

To answer the core questions, the RHMP study uses an iterative process that has included extensive research of historical information for the four harbors, mapping of the harbors into strata, identification of indicators to be monitored, establishment of reference ambient values (i.e., threshold levels) and pre-set targets (i.e., percentage of stations with levels of pollutants above threshold values), and utilization of statistical methodologies to evaluate findings in a scientifically rigorous manner that also complements the larger Bight regional monitoring program. The RHMP uses a weight-of-evidence approach to assess the condition of the harbors and to compare findings to recent historical conditions, and then to determine whether conditions are improving or deteriorating over time. Contaminants within surface waters and sediments, toxicity levels, and conditions of biological communities are quantified to determine the health and overall status of the harbors. Key indicators of ecological health measured in this program and reported herein include: (1) quantification of contaminants within surface waters and sediments, (2) laboratory toxicity tests of whole sediments, (3) characterization of benthic infaunal communities, and (3) characterization of demersal fish and epibenthic macroinvertebrate communities.

1.1 Recent History of the RHMP

1.1.1 RHMP Pilot Project and Historical Baselines

A three-year RHMP Pilot Project began in 2005 to validate the efficacy of the RHMP study design and to help establish an appropriate level of sampling effort. The Pilot Project illustrated that a stratified random study design with approximately 15 stations in each of 5 strata is appropriate for analysis of RHMP status among harbors and strata, and trends over time, and is

[1] Not addressed in the 2013 RHMP. See Section 1.2 for a discussion related to these questions.

also consistent with the Bight program methodology. Historical conditions of the harbors were determined based on a review of various targeted and randomized studies completed during a 10-year period between 1994 and 2004. Data from these studies were used to establish pre-set targets as the percentages of stations with results at or below threshold values (Weston, 2008). Ultimately, the RHMP was originally designed to address five questions regarding the status of harbors, listed in the previous section.

1.1.2 Relationship to the Bight Regional Monitoring Studies

The Southern California Bight Regional Study (Bight Program) began in 1994. Its goal was to complete a comprehensive regional monitoring survey every five years to provide a "snapshot" of conditions in the Southern California Bight, and to ultimately describe trends and changes that occur on a region-wide scale (Southern California Coastal Water Quality Control Board [SCCWRP], 1998). The RHMP was developed to compliment and support the Bight Program while assessing the five core questions specific to the San Diego Regional Harbors. The RHMP also has included special studies to address specific questions determined to be locally important to the region by the RHMP Agencies. Methodologies and overall monitoring are consistent with that required by the Bight Program and data derived by the RHMP are submitted to SCCWRP for inclusion into the Bight database. Representatives of the RHMP participated on most of the Bight '13 workgroup committees throughout development of the key goals, questions and planning documents, and continue to participate through on-going Bight-wide quality assurance/ quality control (QA/QC), data analysis, and reporting efforts.

Harbor Characteristics
The four harbors monitored under the RHMP are similar in many ways (i.e., semi-enclosed embayments in southern California), but each has its own unique set of characteristics that are important to consider when interpreting data and making comparisons among them. Their geography and current and historical uses both have considerable influence on current water and sediment quality conditions.

Dana Point Harbor
Dana Point Harbor is a small, man-made recreational harbor constructed in the late 1960s. Of the four harbors encompassing the RHMP, Dana Point Harbor has the highest overall density of resident commercial and recreational vessels. The harbor is divided into two main northern and southern regions with approximately 2,500 boat slips in an area encompassing approximately 0.35 square mile (0.9 square kilometer [km^2]). Sampling stations in this harbor represent three RHMP strata: marina, shallow, and deep. The entire perimeter of the harbor is surrounded by a rip-rap boundary, except for a sandy beach near the northern end of the embayment referred to as Baby Beach. There are multiple municipal storm drain inputs into Dana Point Harbor; however, none are directly from major watershed sources.

Oceanside Harbor
Oceanside Harbor is another small, man-made recreational harbor, created around the same time (1963) as Dana Point Harbor. This harbor is divided into two main northern and southern sections, but is also connected to a third basin farther to the north that is operated by the Marine Corps Base (MCB) at Camp Pendleton. This basin on MCB Camp Pendleton was not assessed

under the RHMP. Sampling stations in Oceanside Harbor included those in both marina and deep RHMP strata. The harbor, excluding the northern Marine Corps Basin, has approximately 800 boat slips in an area encompassing 0.11 square mile (0.28 km^2). The entire perimeter of Oceanside Harbor is surrounded by a rip-rap boundary. There are multiple municipal storm drain inputs into Oceanside Harbor; however, none are directly from major watershed sources.

Mission Bay

Larger in size (approximately 3.9 square miles [10 km^2]), and more diverse in characteristics, Mission Bay is a natural shallow embayment that has been substantially modified by dredging and filling operations that occurred in the late 1940s. Mission Bay is a popular recreational area, with six marinas, several resorts, a golf course, and the Sea World Marine Park all present within its immediate boundaries. Mission Bay has 27 miles (43 kilometers [km]) of shoreline, 19 of which are sandy beaches, with eight locations designated as official swimming areas.

Physical characteristics vary greatly throughout the bay. The entrance and western portions of the bay receive substantial open ocean influence through tidal flushing and are predominantly lined with rip-rap. Conversely, the eastern portion of the bay is predominantly lined with sandy beaches, but is constrained geographically, reducing water movement and exchange, particularly in the far inner reaches (Kinnetic Laboratories, 1994). With the exception of the channel entrance and the semi-enclosed marina in Quivira Basin, the depth of the bay is relatively constant, between 1 and 3 meters mean lower low water (MLLW), throughout. Mission Bay's extensive sloping sandy shorelines and the shallow bottom in many areas provide extensive eelgrass bed habitats throughout much of the bay.

Mission Bay is used primarily for recreation, and is composed of the marina, shallow, freshwater-influenced, and deep RHMP strata. There are approximately 1,800 permanent boat slips in nine marinas and several offshore mooring locations at various locations throughout Mission Bay. Mission Bay has approximately 100 storm drain inputs, all with dry weather flow interceptors, and three watershed inputs from Rose Creek, Cudahy Creek, and Tecolote Creek, which are all located in the eastern portion of the bay and drain a collective watershed area of 80 square miles (207 km^2).

San Diego Bay

The largest and most diverse of the four harbors, San Diego Bay is a natural embayment that has been modified over time by dredging and filling operations beginning in the early 1900s. It is unique among the harbors monitored for the RHMP because it is used for both recreation and industry, and is the only harbor in this study with industrial/port activity. San Diego Bay is 15 miles (24 km) long and varies from 0.2 to 3.6 miles (0.3 to 5.8 km) in width. It is 17 square miles (44 km^2) in area at MLLW (Wang et al., 1998). San Diego Bay had sampling stations encompassing all five RHMP strata types. The larger size and multiple uses of San Diego Bay create smaller micro-environments that may vary greatly from the mouth to the southern portion of the bay.

San Diego Bay is unique among the harbors monitored for the RHMP because of its historical usage and the extent of previous insults to the marine environment within the bay. San Diego grew rapidly in the 1880s, with the establishment of several military installations, and over the

next few decades the population and industry grew rapidly (Canada, 2006). Today, San Diego Bay has a large working waterfront as well as several military facilities. The San Diego International Airport is also adjacent to the bay. Recreational boating is a large component of the activity on the bay with numerous marinas throughout as well as several offshore anchorages. As the largest estuary in southern California, San Diego Bay provides critical habitat for both marine and estuarine fish species. The bay also provides extensive shallow water eelgrass habitat that supports unique assemblages of fishes, as well as important nursery habitat for juvenile fishes (Vantuna Research Group [VRG], 2009).

There are approximately 200 municipal storm drains as well as six urban rivers/creeks (Sweetwater River, Otay River, Switzer Creek, Chollas Creek, Paleta Creek, and Paradise Creek) that contribute watershed inputs into San Diego Bay (City of San Diego, 2013).

1.1.3 2008 RHMP

The RHMP completed its first complete core monitoring program during summer 2008 as a component of the 2008 Southern California Bight Regional Study (Bight ’08) to address the five core questions presented in Section 1.0. The results of the 2008 RHMP suggested the following:

1. Areas of the harbors most closely associated with human uses (i.e., marinas, industrial/port, and freshwater-influenced areas) tended to have elevated chemical concentrations and greater exceedances of chemical thresholds in the surface waters and sediments as compared with areas that were not closely associated with human activity (i.e., deep and shallow strata).
2. Indicator bacteria levels were well below California Assembly Bill 411 (AB 411) standards for total and fecal coliforms and *Enterococci*, with the vast majority of the stations having bacterial levels that were below detection limits.
3. Overall conditions in the harbors supported healthy infaunal biota, demersal fish, and invertebrate communities, with a diversity and abundance of species that were consistent with prior Bight studies.
4. RHMP-wide conditions were improving over time, based on comparisons of multiple lines of evidence (MLOE), including surface water chemistry, sediment chemistry, sediment toxicity, and benthic infaunal community health.

1.2 Refinements to the 2013 RHMP

In 2013, the RHMP focused on answering three core questions directly from the SDRWQCB §13225 letter:

1. ***What are the contributions and spatial distributions of inputs of pollutants?***
2. ***Do the waters and sediments in the harbors sustain healthy biota?***
3. ***What are the long-term trends in water and sediment quality?***

Efforts to answer these three questions are reported herein. Efforts to assess the degree of bioaccumulation of selected contaminants from the sediments through the food web (the fourth question posed in SDRWQCB's initial request) were also initiated during this program, but analyses are still in progress at the time of this publication and the results of this effort will be provided at a later date under separate cover.

The 2013 RHMP was refined on the basis of findings from the 2008 RHMP, and was again closely associated with the Bight '13 Regional Monitoring Program. Several notable adjustments were made to the overall program in 2013 (including changes to the core questions), as follows:

1. The focus of the fourth original core question identified in the SDRWQCB §13225 letter, regarded the safety of fish for human consumption. This original core question is being addressed with a primary focus on San Diego Bay through a much larger coordinated effort currently being led by the SDRWQCB in collaboration with the SCCWRP, the United States Fish and Wildlife Service (USFWS), and other multiple interested stakeholders. These ongoing efforts are targeting fish that are more typically caught by fisherman on hook and line and are surveying fishermen to better understand human consumption patterns. To supplement this effort, the 2013 RHMP in coordination with the Bight Program, included a focused task to better understand the degree of trophic transfer of bioaccumulative compounds in resident aquatic species and nesting birds (eggs) in relation to available wildlife risk thresholds. Additionally, the RHMP was enhanced substantially from the effort in 2008 to collect sediment-dwelling infauna, epibenthic macroinvertebrates, and demersal fish for chemical analysis of their tissues at each of the 15 total locations where benthic trawls were performed among the four harbors. This report briefly summarizes the methodology for this effort; however, data analyses were still in progress at the time of publication of this report. A supplemental stand-alone report describing these methods and findings will be provided in fall or winter of 2016. These data will eventually be incorporated into the larger southern California region-wide ecological and human health risk assessment in progress under direction of the SDRWQCB in coordination with SCCWRP and the USFWS.
2. The fifth core question identified in the §13225 letter by the SDRWQCB was related to whether the waters are safe for swimming. This question was omitted during the 2013 RHMP core monitoring for several reasons. First, addressing this particular question requires more intensive efforts than what can be concluded from a once-in-every-five-years ambient monitoring program due to extreme temporal and spatial variability associated with bacteria indicators well documented in both freshwater and marine environments. As such, more focused monitoring to assess public health is currently underway at beaches and bays throughout southern California. Specifically, beach water quality is assessed through the California State AB 411 program. In addition, there are several current total maximum daily loads (TMDLs) at identified areas of particular concern in southern California. Particularly relevant to the four RHMP harbors is the TMDL for Indicator Bacteria at Baby Beach, Shelter Island Shoreline Park, Twenty Beaches and Creeks in the San Diego Region (SDRWQCB Resolution No. R9-2010-0001). Extensive monitoring, assessment, and identification and implementation of best management practices are currently being performed region-wide to comply with this

TMDL. Rationale for the decision to remove studies related to *Question 5* is discussed in a letter provided by the Port of San Diego to the Regional Water Quality Control Board submitted on May 15, 2013 (Appendix P).

3. Synthetic pyrethroid insecticides and chlorinated pesticides were dropped from the 2013 RHMP analyte list in the water column due to the lack of detections during the 2008 RHMP. Existing ambient concentrations of these compounds in coastal waters are well below current standard method detection limits. Special studies implemented by SCCWRP used *in situ* passive and active sampling methods to concentrate pyrethroid and chlorinated pesticides for low-level quantification at a few select locations in San Diego Bay and Newport Harbor during the Bight ’13 activities. The compound methyl tert-butyl ether (MTBE) was also not measured in 2013 based on the lack of detections in 2008 and its unlikely presence in ambient marine waters. MTBE is a volatile gasoline additive that is sparingly soluble in water (Winterberg et al., 2010). Its presence is of greater concern in groundwater used for drinking water supplies at locations influenced by fuel leaks (http://archive.epa.gov/mtbe/web/html/).

4. The 2013 RHMP supported four new special studies of the Bight program; each will be reported separately through the Bight program. They are as follows:

   a. Assessment of plastics and other marine debris collected from benthic trawls, sediment cores, and fish stomachs.

   b. Analysis of contaminants of emerging concern (CECs) in a subset of Bight samples: (1) perfluorooctane sulfonate (PFOS), a perfluorinated compound (PFC) used in stain repellants; (2) p-nonylphenol, and (3) alkylphenol. The CECs bifenthrin and permethrin (two pyrethroid pesticides) and polybrominated diphenyl ethers (PBDEs) (used as flame retardants) are now part of the standard suite of analytes measured Bight-wide and were included for analysis in all RHMP samples.

   c. Bioanalytical screening of Bight ’13 sediment extracts, a new special study designed to answer the following specific questions:

      i. What is the response of a battery of cell-based in-vitro bioassays to extracts of Bight sediment representing a range of chemical contamination?

      ii. How do bioassay responses correlate with the sediment concentrations of contaminants measured as part of the Bight ’13 monitoring design?

      iii. How do bioassay responses correlate with legacy (i.e., routinely monitored) contaminant concentrations? How do they correlate with CECs such as PBDEs and PFCs?

   d. Collection of juvenile California halibut to help evaluate a new technique being developed by the California Department of Fish and Wildlife (CDFW) to determine the sex using ultrasound.

The specific methods implemented under RHMP to support these studies are described in Section 2. Results of these special studies (except for pyrethroid pesticide and PBDE concentrations) will be reported later under separate cover by SCCWRP and CDFW. Pyrethroid and PBDE results for all RHMP-monitored stations are presented herein.

1.3 2013 RHMP Report

This report presents the results of the 2013 RHMP core monitoring study, which assessed the overall health of the harbors based on MLOE: water quality (Section 3.1), sediment quality (Section 3.2), and demersal fish and macroinvertebrate communities (Section 3.3). The conclusions of the 2013 RHMP are discussed in the context of the first three core questions related to status and trends of environmental conditions in the harbors. More in-depth analyses were also performed to help address potential causal relationships where benthic communities were considered most impacted.

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2.0 METHODS

2.1 Field Sampling

Field sampling was conducted by Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler) from August 5 through September 10, 2013. Core monitoring activities consisted of:

- Water quality sampling
- Sediment sampling for chemistry and toxicity
- Benthic infaunal assessments
- Trawl net sampling to quantify the demersal fish and epibenthic macroinvertebrate communities

Additional samples of biota, trash, and sediments were collected to support a variety of new special studies for the Bight program in 2013, as described below.

2.1.1 Station Selection

The locations of 75 sediment and water sampling stations and 15 trawl stations were designated using a probability-based, stratified random sampling approach that was fully integrated into the Bight ’13 Program. Sediment sampling and benthic trawl stations were selected by SCCWRP in accordance with the Bight ’13 Regional Marine Monitoring Survey Coastal Impact Assessment Work Plan (SCCWRP, 2013a). These stations served as locations for both RHMP and Bight ’13.

As during the 2008 RHMP, the harbors were classified into five strata: marina, industrial/port, freshwater-influenced, deep (>12 feet MLLW), and shallow (<12 feet MLLW) areas. The strata were assigned to sites based on the most likely direct influence(s) to the marine environment from anthropogenic sources with the exception of the deep and shallow strata which were located further from a specific direct source. The strata were developed to help tease out status and trends in specific geographic regions with various activities/ influences from the overall RHMP-wide dataset. All five strata are present in San Diego Bay; Mission Bay has four strata (freshwater-influenced, marina, shallow, and deep); Dana Point Harbor has three strata (marina, shallow, and deep); and Oceanside Harbor has just two strata (marina and deep). Freshwater-influenced areas were considered to be those areas that had either large nearby storm drains (greater than 36 inches in diameter) or nearby creek or river inputs.

Uniformly sized hexagons depicting the strata were overlaid on maps of each of the harbors. Hexagons were set at 30.5 meters per side. In each stratum, 15 stations were randomly selected for sampling, with each harbor having at least one station for each of its strata. Sampling was conducted within a 100-meter radius of the nominal station coordinates in accordance with Bight ’13 protocols, as determined by a differential Global Positioning System (dGPS), and coordinates of sampling stations were recorded.

Otter trawl sampling stations were selected at a total of 15 RHMP stations using the probability based, random-sampling approach. There were 10 trawl stations in San Diego Bay, three in Mission Bay, and one each in Dana Point Harbor and Oceanside Harbor. An analysis of the epibenthic communities was derived from net tows conducted using standard Bight protocol at each of the 15 2013 RHMP trawl stations.

In a few cases due to physical geography (i.e. impermeable or sloped sediment surfaces) or access and safety restrictions, final sample locations differed from the original proposed sites though all were within the 100 meter (m) radius protocol set for the RHMP and Bight Programs. Differing depths at some locations compared to prior surveys and the requirement to move sample locations slightly from proposed sites resulted in a re-designation of strata types in a few cases. In such cases, the stratum originally assigned was adjusted to the appropriate stratum based on the actual sampling location. In the end, there was a relatively even distribution of stations across strata; 15 stations each were sampled in marina and shallow strata, 14 stations in the industrial stratum, 16 in the deep stratum, and 15 in the freshwater-influenced stratum. A total of four sediment and water quality stations were sampled in Dana Point Harbor, three in Oceanside Harbor, nine in Mission Bay, and 59 in San Diego Bay. The number of stations among harbors was based on the overall size of each harbor.

In Dana Point Harbor, most of the area assessed was categorized as marina (two of four stations), and there was one sampling station in each of the deep and shallow strata in central channel regions outside of the marinas (Figure 2-1a).

In Oceanside Harbor, a single station was located within a marina stratum, and two were in the deep stratum (one near the mouth of the harbor and another in the central channel (Figure 2-1b).

Mission Bay was sampled relatively evenly across its four strata. Of the nine sediment and water quality stations, three were located in the shallow stratum, two were in the deep stratum, two were in the freshwater-influenced stratum (near Rose Creek and Cudahy Creek outflows in eastern Mission Bay), and two were in the marina stratum within Quivira Basin and the Dana Landing embayment (Figure 2-1c).

The number of samples in each stratum in each harbor is listed in Table 2-1. The locations of the sediment, water quality, and trawl sampling stations in each harbor are shown in Figures 2-1a through 2-f (from north to south).

Table 2-1.
RHMP Sampling Strata Summary

Harbor	Number of Samples in Each Stratum					Total
	Marina	Freshwater-Influenced	Industrial/ Port	Shallow	Deep	
Dana Point Harbor	2	0	0	1	1	4
Oceanside Harbor	1	0	0	0	2	3
Mission Bay	2	2	0	3	2	9
San Diego Bay	10	13	14	11	11	59
Total	15	15	14	15	16	75

In San Diego Bay, of the 59 sediment and water quality stations, 14 were located in the industrial/port stratum; 10 were in the marina stratum; 13 were in the freshwater-influenced stratum; 11 were in the shallow stratum; and 11 were in the deep stratum (see Figures 2-1d, 2-1e, and 2-1f). The marina stations were in Shelter Island Yacht Basin (SIYB), America's Cup Harbor, Harbor Island Marina, Glorietta Bay, and the Coronado Cays. Eight of the 13 freshwater-influenced stations were located within the Sweetwater Channel in southern San Diego Bay; four were outside the mouth of Chollas Creek; and the remaining station was near a storm drain in the Laurel Hawthorn embayment. Industrial/port stations were located exclusively along the eastern shoreline of San Diego Bay, extending north from Chollas Creek to the Embarcadero Marina Park.

Of the 75 stations sampled, 59 stations were revisits to locations sampled in prior Bight studies: 12 stations coincided with stations in the Southern California Bight 1998 Regional Monitoring Study (Bight '98), 14 stations from the Southern California Bight 2003 Regional Monitoring Study (Bight '03), and 59 stations from Bight '08. All stations revisited from Bight '98 or Bight '03 were revisited in Bight '08. Of the total, 45 of the revisited stations were located in San Diego Bay; 7 were in Mission Bay; 3 were in Oceanside Harbor; and 4 were in Dana Point Harbor.

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Figure 2-1a. Sampling Stations and Strata in Dana Point Harbor

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Figure 2-1b. Sampling Stations and Strata in Oceanside Harbor

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Figure 2-1c. Sampling Stations and Strata in Mission Bay

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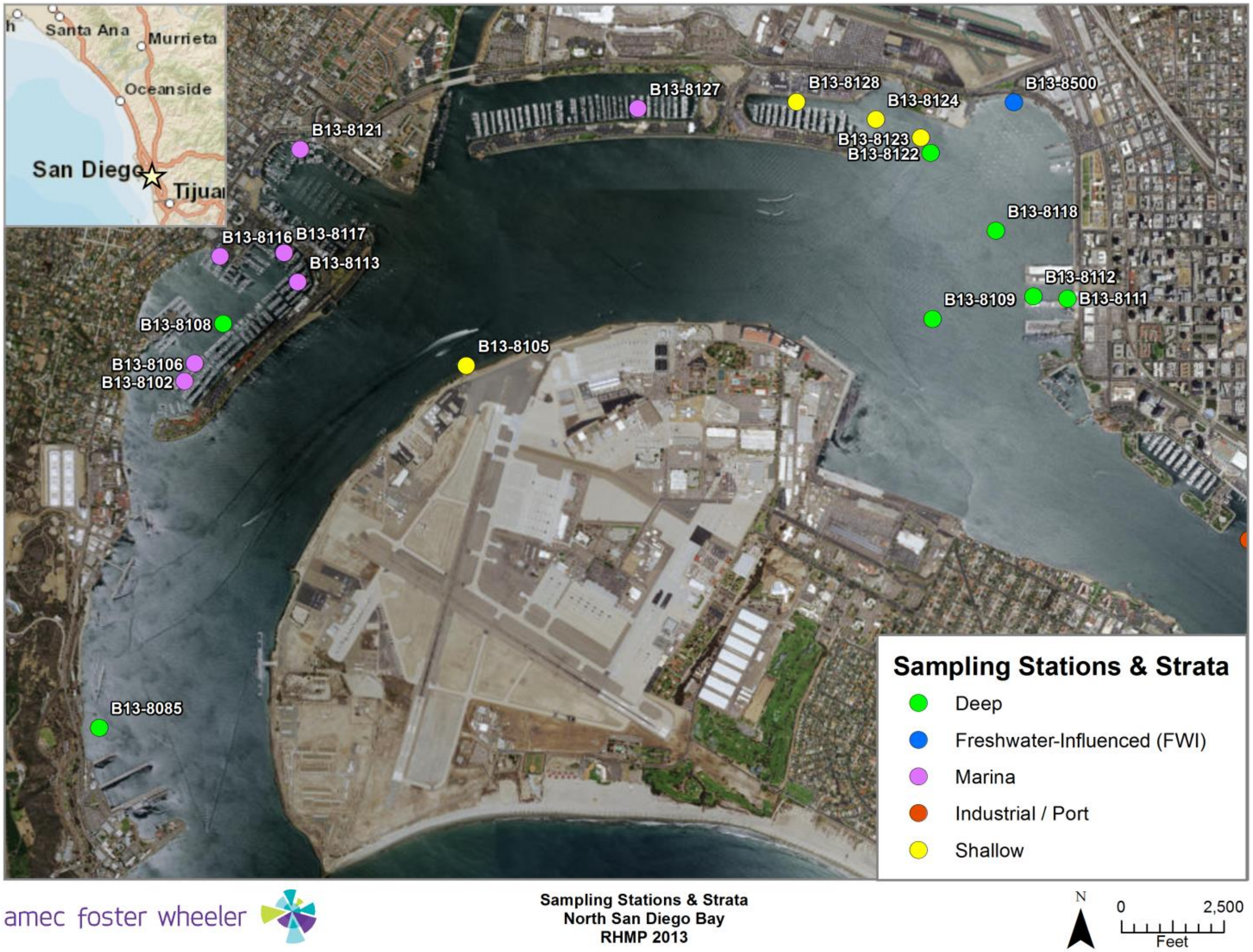

Figure 2-1d. Sampling Stations and Strata in San Diego Bay, Northern Area

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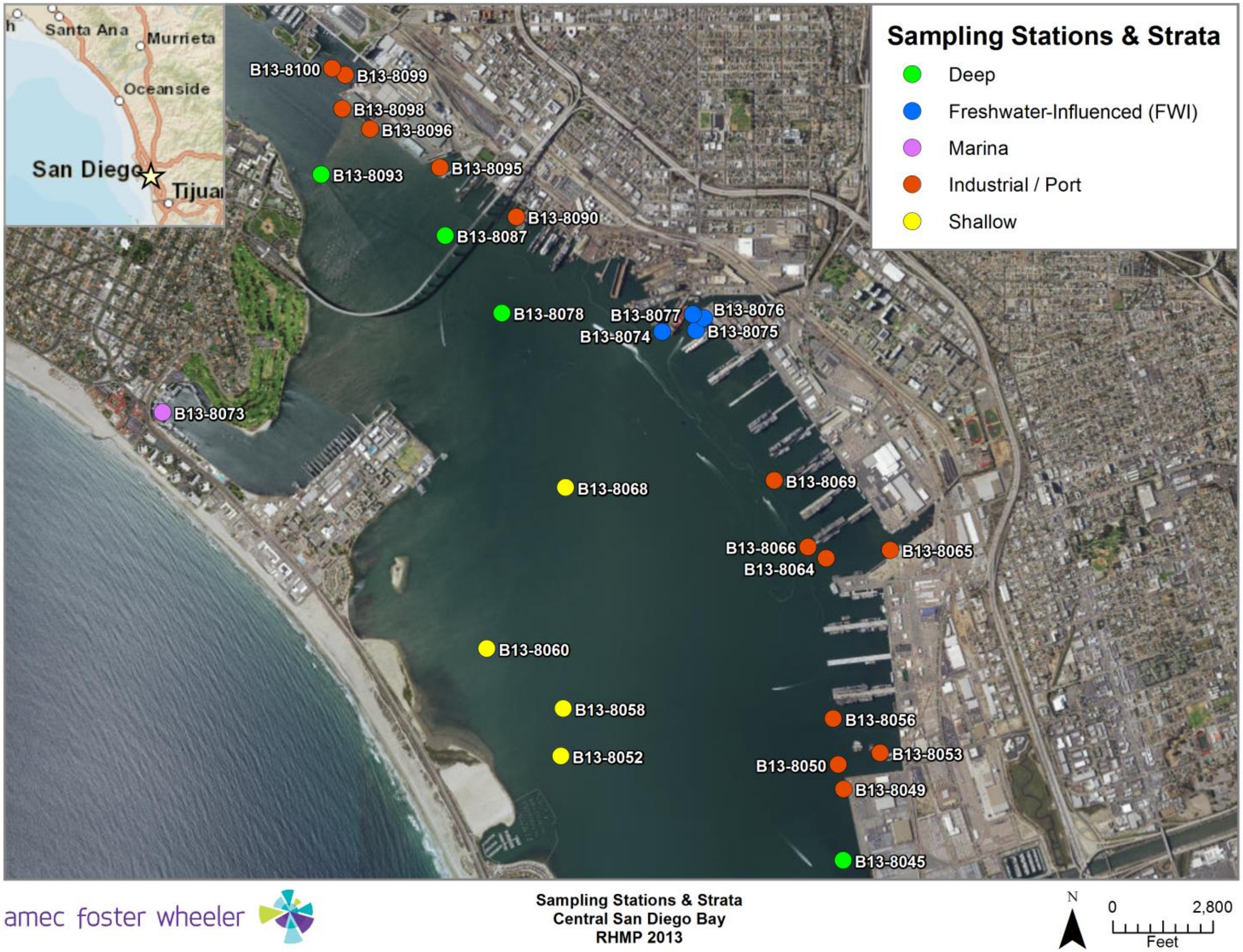

Figure 2-1e. Sampling Stations and Strata in San Diego Bay, Central Area

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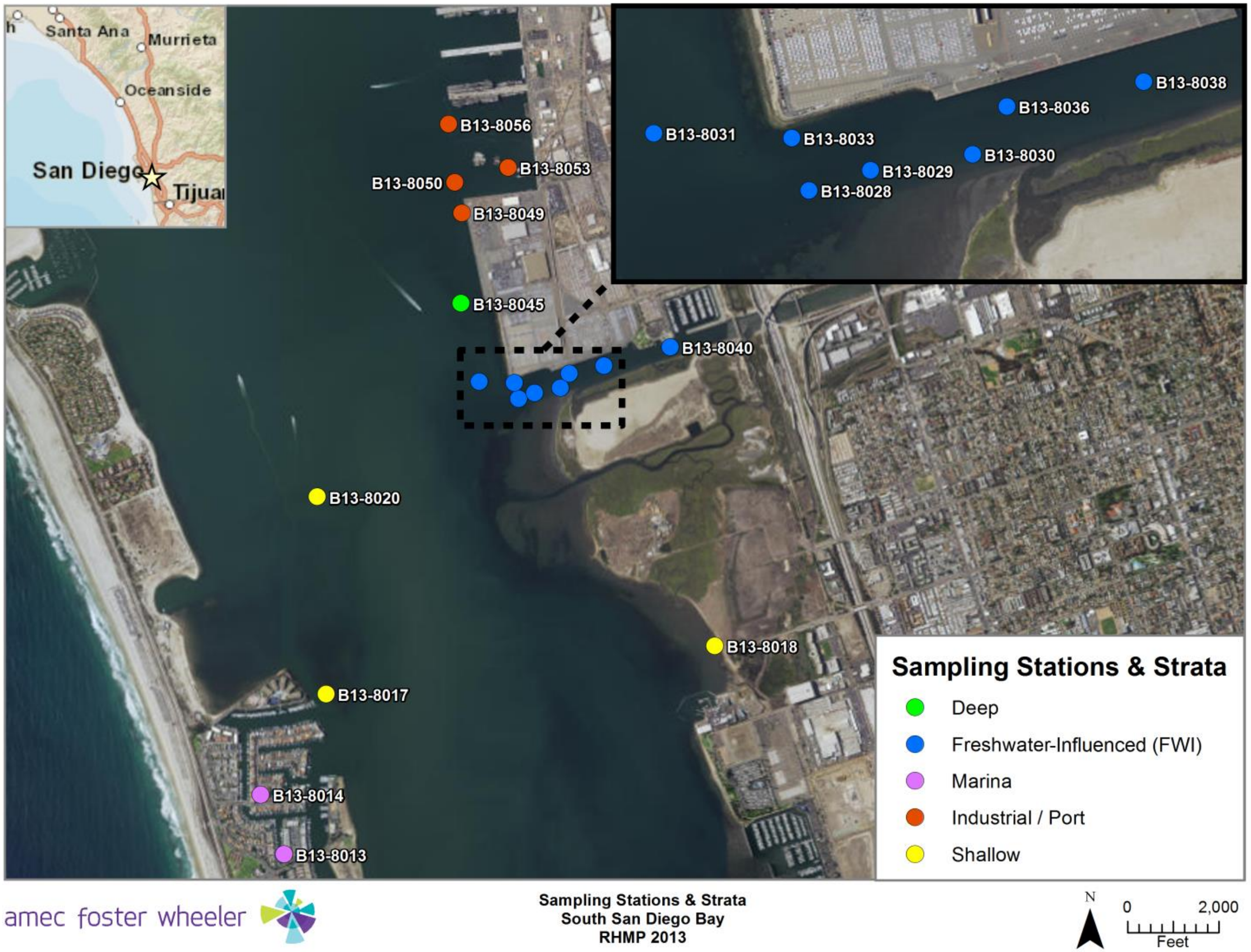

Figure 2-1f. Sampling Stations and Strata in San Diego Bay, Southern Area

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2.1.2 Water Quality Sampling

Water quality was sampled at 75 stations. Methodologies and associated quality assurance and quality control (QA/QC) procedures are detailed in the project-specific Work Plan and QAPP, prepared by Amec Foster Wheeler and approved by the RHMP agencies[2] (Amec Foster Wheeler, 2013a and 2013b). Field observations and coordinates of sampling stations during collection were recorded on sampling data forms and electronically on a tablet computer. Station locations are provided in Appendix A.

Upon arriving at a sampling station, the vessel was anchored with the engine off for at least five minutes prior to initiating water sampling. Discrete water samples were collected at each station 1 meter below the surface using a 2.2-liter acrylic Niskin™ bottle. For dissolved trace metals, a subsample of water from the Niskin bottle was immediately filtered in the field through a 0.45-micron (µm) Whatman fiber filter in a disposable sterile self-contained vessel using a hand pump. The filter apparatus was pre-cleaned in the field with three aliquots of deionized water and rinsed three times with site water prior to collection for analysis of dissolved metals.
Subsamples of water for analysis of total metals, ammonia, nitrate (N), orthophosphate, methylene blue activated substances (MBAS; surfactants), oil and grease (O&G), dissolved organic carbon (DOC), total organic carbon (TOC), and polynuclear aromatic hydrocarbons (PAHs) were carefully poured directly from the Niskin bottle into pre-labeled sample bottles with proper preservative where appropriate. Subsamples for analysis of dissolved metals remained in the sealed filter vessel. All samples were logged on a chain of custody (COC) form, and then transferred immediately to an ice chest and kept at approximately 4 degrees Celsius (°C) on wet ice during holding and transport. Additional data, including weather, wind speed and direction, and water color and odor, were recorded on field data sheets (Appendix E). A complete list of analytes and associated reporting limits (RLs) are provided in Table 2-2 and Appendix B. Samples were submitted to Physis Environmental Laboratories, Inc. (Physis) located in Anaheim, California (CA), for chemical analyses. Subsamples from each station were submitted by Physis to Sunstar Laboratories Inc., located in Lake Forest, CA, for analysis of DOC and total TOC; the other analyses were all performed by Physis. All samples were shipped on ice to Physis within 48 hours of collection and were analyzed within the required holding times.

Table 2-2.
Chemical Analyses of Water Samples[3]

Analyte	Analysis Method	Water Target Reporting Limits[a]	Units
pH	Field Measures	--	--
Specific Conductance	Field Measures	--	µS/cm
Dissolved Oxygen	Field Measures	--	mg/L
Temperature	Field Measures	--	°C

[2] Agencies comprise the Unified Port of San Diego, City of San Diego, County of Orange, and City of Oceanside.
[3]Complete list, including method detection limits and reporting limits for all individual compounds, is presented in Appendix B.

Analyte	Analysis Method	Water Target Reporting Limits[a]	Units
Salinity	Field Measures	--	ppt
Transmissivity	Field Measures	--	%
Ammonia-N	SM 4500-NH3 D	0.05	mg/L
Methylene Blue-Activated Substances (MBAS)	SM 5540 C	0.025	mg/L
Nitrate-N	EPA 300.0/SM 4500-NO3 E	0.05	mg/L
Oil and Grease	EPA 1664A	1.0	mg/L
Dissolved Organic Carbon (DOC)	EPA 415.3	0.5	mg/L
Total Organic Carbon (TOC)	EPA 415.3	0.5	mg/L
Total Orthophosphates P	SM 4500 P E	0.05	mg/L
Aluminum (Al)	EPA 1640	1.0	µg/L
Antimony (Sb)	EPA 1640	0.015	µg/L
Arsenic (As)	EPA 1640	0.015	µg/L
Barium (Ba)	EPA 200.8	0.5	µg/L
Beryllium (Be)	EPA 1640	0.01	µg/L
Cadmium (Cd)	EPA 1640	0.005	µg/L
Chromium (Cr)	EPA 1640	0.025	µg/L
Cobalt (Co)	EPA 1640	0.01	µg/L
Copper (Cu)	EPA 1640	0.01	µg/L
Iron (Fe)	EPA 1640	1.0	µg/L
Lead (Pb)	EPA 1640	0.005	µg/L
Manganese (Mn)	EPA 1640	0.02	µg/L
Mercury (Hg)	EPA 245.7	0.02	µg/L
Molybdenum (Mo)	EPA 1640	0.01	µg/L
Nickel (Ni)	EPA 1640	0.005	µg/L
Selenium (Se)	EPA 1640	0.015	µg/L
Silver (Ag)	EPA 1640	0.02	µg/L
Thallium (Tl)	EPA 1640	0.01	µg/L
Tin (Sn)	EPA 1640	0.01	µg/L
Titanium (Ti)	EPA 1640	0.07	µg/L
Vanadium (V)	EPA 1640	0.04	µg/L
Zinc (Zn)	EPA 1640	0.005	µg/L
Polycyclic Aromatic Hydrocarbons (PAHs) [b]	EPA 625	5.0	ng/L

Notes:
Metals analysis included of both total and dissolved fractions. Filtering for the dissolved fraction took place in the field immediately after collection.
a Reporting limits provided by Physis Environmental Laboratories.
b 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, dibenzothiophene, 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.
°C = degrees Celsius; µS/cm = microSiemens per centimeter; µg/L = micrograms per liter (parts per billion); cm = centimeter; EPA = United States Environmental Protection Agency method; mg/L = milligrams per liter; ng/L = nanograms per liter; ppt = parts per thousand; SM = Standard Method

After collection of water samples for chemical analysis, physical parameters of the water column were assessed using a Seabird Electronics SBE-19 Plus™ conductivity-temperature-depth (CTD) profiler instrument (equipped with sensors that measure specific conductance, temperature, dissolved oxygen (DO), pH, and light transmission (transmissivity). The DO and pH sensors were calibrated prior to the week of monitoring; the transmissivity, conductivity, and

temperature sensors were calibrated annually by Sea-Bird Electronics, Inc. To initiate a cast, a 3-minute acclimation period was conducted to bring the CTD sensors into thermal equilibrium with the ambient seawater and to ensure that all sensors were reading accurately. The CTD was then lowered at a speed of 0.25–0.50 meter per second (m/sec), while scanning and logging measurements at 8 scans per second, until it was within 1 meter of the bottom. After casts at each station, data were downloaded and saved onto a field computer, and then checked to ensure that the CTD had been turned on properly, the depth was accurate, and all water quality measurements had been recorded throughout the cast. A post-cruise calibration of the CTD was performed after each week of sampling.

Photographs 1 through 4 show the sample collection and filtration process aboard the research vessel.

Photographs 1 and 2. Collection of water samples using a Niskin bottle and subsequent processing aboard the R/V Early Bird II

Photograph 3. Field filtration for analysis of dissolved trace metals

Photograph 4. Water column profile sampling using a CTD in San Diego Bay

2.1.3 Sediment Sampling

Sediment sampling was performed at the same 75 stations as the water quality sampling (generally on the same day), following the Bight '13 protocols outlined in the *Bight '13 Field Operations Manual* (SCCWRP, 2013a), and the project-specific Work Plan and QAPP for RHMP (Amec Foster Wheeler, 2013a and 2013b). Detailed field notes regarding the sampling location, visual sediment characteristics, and other observations of potential value at the site were recorded during sample collection. Field observations and the sampling station coordinates were recorded on sediment sampling data forms on a field computer that was integrated with the dGPS unit. Station coordinates are provided in Appendix A. Raw field data sheet scans are provided in Appendix E. All samples were logged on a COC form, and then placed in a cooler on ice. Samples were stored at 4°C in the dark until delivered to the appropriate laboratory for analysis following collection.

Benthic sediments were collected using a stainless-steel, 0.1-square-meter (m^2) Tandem Van Veen (TVV) grab sampler (Photograph 5). A minimum of two sediment grabs per station were collected for the following analyses: benthic infauna, chemistry, grain size, and toxicity. A sample was considered acceptable if the surface of the grab was even, the surface disturbance was minimal, and the penetration depth was at least 7 centimeters (cm). Rejected grab samples were discarded and resampled. Prior to subsampling for analyses, the physical characteristics

of each grab sample were recorded (color, odor, grain size, any macrofauna or algae observed, shell debris, etc.). A photograph of each sample processed was taken (including sampling station identification date, and time, recorded on a white board as shown in Photograph 6). A photograph log of all sediments collected is provided for reference in Appendix M.

The two grab samples from the first deployment of the TVV were used for chemistry and benthic infaunal samples, while subsequent grabs were used to fill remaining chemistry jars, sediment toxicity collection containers, and containers for grain-size analysis. Samples for sediment toxicity and chemistry analyses were collected from the top 5 cm of the grab, avoiding sediment within 1 cm of any side of the TVV. A total of 5 L of sediment were collected for acute and chronic toxicity testing, placed in five 1-L plastic containers, and stored on ice. Chemistry samples were collected first from one portion of the first deployment grab, and then benthic samples were collected from the adjacent undisturbed grab. In an attempt to create representative composites, chemistry and toxicity bottles were filled by incrementally adding small volumes of sediment to each sample container in a serial manner as prescribed by the Bight ’13 sampling protocol (SCCWRP, 2013a). Additional deployments were then conducted as needed to collect enough sediment to fill all chemistry jars and toxicity containers.

The incremental sampling method is intended to result in an equal and representative sample in each jar, but given small-scale variability often apparent in surface sediments, this can be challenging and creates the potential for unintended variation among the different containers. Given this challenge, a strong recommendation has been made for future Bight programs to consider homogenizing sediments in the field from a given sampling location prior to distributing to both chemistry and toxicity containers.

Sediment samples were analyzed for the analytes listed in Table 2-3.

Table 2-3.
Chemical Analyses of Sediment Samples[4]

Analyte	Analysis Method	Sediment Target Reporting Limits [a,b]	Units
Total Solids	SM 2540 B [c]	0.1	%
Total Organic Carbon	9060	0.01	%
Grain Size	SM 2560	0.1	%
Aluminum	6020/6010B [d]	5.0	mg/kg
Antimony	6020/6010B [d]	0.05	mg/kg
Arsenic	6020/6010B [d]	0.05	mg/kg
Barium	6020/6010B [d]	0.05	mg/kg
Beryllium	6020/6010B [d]	0.05	mg/kg
Cadmium	6020/6010B [d]	0.01	mg/kg
Chromium	6020/6010B [d]	0.05	mg/kg
Copper	6020/6010B [d]	0.01	mg/kg
Iron	6020/6010B [d]	5.0	mg/kg

[4] Complete list, including method detection limits and reporting limits for all individual compounds, is presented in Appendix B.

Analyte	Analysis Method	Sediment Target Reporting Limits [a,b]	Units
Lead	6020/6010B [d]	0.01	mg/kg
Mercury	6020/6010B [d]	0.02	mg/kg
Nickel	6020/6010B [d]	0.02	mg/kg
Selenium	6020/6010B [d]	0.05	mg/kg
Silver	6020/6010B [d]	0.02	mg/kg
Zinc	6020/6010B [d]	0.05	mg/kg
Total Nitrogen	EPA 6090	4.0	mg/kg
Total Phosphorus	EPA 6020	4.0	mg/kg
Ammonia	SM 4500-NH3	0.2	mg/kg
Acid Volatile Sulfides	Plumb 1981 and TERL	0.1	mg/kg
Simultaneous Extracted Metals	EPA 200.8	0.0004-0.0124	µmol/g
PAHs [e]	EPA 8270C [d]	5.0	µg/kg
Chlorinated Pesticides [f]	EPA 8270C [d]	0.5-50	µg/kg
Pyrethroid Pesticides	EPA 8270 C NCI	0.5-10	µg/kg
PCB Congeners [g]	EPA 8270C [d]	0.2	µg/kg
PBDEs [h]	EPA 8270 C NCI	0.1	µg/kg
Alkylphenol [i,j]	GC/MS SIM	0.02-0.6	mg/kg
Perfluorinated Compounds [i,k]	EPA 537M	5.0	µg/kg

Notes:
a Sediment minimum detection limits are on a dry-weight basis.
b Reporting limits provided by Physis Environmental Laboratories.
c Standard Methods for the Examination of Water and Wastewater, 19th Ed. American Public Health Association, 1995.
d United States Environmental Protection Agency (USEPA) 1986-1996. SW-846. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, 3rd Ed.
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, dibenzothiophene, 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 cis-chlordane, trans-chlordane, o.p'-DDT, p,p'-DDT, o.p'-DDD, p,p'-DDD, o.p'-DDE, p.p'-DDE, p,p'-DDMU, aldrin, BHC-alpha, BHC-beta, BHC-gamma, cis-nonachlor, trans-nonachlor, oxychlordane, DCPA (Dacthal), dicofol, dieldrin, toxaphene, endosulfan sulfate, endosulfan-I, endosulfan-II, endrin, endrin aldehyde, enrin ketone, heptachlor, heptachlor epoxide, methoxychlor, mirex, and perthane.
g 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, 200-201, 203, 206, and 209.
h Includes PBDE-17, 28, 47, 49, 66, 85, 99, 100, 138, 153, 154, 183, and 209.
i Collected only at Stations B13-8163, B13-8040, B13-8077; transferred to SCCWRP for analysis.
j Includes nonylphenol, nonylphenol diethoxylate, nonylphenol monoethoxylate, 4-tert-octylphenol, and bisphenol A.
k Includes perfluorooctanoic acid and perfluorooctane sulfonate.
µg/kg = micrograms per kilogram (parts per billion); mg/kg = milligrams per kilogram (parts per million); N/A = not applicable; SM = Standard Method; SOP = standard operating procedure

Five pre-labeled 8-ounce (oz) jars were filled with sediment for chemical analyses; a sixth jar was filled and saved as an archive sample. The jars were stored during collection efforts at 4°C on ice, and frozen at -20°C within 24 hours. The five jars for chemical analyses were shipped frozen to Physis within one week of collection for analyses; the sixth jar was transferred to the Amec Foster Wheeler San Diego office for archiving frozen. Subsamples from each station were submitted by Physis to the Institute for Integrated Research Materials Environment and Society (IIRMES) Laboratory at California State University, Long Beach, for analysis of total nitrogen (N) and TOC; the remaining analyses were performed by Physis. A subset of three samples from selected stations were collected into polycarbonate containers provided by SCCWRP for special

studies related to analysis for perfluorinated compounds (PFOS), alkylphenols, and bioanalytical screening of sediment extracts. These samples were also stored during collection activities at 4°C on ice, and frozen at -20°C within 24 hours. The samples were then transferred frozen directly to SCCWRP for the special studies. Approximately 150–200 grams (g) of sediment were also collected for grain-size analysis at each sampling station. These samples were each placed in a pre-labeled 1-quart Ziploc™ bag and kept frozen at -20°C prior to delivery to SCCWRP, and then transferred to the Environmental Monitoring & Technical Services Laboratory at the City of San Diego for analysis of grain size using a laser particle counter.

Samples for toxicity testing were placed on ice and transported to Nautilus Environmental, LLC (Nautilus) located in San Diego, CA, for laboratory testing of whole sediments using embryos of the Mediterranean mussel (*Mytilus galloprovincialis*) and a marine amphipod (*Eohaustorius estuarius*).

For infaunal analysis, the depth of an intact grab sample was recorded and the entire sample was sieved onboard the vessel immediately after collection. The sieve consisted of a 1.0-millimeter (mm) stainless-steel mesh screen mounted at the bottom of an aluminum sieve box. Site water that was pre-filtered through an in-line 20-μm fiber filter was used to wash the sediment through the screen. After sieving, the remaining debris and infauna were carefully transferred to one or more pre-labeled 1-liter polycarbonate containers and treated with a relaxant solution of Epsom salts for approximately 30 minutes. After the relaxant exposure, the infaunal samples were preserved in the field with a 10% formalin solution, and inverted several times to mix them thoroughly.

Photographs 5 through 10 show the sampling process using the Van Veen grab sampler.

Photograph 5. *Tandem Van Veen grab sampler upon retrieval*

Photograph 6. *Van Veen grab showing an acceptable intact sediment sample for processing*

Photographs 7 and 8. *Subsampling sediments from the top 5 centimeters of the Van Veen grab sampler for chemistry analysis and photo documentation*

Photographs 9 and 10. *Processing a sediment grab through the 1-millimeter sieve for benthic infauna analyses*

2.1.4 Marine Debris: Sediment Sampling Special Study

All anthropogenic debris observed in the benthic infauna grab was enumerated and categorized for subsequent taxonomic analysis. Larger debris (greater than [>] 2 cm) was removed from the infaunal sample after screening the material and was placed in a properly labeled Ziploc™ bag. Smaller debris inside the grab (less than [<] 2 cm) was placed in the sample container with the infaunal organisms and other material from that sample. During sorting, debris was separated, quantified by recording the specific types of material and their quantities, and saved in sample vials. Debris samples generated during benthic processing were sent to SCCWRP for characterization and quantification.

2.1.5 Fish and Macroinvertebrate Trawl Sampling

Demersal fish and epibenthic macroinvertebrate samples were collected with a standard 25-foot (ft) semi-balloon otter trawl with a 29-ft footrope, 1.5-inch mesh, and 0.5-inch cod-end mesh, following Bight ’13 protocols (SCCWRP, 2013b) and the project-specific Work Plan and QAPP (Amec Foster Wheeler, 2013a and 2013b). Trawls were performed along isobaths for a minimum of 5 minutes (bottom time) at an approximate speed of 2.0 knots at each station. Station information was recorded directly onto electronic field data sheets created specifically for the Bight ’13 program as well as hard-copy field data sheets. Trawl sampling start and end coordinates were automatically recorded on the field computer, as were interim coordinates along the trawl track. Trawl depths and bottom times were recorded with a Lotek™ temperature and pressure sensor mounted on the trawl door. Trawl station coordinates are provided in Appendix A. Trawl sampling dates and distances trawled provided in the field data sheets in Appendix E. Figures 2-2a through 2-2f display the trawl locations and tracks.

Figure 2-2a. Trawl Locations in Dana Point Harbor

Figure 2-2b. Trawl Locations in Oceanside Harbor

Figure 2-2c. Trawl Locations in Mission Bay

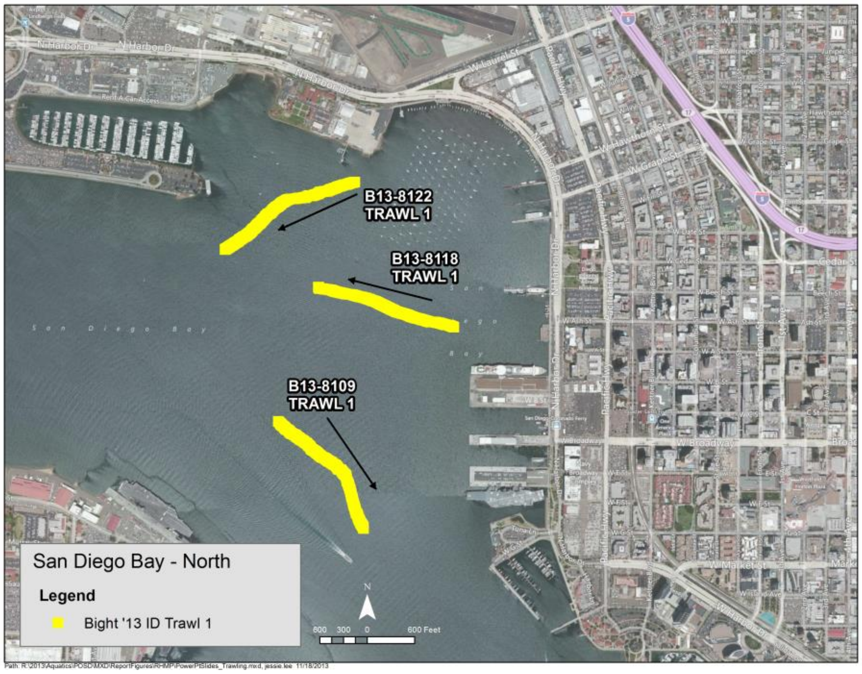


Figure 2-2d. Trawl Locations in Northern San Diego Bay

Figure 2-2e. Trawl Locations in Central San Diego Bay

Figure 2-2f. Trawl Locations in Southern San Diego Bay

Upon retrieval of the trawl net after a successful deployment, the catch was placed in shallow tubs for sorting and processing. All specimens were sorted into broad taxonomic categories, and then counted and identified to the lowest possible taxon. Unidentified organisms were fixed using 10% buffered formalin, preserved using 70% ethanol, and returned to the laboratory for further identification (FID). A single representative of each species encountered was retained and preserved (in the same manner as FID species) to be added to the project voucher collection of the entire Bight ’13 trawl catch. When applicable, a second specimen of the same species was retained for an additional verification step, deoxyribonucleic acid (DNA) bar-coding. DNA vouchers were preserved in 95% ethanol. If only one individual for a given species was caught, or if organisms were too large for preservation, a fin clip or an appendage (from invertebrates, when applicable) was used for the DNA voucher. If organisms were too large to be easily preserved (e.g., large bat rays), or their identification was obvious from a photograph (e.g., California spiny lobster), photographic vouchers were created and the specimens were released.

For both fish and invertebrates, each individual specimen was visually examined for abnormalities and disease symptoms (e.g., tumors, parasites, fin erosion, and internal and external lesions), which, if found, were noted on the field data sheets. (For a full list of potential abnormalities, see the field data sheets in Appendix E). When fish and invertebrates exhibited a new instance of disease or parasite, pathology vouchers were also created and catalogued.

Photographs were taken of each individual with species ID, date, and sampling station identifier information. (See Appendix N for a field photograph log with representative photographs of each species collected). A complete library with photographs of all specimens collected during the RHMP trawls is available in electronic format. Individual specimens saved for vouchering were retained by being fixed in 10% buffered formalin and later preserved with 70% ethanol (or, for DNA vouchers, 95% ethanol), and the rest of the catch was released immediately after sorting.

After taxonomic identification, fish specimens caught were enumerated and measured for standard length (i.e., to the end of the vertebrae) and grouped into 1-cm interval size classes. All individuals for each species were then combined and batch-weighed to the nearest 0.1 kilogram (kg) to provide a wet weight biomass estimate for each species. If the combined weight of all individuals from one species totaled less than 0.1 kg, then the species lot was combined with other species lots having weights less than 0.1 kg to yield a composite taxa weight. Larger organisms were weighed individually and their biomass added to the total weight for that particular species. At stations where more than 300 individuals of one species were caught, the aliquot method (as detailed in SCCWRP, 2013a) was used to determine the number of individuals and catch weight. Macroinvertebrates were enumerated and weighed using the same procedure as for fish, where smaller species were grouped into a batch weight and larger individuals were weighted separately and then totaled per species. *In situ* QA/QC procedures were conducted on a subsample of both fish and macroinvertebrates caught at each station. A more complete description of QA/QC procedures related to the benthic trawls is provided in the Bight ’13 QA Manual (SCCWRP, 2013c) and the project-specific Work Plan and QAPP (Amec Foster Wheeler, 2013a and 2013b).

Photographs 11 through 13 show the trawl sampling procedures used.

Photograph 11. *Otter trawl retrieval in Mission Bay*

Photograph 12. *Species sorting and documentation aboard the R/V Early Bird II following a trawl*

Photograph 13. *Fish identification and measurement following a trawl*

2.1.5.1 Trawl Special Studies

Three special studies were conducted concurrently with RHMP trawl sampling:

- ***Marine Debris – Trawl and Sediment Sampling:*** Any debris collected during a trawl (e.g., plant material, plastic, and cans) was quantified by recording the specific types of material and their quantities on the Trawl Debris Form (see Appendix E). Debris was collected and stored in plastic bags, labeled appropriately, and returned to SCCWRP. Any anthropogenic debris observed during the benthic infauna sorting process was also

retained in small glass voucher specimen vials, labeled, and submitted to SCCWRP for analysis and quantification.

- ***Marine Debris – Fish Ingestion:*** At selected stations, five individuals of any fish species listed in the following three feeding guilds (see Items a, b, and c, below) were placed in plastic bags, labeled with station number and date, and frozen for a special study to quantify ingestion of plastic debris by select fish species. Whole fish were sent to SCCWRP for processing and analysis. Detailed methods are described in the *Bight '13 Debris Work Plan* (SCCWRP, 2013f). Bight-wide target species included the following, only some of which are present in enclosed bays and estuaries:

  a. Pelagobenthivores (Pacific sanddab, longfin sanddab, speckled sanddab, bay goby, and longspine combfish)

  b. Benthivores (English sole, curlfin sole, hornyhead turbot, blackbelly eelpout, and bearded eelpout)

  c. Fish previously found to have ingested plastics (white croaker, queenfish, shiner perch, spotted cusk-eel, and California lizardfish)

- ***California Halibut Essential Fish Information:*** The CDFW evaluated a new technique for determining the sex of California halibut using ultrasound. The goal was to perfect this technique to avoid future lethal sampling, thus benefiting the species and its populations during future studies. The CDFW project goal was to obtain up to 40 sublegal or "short" California halibut to test experimental methodologies. Sublegal California halibut (1–22 inches) were placed in plastic bags, labeled with station number and date, frozen, and relinquished to the CDFW.

2.1.6 Bioaccumulation Sampling Special Study

The primary objective of the special study is to fulfill data needs as part of a current region-wide assessment of the trophic transfer of bioaccumulative contaminants of concern throughout the food web and to assess chemical exposure risk to local wildlife. The eventual goal is to calculate empirical contaminant transfer ratios, calibrate and validate bioaccumulation models for sediment quality objectives, and compare contaminant transfer and wildlife risk at different locations. Two food chain pathways (benthic and water column) were quantified across all four embayments sampled during the RHMP. Some of the information collected as a part of this effort will also support a more intensive ongoing effort to assess current risk to human health as related to the consumption of fish caught from bays and estuaries in Southern California.

The RHMP supported sample collection and tissue analysis for the benthic pathway at one station each in Dana Point Harbor (Station 8263), Oceanside Harbor (Station 8239), and Mission Bay (Station 8159), and at nine stations in San Diego Bay, representing the northern section (Stations 8122, 8118, and 8109), the central section (Stations 8078, 8060, and 8052), and the southern section of the harbor (Stations 8029, 8020, and 8017).

For the benthic bioaccumulation assessment pathway, bulk sediment concentrations were sampled during the core RHMP monitoring activities. Infauna was collected at the same times and stations as were the sediment samples. At these 12 designated stations, up to 10 or 12

additional grab samples using the TVV were collected to accumulate enough soft-bodied infauna tissue for chemical analysis (wet-weight minimum of approximately 5 grams). Soft-bodied organisms that were retained on a 2.0-mm screen were live-sorted in the field to separate out polychaetes, bivalves, crustaceans, and gobies. When found in sufficient numbers, additional species (e.g., gastropods, phoronids, and burrowing anemones) were retained for future analysis or tissue mass, if needed. Each group of specimens was carefully placed on a piece of heavy-duty aluminum foil (dull side up) that had been pre-rinsed with acetone. After collecting sufficient biomass, photographs were taken of each individual sample with appropriate species, date, and sampling station identifier information. (See Appendix N for a log with representative photographs of each species collected). A complete library with photographs of all specimens collected for tissue analysis during the RHMP trawls is available in electronic format. The tissues were given a quick rinse with deionized water before being carefully wrapped in the foil. The sample was then placed in a pre-labeled plastic Whirlpack™ or Ziploc™ bag along with a waterproof label with appropriate sample identifier information. All samples were immediately placed in an onboard freezer at -20°C after collection.

Benthic fish and macroinvertebrates for tissue analyses were collected during the trawling used to quantify species abundance and diversity. Primary fish species targeted were gobies, killifish, and one flatfish (either turbot or halibut); secondary target species included croakers, sand bass, queenfish, and mullet. Given the opportunistic nature of fishing, additional relevant fish species were collected and saved as deemed appropriate. It was necessary to perform multiple trawls at each general location in an attempt to collect at least five fish per target species to provide a representative composite sample. Each fish was measured, photographed, and processed in the same manner as described above for the infaunal samples. Multiple fish were often included in each foil-wrapped sample, but different species were not mixed. Photographs 14 and 15 show the process for tissue analysis.

Tissue samples were submitted to Physis for analysis of PAHs, organochlorine pesticides, polychlorinated biphenyls (PCBs), PBDEs, mercury, selenium, percentage of moisture, and percentage of lipids.

Photographs 14 and 15. *Processing and photo documentation of fish and invertebrates for tissue analyses*

2.2 Laboratory Analyses

Laboratory analyses included chemical analysis of water and sediment samples, sediment toxicity testing, benthic infaunal species identification, grain-size analysis, and special studies analyses (marine debris and bioaccumulation).

2.2.1 Chemistry

A complete list of chemical constituents and the associated analytical methods and detection limits for both water and sediment chemistry is provided in Appendix B. All chemical analyses were conducted according to the specifications of the State Water Resources Control Board (SWRCB) Surface Water Ambient Monitoring Program (SWAMP) http://www.waterboards.ca.gov/water_issues/programs/swamp/. Analyses were performed by Physis in accordance with the United States Environmental Protection Agency (USEPA) or Standard Methods. In addition to chemical analyses, sediment samples were also analyzed for grain size (partitioned into gravel, sand, silt, and clay) at the City of San Diego Public Utilities Department Environmental Monitoring and Technical Services Division, using the (ASTM International (formerly American Society for Testing and Materials) D4464M laser method.

2.2.2 Toxicity

Sediment bioassay tests were used to quantify species-specific responses following exposure to surficial sediments under controlled laboratory conditions by Nautilus. In accordance with sediment quality objectives (SQOs) and Bight ’13 guidance, an acute solid-phase (SP) toxicity test and a chronic sediment-water interface (SWI) test were used to assess sediment toxicity, as described below.

Standard QA/QC measures for toxicity testing included an assessment of concurrent laboratory control performance, replicate variability, and statistical power as described in the Bight ’13 Toxicity Testing Manual (SCCWRP 2013d). An added QA measure for the amphipod test was the inclusion of a fine-grained sediment control with each batch of tests to assess whether fine material, common in bays and harbors, might have a negative impact on amphipod survival. Fine-grained material has been documented as an occasional confounding factor for *Eohaustorius,* which naturally occurs in medium- to coarse-grain-sized sediments. Reference toxicant tests were also performed with each test batch for both species to assess relative sensitivity of the test organisms to a single known chemical (ammonia) over time and between laboratories.

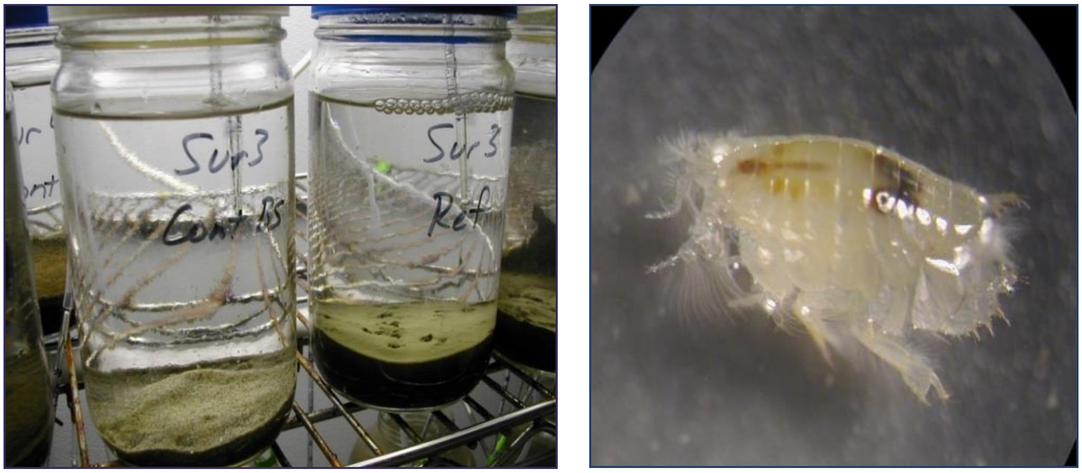
Detailed project-specific methods for these tests are provided in the *Bight ’13 Sediment Toxicity Manual* (SCCWRP, 2013d) and the project-specific Work Plan and QAPP (Amec Foster Wheeler, 2013a and 2013b). A summary of methods is also provided in a stand-alone report prepared by Nautilus and is included in Appendix G.

2.2.2.1 Solid Phase (SP) Testing

Ten-day SP acute survival tests using the marine amphipod *Eohaustorius estuarius (E. estuarius*) were conducted in accordance with procedures outlined in the United States Environmental Protection Agency (USEPA) amphipod testing manual (USEPA, 1994a) and the ASTM method E1367-03 (ASTM, 2006a). On the day before test initiation, 2-cm aliquots of sediment from each site were placed in each of five replicate glass jars, followed by approximately 800 milliliters (mL) of filtered clean seawater. Five replicate controls were used to determine the health of the amphipods and application of proper test procedures by exposing the amphipods to clean sediment following the same protocols used for the test sediments. The test chambers were acclimated overnight and, on Day 0 of the test, 20 amphipods were placed in each of the test chambers. Amphipods that did not bury in the sediment within 1 hour were removed and replaced. Samples were monitored daily for obvious mortality, sublethal effects, and/or abnormal behavior as described in the amphipod testing manual. Water quality parameters, including DO, temperature, salinity, and pH, were monitored daily. Overlying and interstitial ammonia was also measured at test initiation and test termination. At the end of the test, organisms were removed from the test chambers by sieving the sediment through a 0.5-mm mesh screen and survival in each chamber was recorded. The survival percentage was calculated for control and test sediments, and tests were considered to be acceptable if there was >90% mean survival in the control.

A 96-hour reference toxicant test was conducted concurrently with the sediment test to assess sensitivity of the test organisms relative to historic control chart measurements and to evaluate the potential influence of ammonia (NH_4) toxicity on the test organisms. The reference toxicant test was performed using ammonium chloride (NH_4Cl) with target concentrations of 15.6, 31.2, 62.5, 125, and 250 milligrams (mg) of NH_4 per liter (L). Ten test organisms were added to each of the four replicates of each concentration. Subsamples of water were obtained at test initiation and were analyzed for total ammonia. The more toxic un-ionized fraction of ammonia was then calculated using total ammonia along with pH, salinity, and temperature. The concentrations of total ammonia and un-ionized ammonia that resulted in 50% mortality of the organisms (LC_{50}, the median lethal concentration) were calculated from the data. The LC_{50} values were then compared with historical laboratory data for the test species following exposure to ammonia to assess relative sensitivity over time, as a basis for comparison to ammonia measurements in sediment pore water. The results of this test were used in combination with the control performance to assess the health of the test organisms and application of proper test procedures. Finally, as with sediment chemistry, a single blind duplicate sample was tested in each laboratory to assess comparability region-wide among laboratories.

An example SP test set-up and picture of the amphipod *Eohaustorius estuarius* is shown in Photographs 16 and 17.



Photographs 16 and 17. *Solid-phase toxicity testing using the amphipod Eohaustorius estuarius; *note the burrows in the jars at the sediment surface*

2.2.2.2 Sediment-Water Interface (SWI) Testing

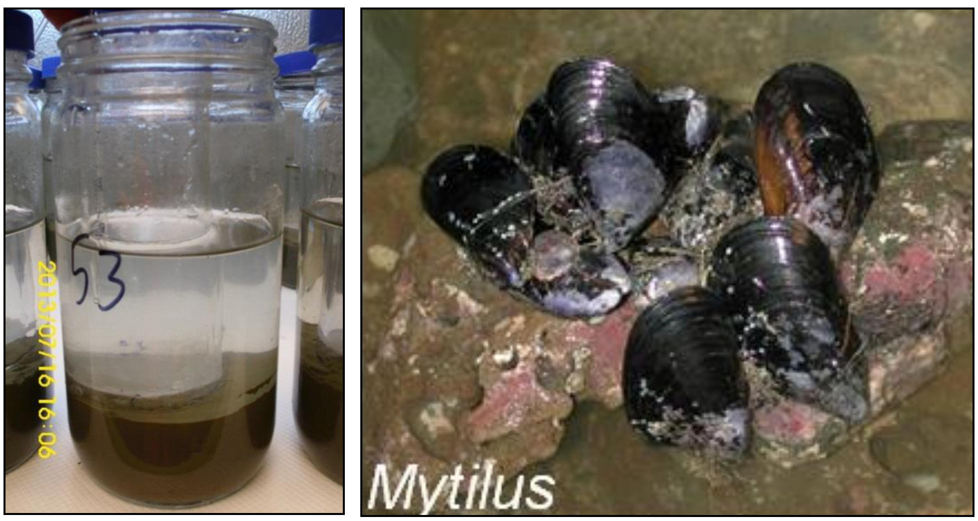
SWI bioassays were performed to estimate the potential chronic toxicity of contaminants fluxed from sediments to overlying water. Forty-eight-hour SWI bioassays using the Mediterranean mussel *M. galloprovincialis* were conducted in accordance with procedures outlined in USEPA, 1995, and Anderson et al., 1996. On the day before test initiation, 5-cm aliquots of sample sediment were placed in each of five replicate glass chambers, followed by approximately 300 mL of clean filtered seawater. Five replicate method controls were used to verify that the test system was not causing toxicity by exposing the bivalve larvae to test chambers with screen tubes but no sediment. Following addition of sediment and water, test chambers were left overnight to acclimate prior to addition of the mussel embryos. Polycarbonate tubes with a 20-µm Nitex™ mesh screen mounted inside (approximately 1 cm above a bottom lip) were lowered into each glass chamber so that the sediment surface was located just below the mesh screen. Approximately 250 bivalve embryos were placed inside the screen tube in each of the test chambers. During the first 24 hours of development, embryos remain on the screen near the sediment surface, before becoming water-borne veliger larvae. Water quality parameters, including DO, temperature, salinity, and pH, were measured daily; overlying and interstitial NH_4 was also measured at test initiation and test termination. At the end of the test, organisms were retrieved from the test chambers by removing the screen tubes and gently rinsing the embryos into glass shell vials with clean filtered seawater. The vials were preserved with formalin and scored by technicians at Nautilus. The percentage of normal-alive embryo development was calculated for the control and test sediments. Tests were considered to be acceptable if there was >70% mean control normal-alive embryo development.

A 48-hour reference toxicant test was also conducted concurrently with the SWI test to assess sensitivity of the test organisms relative to historic control chart measurements and to evaluate the potential influence of NH_4 toxicity on the test organisms. The reference toxicant test was performed using NH_4Cl, with target concentrations of 1.0, 2.0, 4.0, 6.0, 8.0, 10, and 20 mg of

NH_4 per liter[5]. Approximately 250 embryos were added to each of five replicates of each concentration. Subsamples of water were obtained at test initiation and were analyzed for total ammonia. The more toxic un-ionized fraction of ammonia was then calculated using total ammonia along with pH, salinity, and temperature.

The concentrations of total ammonia and un-ionized ammonia that caused 50% mortality (LC_{50}) and 50% reduction in normality (or median effective concentration [EC_{50}]) of the organisms were calculated from the data. The LC_{50} and EC_{50} values were then compared with historical laboratory data for the test species with NH_4Cl. The results of this test were used in combination with the control performance to assess the health of the test organisms and application of proper test procedures.

An example test set-up and picture of the adult Mediterranean mussel (*M. galloprovincialis*) is shown in Photographs 18 and 19.



Photographs 18 and 19. *Sediment-water interface toxicity testing using embryos of the bivalve Mytilus galloprovincialis – embryos added to the inner screened chamber. Adult Mytilus species shown on the right.*

2.2.3 Benthic Infauna Sample Processing

Benthic infaunal samples were transported from the field to the laboratory and stored in a 10% formalin solution for at least six days for proper fixation of specimen tissue. The samples were then transferred from formalin to 70% ethanol for laboratory processing. In accordance with the Bight ’13 *Macrobenthic (Infaunal) Sample Analysis Laboratory Manual* (SCCWRP, 2013e), the organisms were initially sorted (using a dissecting microscope) into nine categories: annelids, annelid fragments, arthropods, echinoderms (non-ophiuroid), ophiuroids, ophiuroid arms, molluscs, miscellaneous phyla, and debris and plastics.

[5] These toxicant test concentrations represent a range that it likely to encompass a typical dose response for each test species.

Initial sorting of the samples to remove debris and to group organisms into taxonomic classes was performed by Merkel and Associates, Inc., (Merkel) located in San Diego, CA. Species identification to the lowest possible taxon and enumeration of species in the sorted samples were performed by specialized taxonomists of Dancing Coyote Environmental (DCE), based in Pauma, CA. For nomenclature and orthography, taxonomists primarily used the keys included in the publication entitled *A Taxonomic Listing of Soft Bottom Macro- and Megainvertebrates from Infaunal and Epibenthic Monitoring Programs in the Southern California Bight,* edition 8, developed by the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT, 2013). A QA/QC procedure was performed on each of the sorted samples to ensure 95% organism removal efficiency. This procedure was performed by subsampling a 10% aliquot of each sample which was then re-sorted by a senior technician trained in the QA/QC procedure. The number of organisms found in the aliquot was multiplied by 10 and added to the total number found in the sample. The original total was divided by the new total to calculate the percentage of sorting efficiency. When the sorting efficiency of the sample was below 95%, the remainder of the sample (90%) was re-sorted.

2.2.4 Physical Water Quality Parameter Processing

Sea-Bird™ CTD profile scans were uploaded daily to Amec Foster Wheeler's computer system server for processing by Sea-Bird™ data processing software, which averaged the scans by 1-meter depth intervals to produce a manageable data set for analysis. Vertical profile plots were prepared for each measured parameter at each sampling station provided in Appendix E.

2.3 Data Analysis

Simple tabular and graphical summaries were prepared for all measurements made under this program. Many of the key measures were also plotted on maps for easy spatial reference and comparison. Median values and ranges of water and sediment chemistry, toxicity, and benthic community metrics were calculated separately for each of the five strata and each of the four harbors. Because of its size, San Diego Bay was divided into three areas (northern, central, and southern) for more refined comparisons. Benthic trawl data and associated species metrics were summarized similarly. Following a summary of current conditions, analyses focused on two key areas of interest: (1) integration of multiple lines of evidence using the SQO approach for an overall assessment of conditions; and (2) historical trend analyses. A more in-depth analysis of select locations with impaired benthic communities was also performed for this report.

This section presents the calculation methods for individual and various integrated metrics, statistical comparison methods, and methodology developed to assess changes in key metrics over time (i.e., trends). Metric analyses included comparing field results with threshold values (established during the RHMP Pilot Project) for water chemistry and sediment chemistry, toxicity, and benthic infaunal community. Additionally, sediment data were assessed following the recently updated SQO protocol (Bay et al., 2014), which utilizes sediment chemistry, sediment toxicity, and benthic community data to evaluate overall station conditions. Individual

SQO lines of evidence (LOEs) and the integrated SQO assessment results were compared with scores derived from the 2008 RHMP[6].

2.3.1 Comparison with Established Threshold Values

Monitoring data collected by RHMP in 2013 were compared with historical data to assess changes over time in water and sediment chemistry, sediment toxicity, benthic infauna, and demersal fish and macroinvertebrate populations. Temporal and spatial trends were analyzed to determine the proportion of samples above pre-established thresholds and how they have changed over time, how strata differ from each other within and among harbors, and how differences in both strata and harbors have changed over time. Historical data were compiled to establish threshold levels and present targets by which to measure changes in the harbors (Appendix D, Table D-2). Historical data calculations were derived from the Bight '98, and Bight '03 programs, and the Bay Protection and Toxic Cleanup Program (BPTCP), as well as San Diego Bay specific studies that quantified demersal fishes (VRG, 2006; Allen, 1999). Data that had similar detection limits (chemistry), test species (toxicity), sampling equipment, and screen size (benthic infauna) were used to determine threshold levels (Weston Solutions, Inc. [Weston], 2005b). Threshold levels comprised of chemical constituent concentrations, toxicity responses relative to controls, and diversity measures and the benthic response index (BRI) for infauna.

Pre-set targets were determined by defining the proportion of historical samples collected in the harbors which exceeded the established threshold levels. Pre-set target proportions were defined to be the constant in the binomial model for comparison to RHMP data from the harbors. Proportions of stations with results exceeding the threshold level were compared with the pre-set target to determine differences between the historical conditions of the harbors and present-day conditions. For all indicators, a significantly fewer number of sites that exceed the threshold values would indicate that conditions are improving.

A summary of the established threshold levels and pre-set targets is provided in Appendix D (Table D-1) and Table 2-4. Selected constituents were grouped into primary and secondary indicators. Primary indicators for the study were selected because they are either major known constituents of concern or they provide information on a suite of measurements (e.g., the mean effects range-median [ER-M] quotient for sediments). Secondary indicators were used as supporting data to enhance the interpretation of the primary indicators (Weston, 2005a). The selection of individual primary and secondary indicators for water column chemistry, sediment chemistry, sediment toxicity, and benthic infauna is further discussed in Sections 2.3.1.1 through 2.3.1.5.

It should be noted that there has been as slight shift in the way the pre-set targets are presented and discussed in this report as compared to the 2008 RHMP report. Previously, the 2008 RHMP pre-set targets were defined as the proportion of samples that did not exceed relevant threshold values. The 2013 RHMP report defines the targets as the proportion of samples that

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[6] Several discrepancies from the latest SQO calculation protocol were found during a review of the 2008 RHMP benthic community data; however, comparisons with the 2008 RHMP SQO results are presented as-is within this report without recalculating metrics from prior efforts.

exceed the threshold values. Inversing the targets was conducted to increase consistency with regard to comparisons made throughout the report for the primary and secondary indicators. With the exception of two secondary indicators (SWI and number of taxa), an exceedance of both threshold values and historic pre-set targets is now always associated with values that are elevated, which is more conventional in the scientific and regulatory literature for measures of chemistry and toxicity, and less confusing for comparison purposes overall. Note that this does not change manner in which the pre-set targets were established; rather it changes the way the values are represented on the figures and discussed within the text. For example, a pre-set target of 58% below the threshold in the 2008 RHMP is represented conversely as a pre-set target of 42% above the threshold value in the 2013 RHMP.

It should also be noted that despite generally consistent methods and sampling equipment, some of the sampling designs and goals of the various studies used to develop historic pre-set values varied from the randomized approach used for RHMP and Regional Bight Program. In particular, some of these studies included targeted designs focused on identifying conditions at potential hot spots (i.e. the Bay Protection and Toxic Cleanup Program), or site-specific characterization programs. These differences, along with the discrepancies noted related to the calculation of benthic indices must be considered carefully when drawing conclusions based on historic trend analyses with existing pre-set targets. Given these differences/ discrepancies the use of statistical analyses for trend comparisons were limited, with a focus more so on less rigorous quantitative comparisons at this time.

All of the primary and secondary indicators measured in the RHMP were plotted for visual comparison in relation to the threshold levels and comparison with the pre-set targets as provided in Appendix K. Data from both 2008 and 2013 were summarized in results tables and plotted as data distribution curves for a few key measures as shown with an example in Figure 2-3. A horizontal line overlaid on the graph defines the pre-set target based on historical baseline samples (grey line). The point at which the 2008 (red) and 2013 (blue) distribution curves cross the threshold value reflects the proportion of samples below and above the pre-set target. If the proportion of samples below the threshold value increases over time, conditions are improving.

The results for each indicator were also compared with the pre-set target to determine whether the percentage of samples below the threshold value was higher or lower than historical conditions for the four harbors, as detailed in Section 2.3.1.

Table 2-4.
RHMP Threshold Levels and Pre-set Targets

Measure	Threshold Value	Pre-set Target[a] (% of Sites > Threshold Value)
Primary Indicators		
Dissolved Copper (water)	4.8 µg/L	42%
Total Copper (water)	5.8 µg/L	49%
Mean ER-M Quotient	0.2	54%
Benthic Response Index (BRI)	39.96	45%
Amphipod mortality	20% effect relative to control	45%
Secondary Indicators		
Dissolved Zinc (water)	90 µg/L	0
Total Zinc (water)	95 µg/L	1%
Dissolved Nickel (water)	74 µg/L	0%
Total Nickel (water)	75 µg/L	0%
Sediment Arsenic	8.2 mg/kg	48%
Sediment Cadmium	1.2 mg/kg	8%
Sediment Chromium	81 mg/kg	17%
Sediment Copper	175 mg/kg	32%
Sediment Lead	46.7 mg/kg	25%
Sediment Mercury	0.15 mg/kg	74%
Sediment Nickel	20.9 mg/kg	20%
Sediment Zinc	150 mg/kg	55%
Sediment Total PAHs	4,022 µg/kg	21%
Sediment Total Chlordanes	0.5 µg/kg	14%
Sediment Total DDTs	1.58 µg/kg	46%
Sediment Total PCBs	22.7 µg/kg	53%
Shannon-Wiener Diversity Index	2	14%
Number of Taxa	24	18%
Bivalve Embryo Development	40% effect relative to control	40%

Notes:
a Pre-set target values represent the fraction of sample results (pre-2008) exceeding the threshold values, with the exception of Number of Taxa, where an exceedance indicates a taxa count of less than 24.

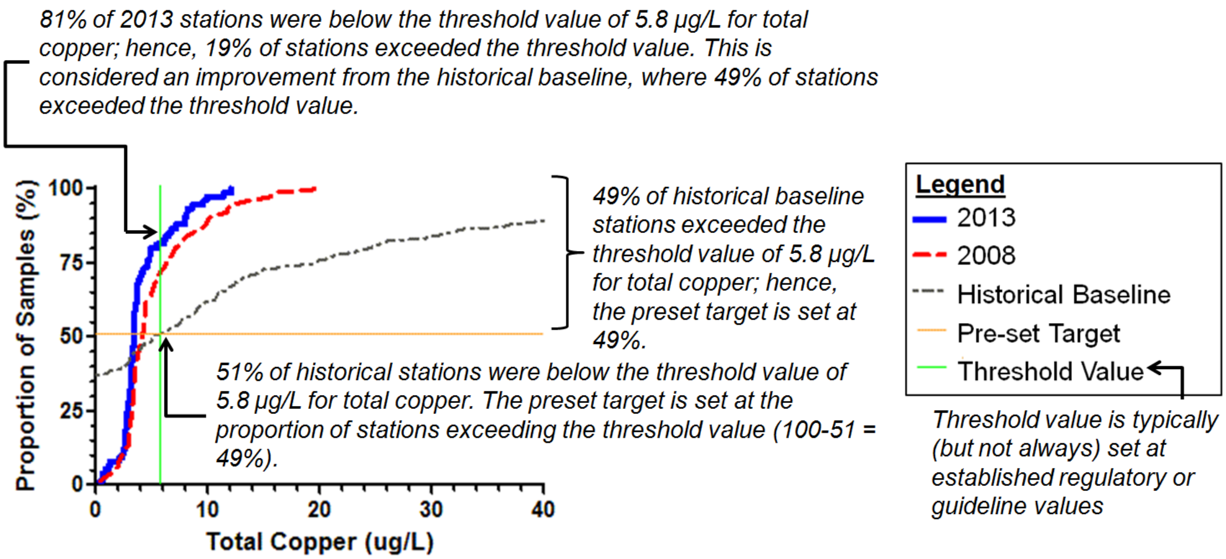

Figure 2-3. Example of Cumulative Distribution Curve

2.3.1.1 Comparisons of Water Column Chemistry with Threshold Values

Applicable historical observations of water column metal concentrations were available for dissolved and total copper, nickel, and zinc (Weston, 2005b). These data, along with benchmark values from the State of California Environmental Protection Agency (Cal/EPA) Region 9 California Toxics Rule (CTR), were evaluated to establish threshold levels. The CTR was created using both literature and toxicity test data, thus making it a relevant threshold to use for aqueous metals (CTR, 2000; http://www.epa.gov/region9/wat/ctr/). Only dissolved copper and total copper were selected as primary indicators for aqueous metals on the basis of the large number of historical results observed above the acute CTR for dissolved copper (i.e., 4.8 µg/L). Dissolved and total zinc and nickel were selected as secondary indicators. The threshold levels and subsequent pre-set targets for these metals are listed in Appendix D (Table D-1) and Table 2-4.

2.3.1.2 Comparisons of Sediment Chemistry with Threshold Values

For sediment chemistry analyses, the ER-M quotient was used as the primary metric for comparing integrated sediment chemistry results of the 2013 monitoring event with the threshold values and subsequent pre-set targets.

The effects range-low (ER-L) guideline values were also used for comparative purposes. The ER-L and ER-M are two effects-based metrics that were developed as basic screening tools to help assess the potential for adverse biological effects (Long et al., 1995). These parameters were developed from an extensive database of sediment toxicity bioassays and chemistry measurements. The ER-L is calculated as the lower tenth percentile of the observed effects concentrations; the ER-M is calculated as the 50th percentile of observed effects concentrations. Concentrations below the ER-L are less likely to result in adverse biological effects, while

concentrations above the ER-M are more likely to result in adverse biological effects (Long et al., 1995). Table 2-5 provides the ER-L and ER-M values for each applicable constituent.

Table 2-5.
ER-L and ER-M Screening Guideline Levels

Chemical		Guideline Level ER-L	Guideline Level ER-M
Metals (mg/kg)	Arsenic	8.2	70
	Cadmium	1.2	9.6
	Chromium	81.0	370
	Copper	34.0	270
	Lead	46.7	218
	Mercury	0.15	0.71
	Nickel	20.9	51.6
	Silver	1.0	3.7
	Zinc	150	410
Organics (µg/kg)	Total PAHs	4,022	44,792
	Total Chlordanes	0.50	6.0
	Total DDTs	1.58	46.1
	Total PCBs	22.7	180

Note that the ER-L and ER-M values, although valuable assessment metrics, have significant limitations as predictive measures of effects, as has been highlighted more recently in the literature (Wenning et al., 2005). The SQOs now provide a new, more regionally relevant set of metrics that can be used as a more effective trend analysis tool in the future, as the data required for these analyses continue to be collected. However, integrated metric comparisons with older data will continue to use the ER-L and ER-M approach for the time being. The following description of the latter approach was derived from the final 2008 RHMP report (Weston, 2010).

A mean ER-M quotient for a given chemical is defined as the ratio of sample concentration to its respective ER-M value (measured concentration/ER-M). The ER-M quotient is a unitless value that can then be summed among all chemicals that have an ER-M value. A summation of the ER-M quotient thus provides a method of integrating the effects of multiple contaminants to assess exposure and potential for effects (Wenning et al., 2005).

For the RHMP, the mean ER-M quotient was calculated using concentrations of the chemicals listed in Table 2-5. Based on various projects with the SDRWQCB, the threshold level for the mean ER-M quotient was set at 0.2 (Weston, 2005b). A review of historic pre-2008 data in the RHMP footprint found 54% of the stations to have an ERM-quotient greater than 0.2.

Secondary indicators for sediment chemistry included total PAHs, total PCBs, total DDTs, total chlordanes[7], and metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc). The ER-L was determined to be an acceptable metric for secondary indicators except copper (Weston, 2005b). The threshold value for copper was calculated on the basis of the concentration at which anthropogenic origins may be contributing to the overall copper concentrations in the sediment. To calculate the threshold for this metric, historical data were used to plot copper concentrations against iron concentrations, both of which occur naturally in harbor sediments. Iron is a reliable indicator of "geological background" levels of metals and therefore normalization to iron is a common approach to understanding the influence of potential enrichment via anthropogenic inputs. When trace metals such as copper co-vary with iron, they are generally viewed as being within geological background profiles; i.e., they are not attributed to anthropogenic influences (Schiff and Weisberg, 1999). Lower concentrations of copper within the historical data set exhibit a strong linear relationship with iron; however, this relationship diverges at a copper concentration of about 175 milligrams per kilogram (mg/kg), as shown in Figure 2-4 suggesting enhanced anthropogenic influence at this value. This value of 175 mg/kg was thus used as the RHMP threshold value for copper and is also referred to as an ambient threshold limit (ATL) for this constituent.

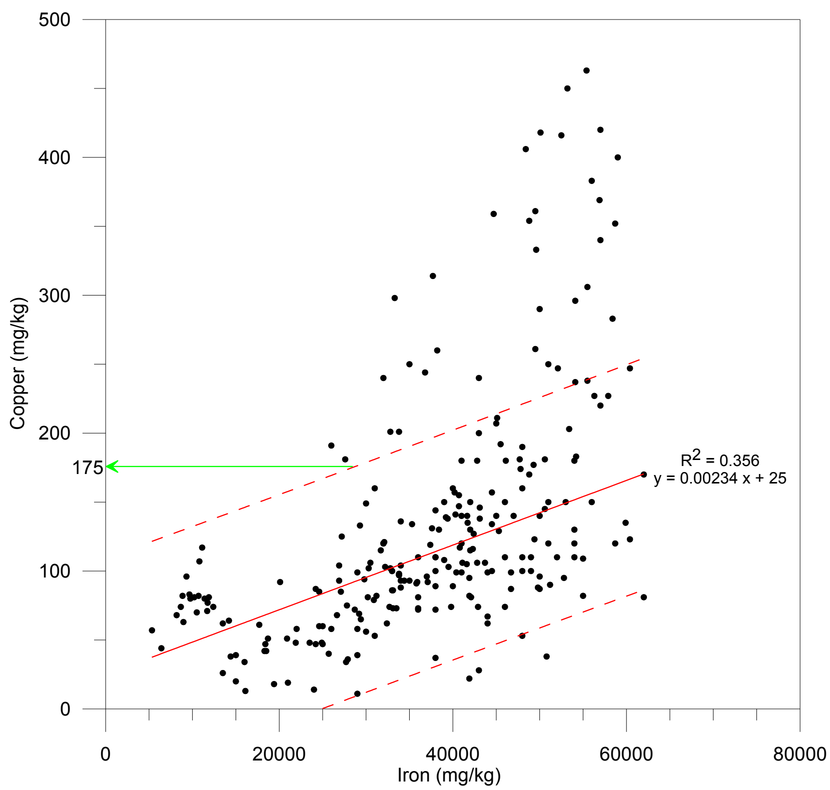

Figure 2-4. Relationship of Copper to Iron in Sediments Derived from Historic Studies used for RHMP Threshold Development

[7] The specific compounds comprising the sums of the PAH and PCB groups are listed in Tables 2-2 and 2-3, and Appendix B. Total DDTs represents the sum of all detectable DDTs (including DDDs, DDEs, and DDTs). Total chlordanes represent the sum of alpha-chlordane and gamma-chlordane.

2.3.1.3 Acid Volatile Sulfide (AVS) – Simultaneously Extracted Metals (SEM)

Bioavailability and potential toxicity of metals in sediments is affected by the physical properties of sediments (e.g., grain size) as well as the presence of other chemicals that interact with the metals (e.g., oxygen and sulfides). The relationship between AVS and the concentration of simultaneously extracted metals (SEM), referred to as the AVS-SEM partitioning model, is a methodology developed by the USEPA to help predict the bioavailability and toxicity of sediments by estimating the capacity of sulfides to bind to metals (USEPA, 2005). In anoxic sediments, there is commonly a substantial reservoir of sulfide in the form of solid iron sulfide (FeS), referred to as AVS. The availability of metals such as cadmium, copper, nickel, lead, zinc, and silver is thought to be controlled in part by their precipitation as insoluble sulfide complexes. Laboratory and field experiments have shown that, if the ratio of SEM to AVS is less than 1, there are not likely to be any biologically available metals in solution, and metal toxicity is not anticipated (Di Toro et al., 2001). A ratio greater than 1 may indicate the potential for toxicity due to enhanced bioavailability of trace metals. A further review of historic regional chemistry and toxicity data from southern California by Weston indicated that an AVS to SEM ratio of >40 provided a more reasonable estimate of a toxic threshold for the RHMP (Weston 2005b). AVS–SEM model predictions of metal toxicity were compared with actual results of sediment bioassay tests.

A review of more recent literature indicates that the fraction of organic carbon has a strong effect on trace metal toxicity and should be taken into consideration when evaluating SEM-AVS rations for predictive purposes. The USEPA normalized SEM-AVS to organic carbon content using the following formula, where fOC is the fraction of organic carbon:

$$\frac{\sum(\mathrm{SEM}-\mathrm{AVS})}{\mathrm{fOC}}$$

In 2005, the USEPA released a document entitled *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metals Mixtures (Cadmium, Copper, Lead, Nickel, Silver, and Zinc)* (USEPA, 2005). Based on numerous evaluations, the USEPA found that equilibrium partitioning sediment benchmarks (ESB) metric values less than (<)130 micromoles per gram of organic carbon ($\mu mol/g_{OC}$) are unlikely to have adverse toxicological effects; values between 130 and 3,000 $\mu mol/g_{OC}$ result in uncertain toxicological effects; and ESB values >3,000 $\mu mol/g_{OC}$ are likely to cause toxicological effects. In general, the ESBs apply only to sediments that have ≥ 0.2% total organic carbon by dry weight (USEPA, 2012). The ESB calculation was also performed for the 2013 RHMP dataset, though a historic threshold has yet to be calculated for this measure for comparative purposes.

2.3.1.4 Comparison of Sediment Toxicity with Threshold Values

Historical toxicity test results for the marine amphipod *E. estuarius* were used to establish the threshold levels for sediment toxicity. *E. estuarius* serves as an ideal test species because of its relatively high sensitivity to toxic substances and the availability of historical data for this species within the study area. Mean survival, normalized to performance in the control, was used for

historical comparisons. The threshold effect level was set at 20% survival relative to the control, a value below that has often been used historically as an indicator of non-toxic sediments (Thursby et al., 1997). Analysis of historic data found 45% of samples in the RHMP footprint to exceed the 20% threshold value for amphipod survival.

The bivalve SWI test using embryos of the Mediterranean mussel *M. galloprovincialis* was used as a secondary indicator of sediment toxicity. The endpoint used to measure toxicity was the control-adjusted percent normal-alive embryo development. The threshold level for normal development was set at 60% (i.e., a threshold value 10% below the control acceptability criterion)[8].

2.3.1.5 Comparison of Benthic Infauna with Threshold Values

Benthic infauna indices used to make historical comparison included the BRI, the Shannon-Wiener Diversity Index, organism abundance, and taxa richness. During development of the RHMP, the BRI was identified as a primary indicator for evaluating infaunal assemblages in the harbors, while the other three indices were considered secondary indicators.

The BRI threshold level for unimpaired communities in embayments is set at 39.96, which is the value separating the reference and low disturbance categories (Ranasinghe et al., 2003). Note that lower BRI scores indicate healthier communities. Based on a review of pre-2008 historic data in the RHMP footprint, 45% of locations were found to exceed the 39.96 threshold value (i.e., degraded conditions).

For the secondary indicators, the Shannon-Wiener diversity threshold level was determined to be 2.0, with a historic pre-set target of 24% of stations with results falling below this value. The threshold for taxa richness was 24, with a pre-set target of 18% of stations with results falling short of this value (Weston, 2005b).

2.3.2 Sediment Quality Objective (SQO) Metric Calculations

The sediment quality of all harbors involved in the monitoring program was assessed using SQOs, as described in the *Water Quality Control Plan for Enclosed Bays and Estuaries–Part 1, Sediment Quality* (SWRCB and California Environmental Protection Agency [Cal/EPA], 2009) and updated methodology to derive SQO calculations in Bay et al. (2014). SQOs are used to evaluate existing biological community conditions and the potential for chemically mediated effects to benthic organisms. The SQOs employ three primary LOEs: sediment chemistry, sediment toxicity, and the condition of the benthic infaunal community. Combined, these three LOEs form a MLOE approach to provide a final integrated station-level assessment (See Figure 2-5 for a general overview of the process). The specific methods used for each LOE and the integration of the MLOE approach are described briefly herein, based on *the Final Sediment Quality Assessment Technical Support Manual* (Bay et al., 2014). SQO metric scoring criteria for each LOE are provided in Appendix C for reference.

[8] Note that the control acceptability criterion for mean combined normal survivorship of bivalve embryos using the SWI test for Bight '13 monitoring is 80% (SCCWRP, 2013d).

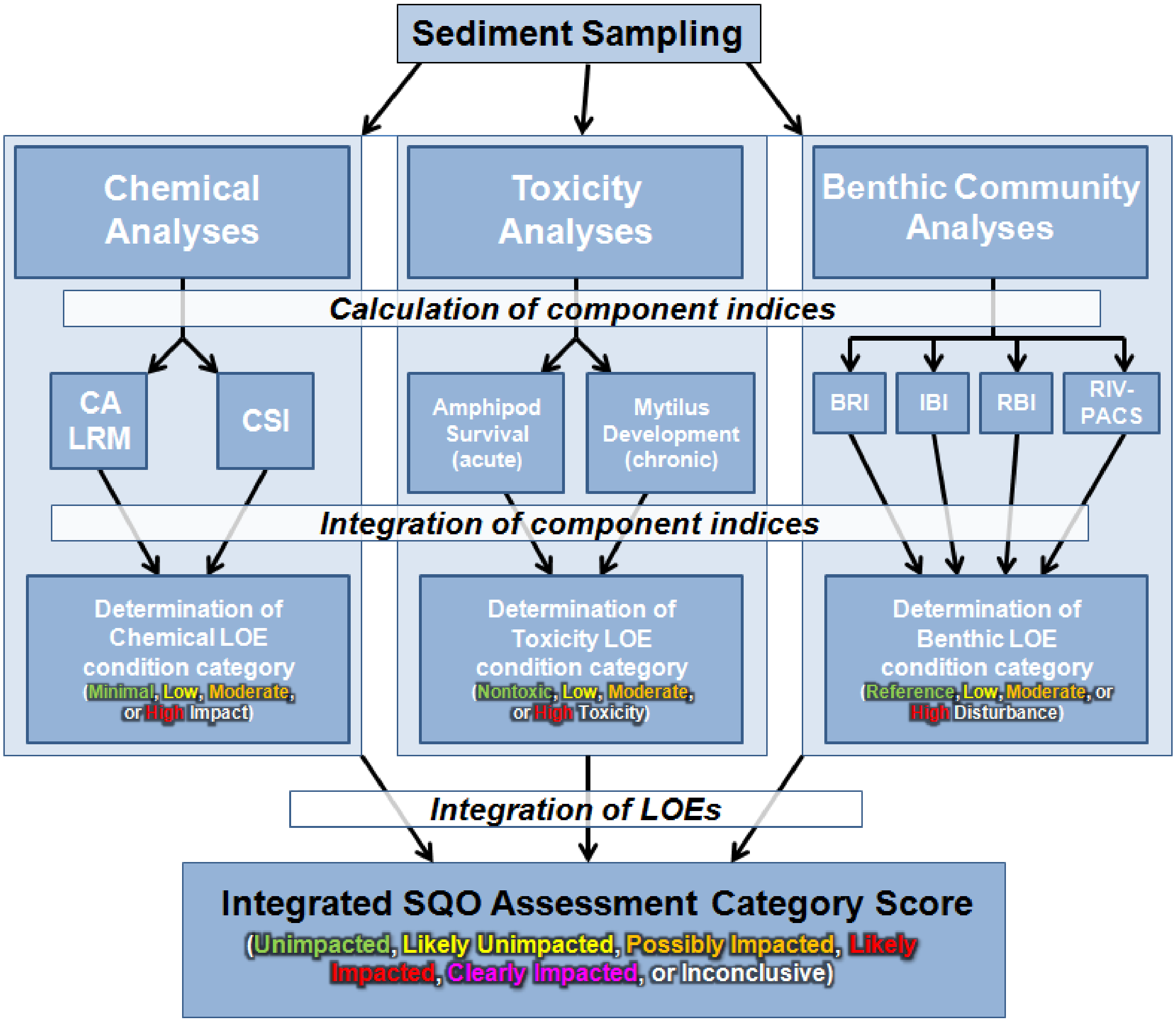

Figure 2-5. Overview of the SQO Station Assessment Process

2.3.2.1 Sediment Chemistry SQO Assessment

Concentrations of chemicals detected in sediments were compared with the California Logistic Regression Model (CA LRM) and the Chemical Score Index (CSI). These SQO methodologies were developed for the State of California, using local data sets and two companion approaches: (1) the Logistic Regression Method (LRM), similar in many ways to the ER-L and ER-M approach relates chemical concentrations to toxic effects, but using data collected only in the State of California; and (2) the CSI criteria, which use chemistry data to predict the occurrence and severity of benthic community disturbance. Selected chemical constituents are compared with a series of concentration ranges that correspond to predicted benthic disturbance levels in southern California (Ritter et al., 2012).

The CA LRM is a maximum probability model (P_{MAX}) that uses logistic regression to predict the probability of sediment toxicity based on chemical concentration; the CSI uses sediment chemistry data to predict benthic community disturbance. The sediment chemistry results were categorized for the level of exposure to pollutants, according to CA LRM and CSI, as minimal exposure, low exposure, moderate exposure, or high exposure with each category assigned a score of 1 to 4 with a score of 1 indicating minimal exposure, and so on. (Appendix C, Table C-2). Each final sediment LOE category was determined by averaging the CA LRM and the CSI. If the average fell midway between two categories, it was rounded up to the greater exposure level category.

The LRM results in a single metric value representing multiple chemicals in the sediments, whereas the CSI results in individual scoring values for a suite of key “indicator” chemicals, as well as a combined integrated score. For this reason, a CSI score can be attributed to individual chemicals as shown in Table 2-6, and also be used to also derive an integrated score using those chemicals with CSI values.

Table 2-6 provides the range of chemical concentrations used to calculate the CSI score.

Table 2-6.
Chemical Concentration Ranges for Chemical Exposure Categories used in the CSI Calculation

Chemical		Chemical Score Index (CSI) Exposure Category			
		Minimal (1)	Low (2)	Moderate (3)	High (4)
Metals (mg/kg)	Copper	≤ 52.8	>52.8-≤96.5	>96.5-≤406	>406
	Lead	≤26.4	>26.4-≤60.8	>60.8-≤154	>154
	Mercury	≤ 0.09	>0.09-≤0.45	>0.45-≤2.18	>2.18
	Zinc	≤112	>112-≤200	>200-≤629	>629
Organics (µg/kg)	HPAH	≤ 312	>312-≤1325	>1325-≤9320	>9320
	LPAH	≤ 85.4	>85.4-≤312	>312-≤2471	>2471
	Alpha Chlordane	≤ 0.50	>0.50-≤1.23	>1.23-≤11.1	>11.1
	Gamma Chlordane	≤ 0.54	>0.54-≤1.45	>1.45-≤14.5	>14.5
	Total DDDs	≤ 0.50	>0.50-≤2.69	>2.69-≤117	>117
	Total DDEs	≤ 0.50	>0.50-≤4.15	>4.15-≤154	>154
	Total DDTs	≤ 0.50	>0.50-≤1.52	>1.52-≤89.3	>89.3
	Total PCBs*	≤11.9	>11.9-≤24.7	>24.7-≤288	>288

Notes:
* Total PCBs for CSI comparison used the sum of selected PCB congeners multiplied by a correction factor. See SQO Technical Manual for more detail (Bay et al., 2014).
DDD = dichlorodiphenyldichloroethane; DDE = Dichlorodiphenyldichloroethylene; HPAH = high-molecular-weight PAH; LPAH = low-molecular-weight PAH.

A comparison of chemicals used to derive the integrated ER-L/ER-M quotient and CSI calculations using the SQO approach are shown in Table 2-7.

Table 2-7.
Comparison of Analytes Used to Derive the Integrated ER-L/ER-M Quotient and the CSI Following the SQO Approach

Chemical		ER-L, ER-M	CSI
Metals	Arsenic	X	
	Cadmium	X	X
	Chromium	X	
	Copper	X	X
	Lead	X	X
	Mercury	X	X
	Nickel	X	
	Zinc	X	X
Organics	LPAHs		X
	HPAHs		X
	Total PAHs	X	
	Total PCBs	X	X*
	Total DDDs		X
	Total DDEs		X
	Total DDTs	X	
	Alpha Chlordane		X
	Gamma Chlordane		X
	Total Chlordanes	X	

Notes:
* Total PCBs for CSI comparison used the sum of selected PCB congeners multiplied by a correction factor. See SQO Technical Manual for more detail (Bay et al., 2014).
CSI = Chemical Score Index

The SQO chemistry LOEs provide a new more regionally relevant set of sediment chemistry metrics that can be used as a more effective trend analysis tool in the future as the specific information required for these analyses continues to be collected over time. A valid comparison of SQO metrics is possible between the 2008 and 2013 surveys and was performed for this report. However, integrated metric comparisons with older data will continue to use the approach described herein for 2013 (using the mean ER-M quotient and suite of secondary indicators), because the CSI and CA LRM were only introduced into the Bight regional monitoring efforts in 2008.

2.3.2.2 Sediment Toxicity SQO Assessment

Sediment toxicity was assessed using methodology described in Chapter 4 of the *Sediment Quality Assessment Technical Support Manual* (Bay et al., 2014) summarized in Appendix C (Tables C-3 and C-4). One-tailed t-test results from each station were compared with control test results to determine whether they were significantly different. Each station was then categorized as being nontoxic, or having low toxicity, moderate toxicity, or high toxicity, based on both statistical significance and percent effect relative to the control, as shown in Table 2-8. The final toxicity LOE category was then calculated using the average of the test responses. When the average fell midway between two categories, the value was rounded up to the higher toxicity category.

Table 2-8.
Thresholds for Calculating Toxicity Categories

Test Species/Endpoint	Nontoxic (%)	Low Toxicity (% of Control)	Moderate Toxicity (%of Control)	High Toxicity (% of Control)
Amphipod - % Survival	90 to 100	82 to 89[a]	59 to 81[b]	<59
Bivalve - %Normal-alive	80 to 100	77 to 79[a]	42 to 76[b]	<42

Notes:
a. If the response is not significantly different from the negative control, then the category becomes nontoxic.
b. If the response is not significantly different from the negative control, then the category becomes low toxicity.

The SQO toxicity LOEs provide a new more regionally relevant set of toxicity metrics that can be used as a more effective trend analysis tool in the future as the specific information required for these analyses continues to be collected over time. A valid comparison of SQO metrics is possible between the 2008 and 2013 surveys and was performed for this report. However, integrated metric comparisons with older data will continue to use the approach described herein for 2013, because the bivalve SWI test, a component of the SQO metrics, was only introduced into the Bight regional monitoring efforts in 2008.

2.3.2.3 Benthic Infaunal Community Condition SQO Assessment

Research in California embayments has shown that the use of a combination of benthic indices provides a more accurate description of benthic invertebrate community condition than does the use of a single index (Ranasinghe et al. 2009). Benthic infaunal community condition was assessed using a combination of four benthic indices specifically tailored to southern California marine bays and estuaries as described in Bay et al., (2014); Chapter 5. An integrated benthic community assessment score is derived from four different benthic indices: (1) the Index of Biotic Integrity (IBI); (2) the Relative Benthic Index (RBI); (3) the Benthic Response Index (BRI); and (4) the River Invertebrate Prediction and Classification System (RIVPACS).

Each index categorizes benthic condition into one of four disturbance categories:

- **Reference**: A community that would occur at an undisturbed reference site for that habitat
- **Low Disturbance**: A community that may exhibit some indication of stress, but is within measurement variability of, or statistically similar to, reference condition
- **Moderate Disturbance**: A community that exhibits clear evidence of physical, chemical, natural, or anthropogenic stress
- **High Disturbance**: A community exhibiting a high magnitude of stress

Details about the history, background, and development of the indices and literature citations are provided in Ranasinghe (2012). A brief summary of the four indices follows:

- **IBI:** The IBI compares the values of four different metrics with the ranges expected under reference conditions. The metrics used to calculate the IBI are the total number of taxa, number of mollusc taxa, abundance of *Notomastus sp*. (a polychaete), and percentage of sensitive taxa.
- **RBI:** The RBI is the weighted sum of (1) four community metrics related to biodiversity (total number of taxa, number of crustacean taxa, abundance of crustacean individuals, and number of mollusc taxa); (2) abundance of three positive indicator taxa; and (3) presence of two negative indicator taxa. The data needed to calculate the RBI are total number of taxa, number of mollusc taxa, number of crustacean taxa, number of crustacean individuals, number of individuals of *Monocorophium insidiosum*, *Asthenothaerus diegensis*, and *Goniada littorea* (positive indicators), and presence of *Capitella capitata* complex and *Oligochaeta* (negative indicators).
- **BRI:** The BRI is the abundance-weighted pollution tolerance score of the organisms present in a benthic sample. The higher the BRI score, the more degraded the benthic community represented by the sample. Two types of data are needed to calculate the BRI: the abundance of each species and its pollution tolerance score, P.
- **RIVPACS:** The RIVPACS index is based on a predictive model and is a ratio of the number of reference taxa present in a test sample (observed or “O”) to the number of taxa expected to be present (“E”) in a reference sample from a similar habitat (the O/E ratio). Calculation of the RIVPACS score is a three-step process. The first step places the test sample habitat into one of 12 Southern California marine bay reference sample groups. This habitat determination is based on the test station’s bottom depth, salinity, latitude, and longitude, using a linear discriminant function. The second step is to determine, for each test sample, the identity and number of taxa expected to occur, based on the probability of group membership per habitat (i.e., taxa with a ≥50% capture rate in the reference pool). In the final step, the reference taxa observed in the sample are counted, the O/E ratio is calculated, and this value is compared to published response ranges to determine the RIVPACS condition category.

Benthic community condition category values were assigned for each index (Appendix C, Table C-5) and benthic condition was then determined by integrating the four benthic indices into a single category. The two median scores of the four benthic indices were used to determine the benthic condition at each sampling station. If the median score fell between two categories, the value was rounded to the higher disturbance category to provide the most conservative estimate of benthic community condition.

A comparison of SQO benthic infauna results is possible between the 2008 and 2013 surveys. However, discrepancies were noted in the calculations of these metrics in 2008; the results by SCCWRP and Weston did not agree, with results presented by Weston generally indicating healthier conditions. There have also been minor updates in the SQO calculation tool since 2008. These factors indicate that the historical comparison made in this report must be interpreted with caution, and it is recommended that a re-analysis of the entire 2008 data set (as well as data from earlier surveys) be completed for more accurate trend analyses. For context, comparisons are presented in tables and graphically in this report with appropriate qualifiers, but more rigorous statistical temporal analysis relationships were not assessed for this metric.

2.3.2.4 Overall Station Level SQO Assessment

The station level assessment determined the overall sediment quality at a station by integrating the three primary SQO LOEs: sediment chemistry, sediment toxicity, and benthic infaunal community condition. The integration uses the decision matrices presented in Appendix C (Tables C-6 and C-7, respectively). The station level assessment results in one of six possible station level assessments: unimpacted, likely unimpacted, possibly impacted, likely impacted, clearly impacted, and inconclusive (Appendix C, Table C-8) to determine whether SQOs are met at each sampling station.

A comparison of overall SQO assessment scores is possible between the 2008 and 2013 surveys. However, as noted above, calculation discrepancies for benthic infauna were noted, thus interpretation of the overall SQO station scores should be made with caution and it is recommended that a re-analysis of the entire 2008 data set (as well as data from earlier surveys) be completed for more accurate trend analyses. As mentioned, comparisons are presented in tables and graphically in this report with appropriate qualifiers, but more rigorous statistical temporal analysis relationships were not assessed for the integrated SQO metric.

2.3.3 Fish and Macroinvertebrate Analyses

Total abundance, biomass, and community indices were calculated for both demersal fish and epibenthic macroinvertebrates captured during the otter trawl samplings.

Community indices calculated were:

- **Taxa Richness:** Defined as the total number of unique organisms identified at a station.
- **Shannon-Wiener Diversity Index:** Calculated using the equation (- pi * log(pi), where pi is the count for species "i" divided by the total count of the sample).

- **Percent Dominance of Top Species:** Defined as the number of different species comprising 75% of the total count of the sample.
- **Pielou's Evenness Index**: Calculated using the Shannon-Wiener Diversity Index ÷ log (species count).
- **Index of Ecological Importance for Individual Fish:** Calculated by (number of fish as a % of catch + weight of the fish as a % of catch) × (% frequency of catch).
- **Percent Phyla Composition for Macroinvertebrates**: Defined as the percentage of each phyla (i.e., Mollusca, Annelida, etc.) making up the total number of macroinvertebrate phyla per station.
- **Predator Abundance:** Defined as the number and percentage of top predators in the population (fish only).

2.3.4 Statistical Analyses

2.3.4.1 Univariate Comparisons

The median value, quartiles, and range of results were used as descriptive statistics for the five strata and four harbors individually, as well as combined sites overall. Box plots were used to graphically show this information. An example is provided in Figure 2-6 for reference. For each of the key metrics or indices, a percentage of stations with a particular score (i.e., reference, low disturbance, moderate disturbance, high disturbance), or above/below specific threshold criteria are summarized by stratum, followed by statistical comparisons. General characteristics between harbors were also assessed, but statistical comparisons were limited because of the uneven distribution of samples among the harbors.

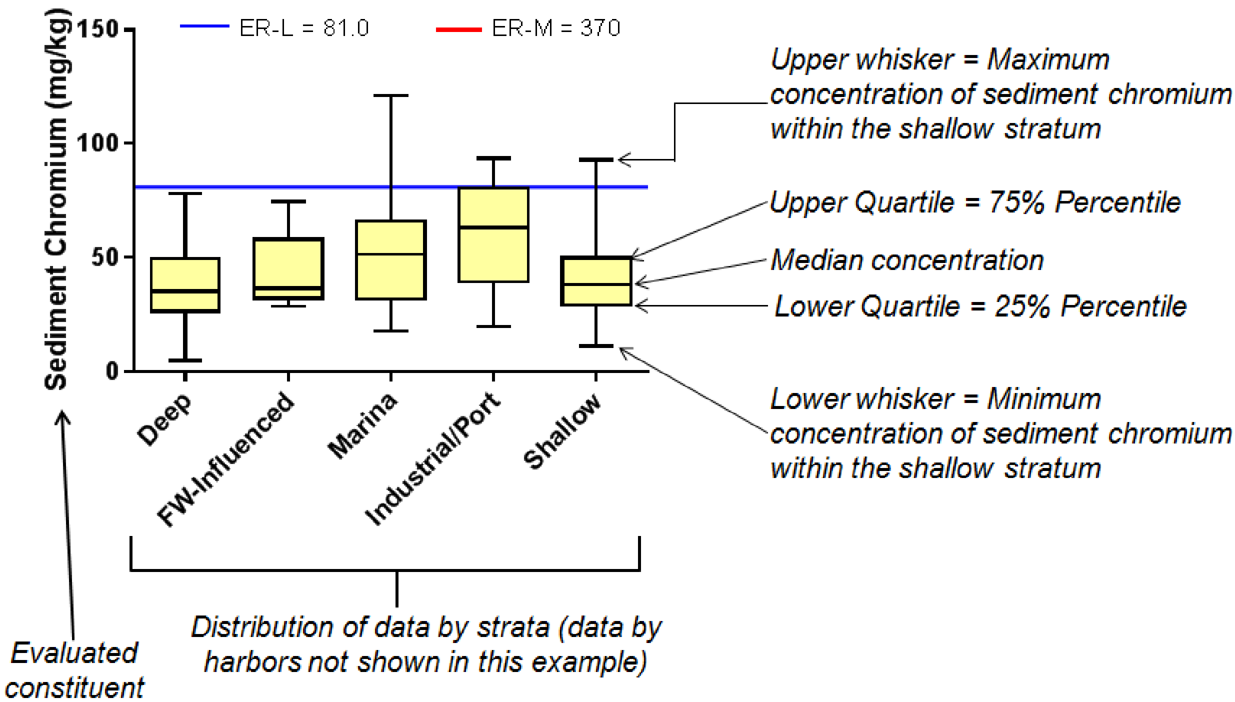

Figure 2-6. Box Plot Example Showing the Median, 25th and 75th Percentiles, and Data Range Values

Differences in surface water, sediment, and benthic infaunal parameters were compared statistically among strata using analysis of variance (ANOVA) or the nonparametric alternative, the Kruskal-Wallis test. The use of ANOVA requires that data must meet assumptions, including normal distribution of the data and equal variances. Normality was tested using the D'Agostino normality test and variances were tested using Bartlett's test and a newer recommended Brown-Forsythe test. When assumptions were not met, data were transformed using the arcsine square root for proportion data (i.e., percent amphipod survival), and square-root or log transformations for the other indicators, following the methods of Zar (1999), and assumptions were retested. Most of the chemistry data were log-transformed prior to analysis, given the skewed distribution of much of these data. If either untransformed or transformed data met the assumptions required for the use of parametric tests, ANOVAs were performed. Otherwise, nonparametric tests were performed (Kruskal-Wallis tests). Untransformed data distributions for key metrics (i.e., integrated scores) and a number of submetrics (i.e., individual chemicals) were plotted as frequency distribution graphs (provided in Appendix K for reference). Differences were considered to be significant at $p<0.05$, which indicates a 95% certainty that the differences were not due simply to chance. ANOVA and Kruskal-Wallis tests can test for overall significant difference, but to discern significant differences between any two given strata or harbors, post hoc multiple comparisons were performed using Tukey's range test.

Spearman rank correlation and regression analyses were also performed to evaluate the relationships among individual chemicals, grain size, TOC, integrated chemistry metrics (mean ER-M quotient and the SQO CSI Index), and various benthic community metrics. A variety of regression analyses were performed and plotted for reference in Appendix K for the various key chemicals of interest, physical parameters, and biological indices reported herein. Additionally, regression analyses were performed to compare the relationship between acid volatile sulfide-simultaneously extracted metals (AVS-SEM) ratios, the ESB based on AVS-SEM normalized to organic carbon, toxicity, mean ER-M quotients, and integrated SQO CSI values. Significance levels were established at $p<0.05$. Graphical figures of regression analyses are presented in Appendix K.

All general statistics and univariate comparisons were performed using Graphpad Prism® Version 6.0 statistical software.

2.3.4.2 Multivariate Comparisons

A suite of multivariate analyses was also employed to help visualize and tease out complicated relationships between benthic community populations among the harbors and strata, as well as benthic community measures and various associated key chemical and physical parameters:

1. Multivariate cluster analysis was performed separately for the benthic fish and benthic infauna to define similar station habitats and species communities, grouped by station and by species. Species included in the analysis were collected at a minimum of two trawl stations. Cluster analysis was also performed for benthic infauna to assess groupings as they relate to harbor, stratum, and integrated SQO scores. The clusters were based on a Bray-Curtis dissimilarity distance matrix using an agglomerative, hierarchical clustering algorithm. Cluster analysis was performed on raw untransformed data using the R Statistical platform (R Core Team, 2013).
2. Principal components analysis (PCA) was performed as an exploratory multivariate tool to assess relationships among the various benthic community indices and scores and sediment chemistry and physical characteristics. This is a valuable and relatively easy-to-use tool to help visualize relationships and partition variance. Although PCA is often used with benthic community data, it is also recognized as not being a preferred approach for species community relationships (Smith el al. 1988) because species community relationships do not typically exhibit a normal distribution. PCA was therefore used only after performing a log transformation of the data, since this technique is less robust on variables that are not normally distributed.
3. Non-linear multidimensional scaling (MDS) is another powerful multivariate data reduction procedure that is often recommended for analysis of benthic community and physical/chemical parameter relationships (Pfeifer et al., 1998). MDS can be used on a direct similarity or dissimilarity matrix, or on one derived from rectangular data with correlations. MDS is related to PCA in function, but MDS can fit an appropriate model in fewer dimensions than PCA and does not assume linear relationships. MDS was applied to the same data as PCA to further investigate relationships between benthic community and sediment chemical and physical characteristics.

Both PCA and MDS were performed using the Systat® Version 13 statistical software and graphing program.

2.4 Quality Assurance and Quality Control (QA/QC)

Specific QA/QC methods for all field activities, laboratory analyses, data analysis, and usability and reporting activities are provided in detail in the project-specific RHMP Quality Assurance/ Quality Control Assurance Plan, and also summarized in the project-specific Work Plan (Amec Foster Wheeler, 2013a and 2013b). QA/QC methodologies were conducted in accordance with the *Bight '13 Field Operations Manual* (SCCWRP, 2013a). The format for the RHMP QAPP followed the SWAMP 25-element structure and associated goals and objectives (http://www.waterboards.ca.gov/water_issues/programs/swamp/tools.shtml#qa).
Specific information related to data analysis and reporting QA/QC is re-summarized below for reference.

2.5 Data Analysis and Reporting QA/QC

QA/QC extends throughout each stage of the entire program. Following initial collection of the data, a third party reviewed the raw data and laboratory reports, as described in Section 2.6. Raw valid data were then entered into the SCCWRP Bight '13 database and RHMP-specific database for analyses not required in the Bight program (e.g., water column chemistry). A 100% quality assurance (QA) check of these data against the laboratory reports and associated raw data was performed before proceeding with subsequent analysis. Subsequent steps included the creation of spreadsheets for statistical analysis and graphing, and summary tables for the report. Each of these steps required a 100% QA check as well to ensure proper transcription, reporting units, analysis parameters and methods, and use of significant figures. Any data and associated conclusions included in the report itself have also undergone a 100% QA check against the raw data and summary tables. A more detailed summary of the complete data QA/QC process (encompassing a review of raw data, data processing and analysis, and reporting activities) is provided in the accompanying QAPP for the RHMP (Amec Foster Wheeler, 2013b).

2.6 Third-Party QA/QC Review

It is critical that all data used for subsequent analyses and interpretation for the RHMP be verified, not only internally by those producing the data, but also by an independent third-party reviewer. Raw chemistry data and associated laboratory reports were submitted to Laboratory Data Consultants (LDC) for third party review. At the time of this report, all of the toxicity data for Bight '13 have undergone a third-party QA/QC review at SCCWRP, and the Bight '13 toxicology committee has finalized a technical report for this component of the regional program (Bay et al., 2015). The Bight '13 chemistry committee is performing final data QA/QC and reporting activities at the time of this publication with an expected completion date in early 2016. The Bight '13 trawl committee has completed QA/QC and a draft report at the time of this publication, with a final deliverable expected late 2016.

A third-party review was also conducted on all final deliverables for the RHMP. Results and conclusions were checked and verified, as were the approaches for deriving all conclusions. A 10% check of the data from initial collection through final reporting was also conducted during the third-party review. Dr. Brock Bernstein and Dr. Allen Burton of the University of Michigan have conducted a third-party technical review of the draft RHMP report. Finally, a peer-review of the draft report was also conducted by the RHMP agencies. A response log with comments from all peer reviewers was prepared and is available upon request.

3.0 RESULTS

3.1 Water Quality

Water quality indicators included field vertical profile measures of pH, DO, temperature, salinity, and light transmittance, and analysis of a suite of physical and chemical parameters (TOC, DOC, nutrients, oil and grease, trace metals, and PAHs).

3.1.1 Physical Water Quality Parameters and Depth Profiles

Data summaries and graphical depth profiles of physical water quality parameters at all 2013 RHMP stations are presented in Appendix E. An overall summary of measurements by harbor and strata is provided in Table 3-1 and Table 3-2, respectively. Continuous measurements were recorded from the surface to the bottom at each station, and data were bin-averaged from 1 meter below the surface to 1 meter above the sea floor. Parameters measured included temperature, salinity, pH, DO, and transmissivity. Physical water quality data provide information that can be used when interpreting biological results and determining potential factors related to any changes observed over time.

Table 3-1.
Ranges of Water Quality Parameters by Stratum

Parameter	Stratum				
	Deep	Freshwater-Influenced	Marina	Industrial/Port	Shallow
Temperature (°C)	15.1–23.9	20.1–25.4	17.3–24.6	15.5–25.2	17.5–26.1
Salinity (practical salinity unit [psu])	31.3–34.7	33.9–35.3	33.4–35.4	31.9–35.2	28.4–35.3
pH	6.91*–8.03	6.89*–7.87	6.67*–8.00	6.86*–7.99	6.80*–7.89
Dissolved Oxygen (mg/L)	4.60–8.60	5.10–7.35	0.80**–10.3	4.26–7.77	3.60–10.1
Light Transmittance (%)	37.5–79.5	22.7–84.3	22.5–82.7	57.0–79.9	29.8–72.0

Notes:
Ranges in this table are based on binned depths (1-meter increments) at all stations. The number of values available at each station varied from 1 to 15, depending on depth.
* Low pH values were noted but verified with field meters, which were calibrated on a daily basis.
** Low concentrations of DO (below 3 mg/L) occurred at one station (B13-8117) at the inner portion of Shelter Island Yacht Basin (SIYB). Factors for a decline in DO within marinas might include reduced flushing and greater stratification.

Table 3-2.
Ranges of Water Quality Parameters by Harbor

Parameter	Harbor			
	Dana Point Harbor	Oceanside Harbor	Mission Bay	San Diego Bay
Temperature (°C)	17.3–19.0	18.1–20.4	19.7–24.8	15.1–26.1
Salinity (psu)	31.9–35.4	28.4–35.1	33.3–33.7	33.5–33.6
pH	6.67*–7.78	6.83*–7.67	6.91*–7.89	6.80*–8.03
Dissolved Oxygen (mg/L)	5.40–8.30	5.40–7.80	3.60–10.3	0.80**–8.50
Light Transmittance (%)	34.8–72	46.8–79.6	22.7–84.2	22.5–79.5

Notes:
Ranges are based on binned depths (1-meter increments) at all stations. The number of data points available at each station varied from 1 to 15, depending on depth.
* Low pH values were noted but verified with field meters, which were calibrated on a daily basis.
** Low concentrations of DO (below 3 mg/L) occurred at one station (B13-8117) at the inner portion of Shelter Island Yacht Basin (SIYB). Factors for a decline in DO within marinas might include reduced flushing and greater stratification.

Temperature

Temperatures did not vary substantially with depth; differences between surface and bottom temperatures for a given station were generally less than 1–2°C and, at their highest, 6.6°C. Deeper stations tended to exhibit more stratified temperatures, with deep and industrial/port strata having the largest differences. Thermoclines are typical of this geographic region during late summer months. In addition, surface temperatures (i.e., within 1 meter of the surface) did not vary substantially among harbors. The distribution of temperature among strata and harbors is shown in Figure 3-1. A single depth-averaged value was calculated for each site prior to inclusion in all field water quality plots.

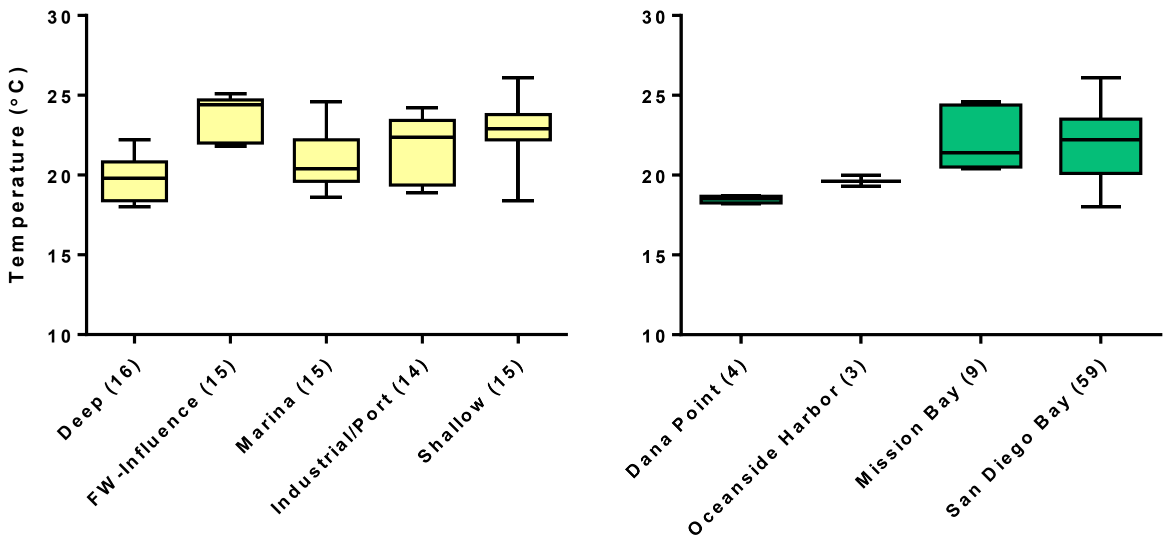

Figure 3-1. Field Measurements of Temperature Showing the Distribution of Results from Averaged CTD Vertical Profiles Within each Strata and Harbor

Note:

The number of samples (n) is shown in parentheses in this first graph only for reference. The same numbers apply to all subsequent graphs in the format. Box plots showing median, 25th percent quartiles, and range of average values of the water column.

Salinity

Salinity varied little with depth, generally less than 1 practical salinity unit (psu) from top to bottom at all 75 stations. On average, salinity values were also very similar among all harbors and strata, with surface salinities ranging from 33.3 psu (B13-8233, Oceanside Harbor, marina stratum) to 35.4 psu (B13-8013, San Diego Bay, marina stratum). The distribution of salinity among strata and harbors is shown in Figure 3-2.

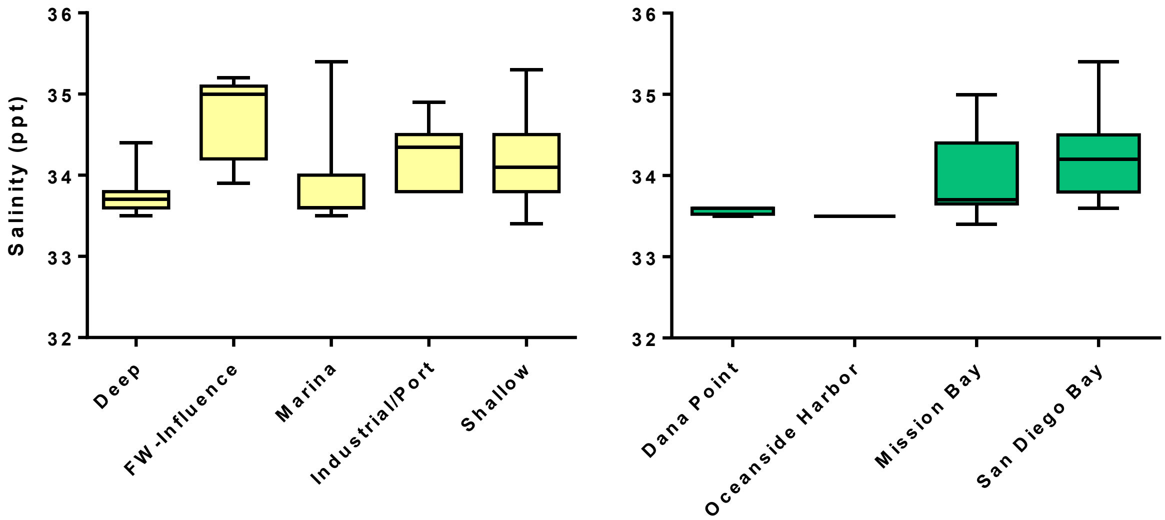

Figure 3-2. Field Measurements of Salinity Showing the Distribution of Results from Averaged CTD Vertical Profiles Within each Stratum and Harbor

Box plots showing median, 25th percent quartiles, and range of average values

pH

Measures of pH were largely consistent with depth at all stations, differing by no more than 0.1 unit from top to bottom at any station. Across all stations, pH within surface waters ranged from 6.67 (Station B13-8259, Dana Point Harbor, marina stratum) to 7.95 (Station B13-8073, San Diego Bay, marina stratum), with average values being slightly basic in all harbors and strata. The distribution of pH among strata and harbors is shown in Figure 3-3.

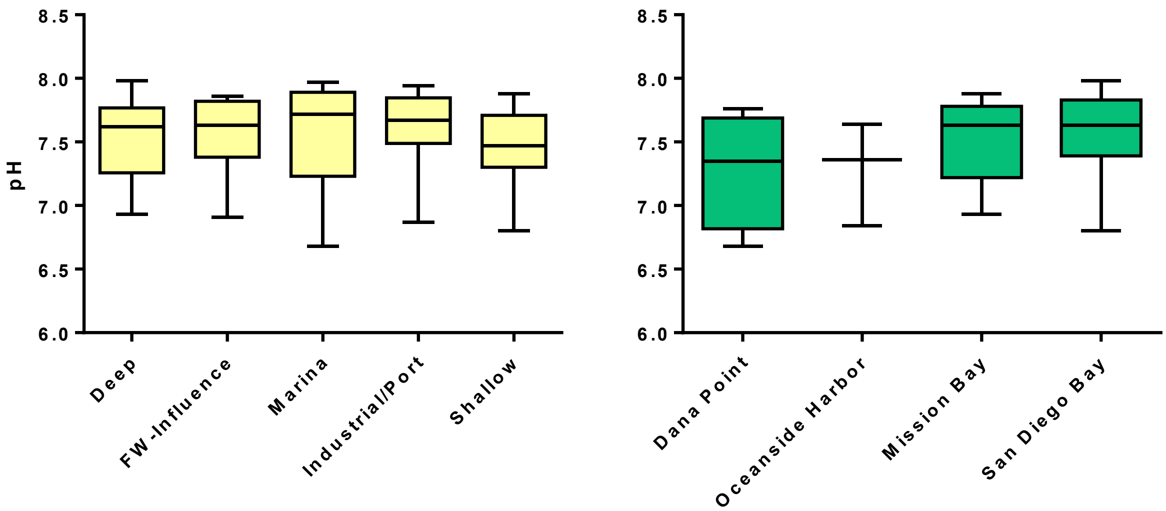

Figure 3-3. Field Measurements of pH Showing the Distribution of Results from Averaged CTD Vertical Profiles Within each Stratum and Harbor

Box plots showing median, 25th percent quartiles, and range of average values

Dissolved Oxygen

Levels of dissolved oxygen tended to decrease with depth for most stations, with the most pronounced declines (and in a few instances, increases) in DO occurring within the marina stratum. At 1 meter below the surface, the concentration of DO at all sampling stations was above the Basin Plan water quality objective (WQO) of 5.0 mg/L, However, at their deepest point, concentrations of DO at eight stations fell below the Basin Plan WQO, including two in the industrial/port stratum in San Diego Bay, one in the deep strata in San Diego Bay, and, and five in the marina stratum; one in Mission Bay and four San Diego Bay. The distribution of DO among strata and harbors is shown in Figure 3-4.

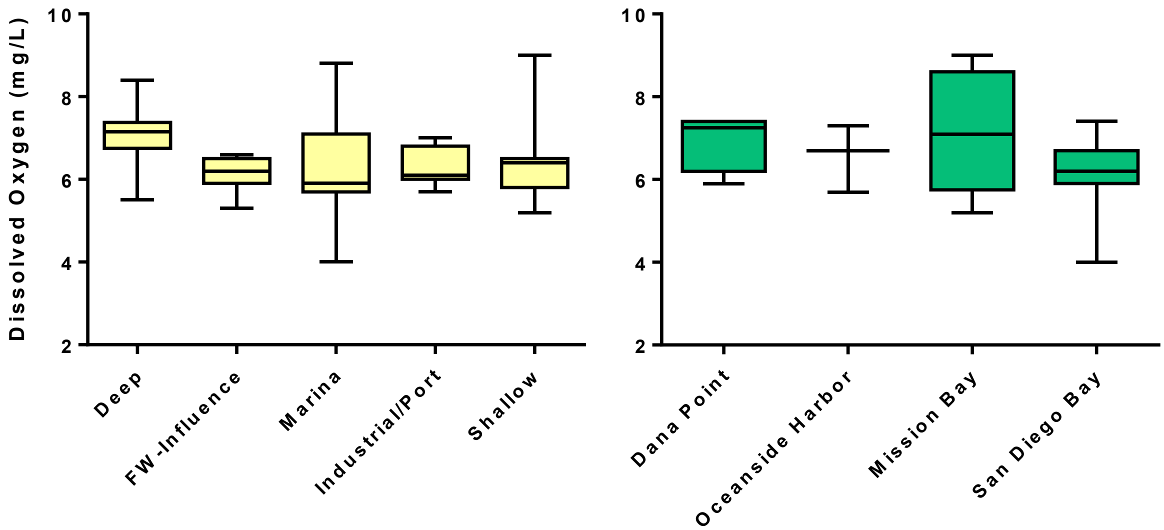

Figure 3-4. Field Measurements of Dissolved Oxygen Showing the Distribution of Results from Averaged CTD Vertical Profiles Within each Stratum and Harbor

Box plots showing median, 25th percent quartiles, and range of average values

Light Transmittance

Transmittance of light (i.e., water clarity) tended to decrease with depth for a majority of stations from surface to bottom, although a subset of 21% of stations experienced increased transmittance between surface and bottom waters. Five of those stations were in the deep stratum, four each in the shallow and industrial/port strata, two in the marina stratum, and one in the fresh water-influenced stratum. Declines in light transmittance from the surface to the substrate were most pronounced in the marina stratum[9], averaging approximately 17.9%, as compared to a decline of just over 2.8% in the fresh water-influenced stratum and between 5.5% and 10% in the industrial/port, shallow, and deep strata. The distribution of light transmittance values among strata and harbors is shown in Figure 3-5.

[9] Known factors for a decline in light transmittance within marinas include reduced flushing and stratification.

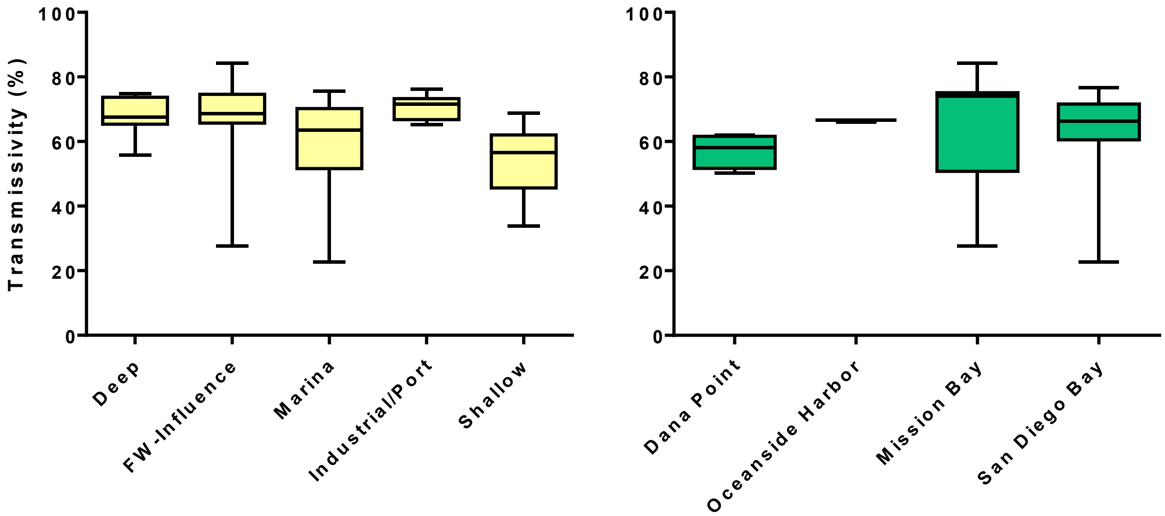

Figure 3-5. Field Measurements of Light Transmittance Showing the Distribution of Results from Averaged CTD Vertical Profiles Within each Stratum and Harbor

Box plots showing median, 25th percent quartiles, and range of average values

3.1.2 Analytical Chemistry for Surface Water

Surface water samples collected from the 75 RHMP stations were analyzed for analytes described in Table 2-1. Surface water chemistry results for primary and secondary indicators at all stations are summarized in Table 3-3, and are reported fully in Appendix F. Statistical comparison summaries are provided in Appendix K. Of all of the metals analyzed, concentrations of only the single primary indicator, copper (both total and dissolved), exceeded RHMP-specific California Toxic Rule (CTR) threshold values. Concentrations of the secondary water quality indicators zinc and nickel were well below acute and chronic CTR and RHMP threshold values at all stations sampled for the 2013 RHMP. Surface water chemistry results are described in detail in the following sections.

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Table 3-3.
RHMP 2013 Water Chemistry Summary

Harbor	Strata	Sample ID	Conventionals (mg/L)							Total PAHs (ng/L)	Dissolved Trace Metals (µg/L)																										
			Dissolved Organic Carbon	Total Organic Carbon	Ammonia-N	Nitrate-N	Total Orthophosphate as P	Oil & Grease	Methylene Blue Active Substance		Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Iron (Fe)	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Tin	Titanium	Vanadium	Zinc	Aluminum	Antimony	Arsenic	Barium	Beryllium
Dana Point Harbor	Marina	B13-8259	0.47 J	0.510	< 0.02	0.02 J	0.03	< 1.00	< 0.005	3.90	5 J	0.110	1.38	6.78	< 0.005	0.054	0.172	0.014	11.2	< 0.50	0.017	3.12	< 0.01	8.60	0.330	0.01 J	0.020	< 0.005	0.008 J	13.9	2.00	40.3	67.0	0.080	1.28	6.97	< 0.005
	Deep	B13-8263	0.54	0.49 J	< 0.02	< 0.01	0.03	< 1.00	< 0.005	< 1.00	3.6 J	0.100	1.43	5.85	< 0.005	0.034	0.165	< 0.005	4.18	< 0.50	0.012	2.47	< 0.01	8.75	0.241	0.0160	0.020	< 0.005	< 0.005	14.3	2.10	14.3	90.3	0.070	1.48	6.58	< 0.005
	Shallow	B13-8265	0.49 J	0.500	0.03 J	< 0.01	0.03	< 1.00	0.008 J	4.10	3.8 J	0.110	1.41	4.72	0.0220	0.039	0.164	0.010	8.63	< 0.50	0.014	2.33	< 0.01	8.76	0.281	0.013 J	0.020	< 0.005	0.314	10.5	2.00	23.9	55.3	0.090	1.32	7.32	< 0.005
	Marina	B13-8267	0.48 J	0.540	0.20	0.01 J	0.03	< 1.00	0.008 J	5.40	3.4 J	0.100	1.35	7.17	< 0.005	0.038	0.163	0.015	6.39	< 0.50	0.017	3.75	< 0.01	8.70	0.319	0.011 J	0.020	< 0.005	0.010	13.9	2.00	23.0	135	0.080	1.43	5.54	< 0.005
Oceanside Harbor	Marina	B13-8233	0.58	0.580	0.07	0.02 J	0.03	< 1.00	< 0.005	6.70	4.2 J	0.110	1.38	6.47	< 0.005	0.033	0.163	0.015	6.07	< 0.50	0.018	14.7	< 0.01	8.69	0.258	0.006 J	0.020	< 0.005	0.015	11.8	2.10	18.8	50.2	0.090	1.38	7.34	< 0.005
	Deep	B13-8236	0.57	0.550	0.04 J	0.02 J	0.03	< 1.00	< 0.005	9.80	4.8 J	0.120	1.32	8.79	< 0.005	0.033	0.173	0.018	5.41	< 0.50	0.011	9.07	< 0.01	8.68	0.250	0.006 J	0.030	< 0.005	0.014	12.2	2.20	20.2	82.1	0.080	1.44	7.98	< 0.005
	Deep	B13-8239	0.50	0.560	< 0.02	0.01 J	0.03	< 1.00	< 0.005	7.70	3.6 J	0.100	1.31	7.09	< 0.005	0.058	0.198	0.014	3.32	< 0.50	0.115	4.12	< 0.01	8.74	0.233	0.009 J	0.020	< 0.005	< 0.005	12.9	2.20	9.90	70.5	0.080	1.44	7.52	< 0.005
Mission Bay	Deep	B13-8145	0.54	0.510	0.09	< 0.01	0.02	< 1.00	< 0.005	3.10	3.2 J	0.110	1.26	5.84	< 0.005	0.022	0.237	0.067	3.99	< 0.50	0.021	1.87	< 0.01	8.79	0.267	0.0180	0.100	< 0.005	0.010	13.2	2.20	15.8	25.6	0.080	1.36	5.30	0.005 J
	Marina	B13-8146	0.57	0.16 J	0.08	< 0.01	0.02	< 1.00	< 0.005	223	3.8 J	0.110	1.43	5.65	< 0.005	0.032	0.218	0.065	6.20	< 0.50	0.025	1.76	< 0.01	9.14	0.290	0.0160	0.090	< 0.005	0.016	13.3	2.20	28.9	10.7	0.090	1.32	6.27	< 0.005
	Marina	B13-8151	0.55	0.064 J	0.04 J	0.01 J	0.02	< 1.00	< 0.005	2.70	4.2 J	0.100	1.47	6.80	0.005 J	0.022	0.227	0.067	1.87	< 0.50	0.021	2.40	< 0.01	8.79	0.244	0.0200	0.100	< 0.005	0.013	15.1	2.30	8.90	74.5	0.090	1.42	6.95	< 0.005
	Deep	B13-8152	0.49 J	0.36 J	< 0.02	< 0.01	0.02	< 1.00	< 0.005	9.90	< 3.00	0.110	1.25	5.30	< 0.005	0.012	0.139	< 0.005	0.244	< 0.50	0.008	1.46	< 0.01	8.97	0.207	0.012 J	< 0.01	< 0.005	0.009 J	10.8	2.00	< 0.0025	41.2	0.100	1.18	6.33	0.005 J
	Shallow	B13-8156	0.62	0.44 J	0.06	< 0.01	0.02	< 1.00	< 0.005	1.00	< 3.00	0.100	1.28	5.03	< 0.005	0.016	0.146	< 0.005	0.445	< 0.50	0.011	2.21	< 0.01	9.07	0.188	0.01 J	< 0.01	< 0.005	< 0.005	11.5	2.10	0.03	54.5	0.100	1.28	6.11	< 0.005
	Shallow	B13-8157	0.74	0.092 J	0.03 J	< 0.01	0.03	< 1.00	< 0.005	1.50	< 3.00	0.120	1.32	9.05	0.005 J	0.018	0.081	0.044	0.481	1.00	0.009	7.05	< 0.01	8.93	0.239	0.0400	< 0.01	< 0.005	0.011	11.8	2.30	< 0.0025	99.9	0.120	1.32	8.81	< 0.005
	Shallow	B13-8159	0.98	0.780	0.07	< 0.01	0.05	< 1.00	< 0.005	3.70	< 3.00	0.170	1.87	12.4	< 0.005	0.018	0.049	0.161	0.737	< 0.50	0.035	15.6	< 0.01	9.41	0.353	0.0230	< 0.01	< 0.005	< 0.005	11.6	3.60	< 0.0025	381	0.140	1.88	13.3	0.0100
	Freshwater-Influence	B13-8160	0.98	0.760	< 0.02	< 0.01	0.06	< 1.00	< 0.005	6.10	< 3.00	0.170	1.84	11.7	< 0.005	0.016	0.040	0.156	0.637	< 0.50	0.041	19.9	< 0.01	9.60	0.379	0.0280	< 0.01	< 0.005	0.006 J	17.7	3.70	< 0.0025	582	0.120	1.99	12.4	0.0190
	Freshwater	B13-8163	1.00	0.720	< 0.02	< 0.01	0.04	< 1.00	< 0.005	8.70	< 3.00	0.150	1.61	10.5	0.005 J	0.020	0.055	0.075	0.887	1.0	0.014	15.8	< 0.01	9.20	0.286	0.0200	< 0.01	< 0.005	< 0.005	12.8	2.70	< 0.0025	18.9	0.140	1.75	11.3	< 0.005
San Diego Bay North	Deep	B13-8085	1.1 J	0.53 J	< 0.02	< 0.01	0.02	< 1.00	0.036	7.80	< 3.00	0.120	1.16	7.27	0.007 J	0.041	0.116	0.010	1.36	< 0.50	0.013	1.34	< 0.01	8.54	0.309	< 0.005	0.020	0.007 J	< 0.005	9.60	2.10	3.30	64.2	0.140	1.28	8.05	0.005 J
	Marina	B13-8102	1.3 J	0.66 J	< 0.02	< 0.01	0.02	< 1.00	0.046	25.4	< 3.00	0.110	1.19	7.93	< 0.005	0.046	0.110	0.017	6.67	< 0.50	0.022	2.74	< 0.01	9.17	0.312	< 0.005	0.020	0.007 J	< 0.005	11.7	2.10	15.6	40.6	0.130	1.31	6.97	< 0.005
	Shallow	B13-8105	1.1 J	1.7 J	< 0.02	0.01 J	0.03	< 1.00	0.035	9.80	< 3.00	0.150	1.34	7.12	< 0.005	0.047	0.129	0.015	1.25	< 0.50	0.046	2.46	< 0.01	9.62	0.340	< 0.005	0.020	0.008 J	< 0.005	10.7	2.20	3.50	224	0.130	1.37	8.54	0.006 J
	Marina	B13-8106	1.9 J	0.70 J	< 0.02	< 0.01	0.02	< 1.00	0.055	13.8	< 3.00	0.110	1.29	6.91	0.006 J	0.041	0.113	0.015	3.78	< 0.50	0.019	2.39	< 0.01	9.47	0.306	0.011 J	0.020	0.006 J	< 0.005	14.2	2.10	8.40	64.6	0.130	1.23	7.11	< 0.005
	Deep	B13-8108	0.79 J	0.82 J	< 0.02	< 0.01	0.02	< 1.00	0.057	10.8	< 3.00	0.120	1.23	7.10	< 0.005	0.045	0.110	0.020	5.96	< 0.50	0.020	2.70	< 0.01	9.70	0.330	< 0.005	0.020	0.008 J	< 0.005	9.70	2.00	12.5	64.0	0.120	1.40	8.30	< 0.005
	Deep	B13-8109	0.43 J	1.6 J	< 0.02	< 0.01	0.03	< 1.00	0.043	15.5	< 3.00	0.170	1.24	7.01	< 0.005	0.055	0.078	0.040	2.29	< 0.50	0.031	2.14	< 0.01	9.76	0.495	0.01 J	0.040	0.007 J	< 0.005	6.70	2.20	5.40	27.9	0.110	1.22	7.21	0.007 J
	Deep	B13-8111	0.8 J	1.1 J	< 0.02	0.01 J	0.02	< 1.00	0.045	40.0	< 3.00	0.140	1.27	8.83	0.006 J	0.047	0.126	0.030	1.62	< 0.50	0.026	4.04	< 0.01	8.65	0.350	0.016	0.01 J	< 0.005	< 0.005	10.0	2.40	5.70	102	0.150	1.41	8.40	0.006 J
	Deep	B13-8112	0.76 J	1.4 J	< 0.02	< 0.01	0.03	< 1.00	0.054	32.9	< 3.00	0.130	1.29	7.85	< 0.005	0.055	0.106	0.026	1.92	< 0.50	0.035	3.66	< 0.01	9.50	0.422	0.011 J	0.020	< 0.005	< 0.005	9.00	2.40	7.60	133	0.140	1.31	8.34	< 0.005
	Marina	B13-8113	1.2 J	1.1 J	< 0.02	< 0.01	0.02	< 1.00	0.040	9.90	< 3.00	0.110	1.26	7.35	0.0100	0.041	0.112	0.028	10.2	< 0.50	0.030	3.09	< 0.01	9.38	0.323	0.01 J	0.020	0.013	< 0.005	12.8	2.10	21.0	70.4	0.130	1.33	8.36	< 0.005
	Marina	B13-8116	1.0 J	0.91 J	0.03 J	< 0.01	0.02	< 1.00	0.063	10.1	< 3.00	0.120	1.14	8.25	< 0.005	0.053	0.166	0.026	8.10	< 0.50	0.039	3.87	< 0.01	9.45	0.331	0.011 J	0.020	0.007 J	< 0.005	11.6	2.00	18.9	86.8	0.120	1.39	9.66	< 0.005
	Marina	B13-8117	1.0 J	1.2 J	< 0.02	< 0.01	0.02	< 1.00	0.053	5.90	< 3.00	0.120	1.22	6.44	0.005 J	0.046	0.121	0.024	8.25	< 0.50	0.025	2.90	< 0.01	9.31	0.331	0.008 J	0.020	0.008 J	< 0.005	12.7	2.00	18.6	53.2	0.120	1.25	6.72	0.007 J
	Deep	B13-8118	0.35 J	1.0 J	< 0.02	< 0.01	0.02	< 1.00	0.042	14.7	< 3.00	0.160	1.22	8.62	< 0.005	0.056	0.093	0.040	2.24	< 0.50	0.024	1.65	< 0.01	9.73	0.444	0.015	0.030	0.007 J	< 0.005	6.40	2.20	5.30	19.1	0.110	1.16	8.00	< 0.005
	Marina	B13-8121	1.2 J	0.99 J	0.02 J	0.01 J	0.03	< 1.00	0.058	17.9	< 3.00	0.130	1.26	7.91	< 0.005	0.051	0.119	0.021	3.85	< 0.50	0.048	3.86	< 0.01	9.54	0.362	0.014 J	0.01 J	< 0.005	< 0.005	10.0	2.20	11.5	190	0.140	1.32	8.75	< 0.005
	Deep	B13-8122	0.45 J	0.94 J	< 0.02	< 0.01	0.02	< 1.00	0.035	17.2	< 3.00	0.140	1.20	8.25	< 0.005	0.053	0.087	0.037	2.43	< 0.50	0.026	2.01	< 0.01	9.94	0.446	0.014 J	0.040	0.010	0.014	6.50	2.30	6.10	24.4	0.100	1.25	7.78	< 0.005
	Shallow	B13-8123	0.91 J	1.1 J	< 0.02	< 0.01	0.02	< 1.00	0.051	12.4	< 3.00	0.130	1.30	9.00	< 0.005	0.055	0.103	0.018	2.05	< 0.50	0.031	2.85	< 0.01	9.33	0.425	0.022	0.020	< 0.005	< 0.005	9.50	2.40	4.80	137	0.130	1.30	7.74	0.006 J
	Shallow	B13-8124	0.85 J	1.1 J	< 0.02	< 0.01	0.03	< 1.00	0.043	15.2	< 3.00	0.130	1.34	7.79	< 0.005	0.060	0.109	0.027	2.65	< 0.50	0.033	4.83	< 0.01	9.54	0.422	0.022	0.01 J	< 0.005	< 0.005	10.4	2.40	8.30	152	0.150	1.21	8.48	< 0.005
	Marina	B13-8127	1.9 J	1.0 J	< 0.02	< 0.01	0.02	< 1.00	0.049	8.40	< 3.00	0.130	1.25	8.29	< 0.005	0.056	0.118	0.016	7.16	< 0.50	0.025	3.85	< 0.01	9.28	0.373	0.022	< 0.01	< 0.005	< 0.005	10.9	2.20	21.4	68.3	0.140	1.22	8.46	< 0.005
	Shallow	B13-8128	0.9 J	0.98 J	< 0.02	0.01 J	0.03	< 1.00	0.047	11.3	< 3.00	0.140	1.30	8.41	< 0.005	0.070	0.087	0.033	4.66	< 0.50	0.032	8.83	< 0.01	9.63	0.427	0.018	< 0.01	< 0.005	< 0.005	10.6	2.40	14.7	124	0.140	1.30	10.3	< 0.005
	Freshwater-Influence	B13-8500	0.77 J	1.3 J	< 0.02	< 0.01	0.02	< 1.00	0.046	20.3	< 3.00	0.130	1.29	9.40	< 0.005	0.051	0.127	0.029	2.02	< 0.50	0.033	3.44	< 0.01	9.36	0.403	0.013 J	0.01 J	< 0.005	< 0.005	10.5	2.40	5.10	142	0.130	1.33	8.39	< 0.005
San Diego Bay Central	Deep	B13-8045	<0.31	1.3 J	< 0.02	< 0.01	0.03	< 1.00	0.039	10.0	< 3.00	0.110	1.00	8.94	< 0.005	0.073	0.053	0.091	2.87	< 0.50	0.007	7.05	< 0.01	10.5	0.640	0.017	0.020	0.009 J	0.008 J	5.70	2.30	5.10	52.4	0.090	1.05	9.19	0.005 J
	Industrial/Port	B13-8049	0.62 J	1.0 J	0.03 J	0.02 J	0.03	< 1.00	0.015 J	29.6	< 3.00	0.150	1.28	10.6	< 0.005	0.068	0.151	0.071	3.07	< 0.50	0.035	8.22	< 0.01	10.2	0.590	0.022	0.050	< 0.005	0.011	12.9	2.90	3.10	89.8	0.140	1.16	9.76	< 0.005
	Industrial/Port	B13-8050	0.64 J	0.88 J	0.100	< 0.01	0.03	< 1.00	0.029	26.6	< 3.00	0.150	1.42	9.37	< 0.005	0.061	0.148	0.071	2.95	< 0.50	0.036	8.18	< 0.01	9.95	0.591	0.021	0.060	< 0.005	< 0.005	13.0	3.00	2.40	103	0.160	1.26	9.17	< 0.005
	Shallow	B13-8052	2.2 J	2.80	< 0.02	0.02 J	0.04	< 1.00	0.041	19.7	< 3.00	0.170	1.31	9.48	< 0.005	0.063	0.041	0.074	2.23	< 0.50	0.040	7.39	< 0.01	10.3	0.549	0.015	0.070	0.009 J	0.008 J	7.90	2.80	4.30	272	0.100	1.19	8.95	0.005 J
	Industrial/Port	B13-8053	1.1 J	0.86 J	< 0.02	< 0.01	0.03	< 1.00	0.047	28.1	< 3.00	0.160	1.17	8.67	< 0.005	0.063	0.099	0.068	2.57	< 0.50	0.018	7.41	< 0.01	9.91	0.576	0.017	< 0.01	< 0.005	< 0.005	9.70	2.70	4.30	112	0.170	1.19	9.92	< 0.005
	Industrial/Port	B13-8056	0.6 J	1.4 J	< 0.02	0.01 J	0.03	< 1.00	< 0.005	25.8	< 3.00	0.140	1.11	9.22	< 0.005	0.069	0.111	0.064	3.01	< 0.50	0.038	7.94	< 0.01	9.69	0.566	0.017	0.050	< 0.005	0.008 J	13.1	2.90	4.00	106	0.130	1.39	10.7	< 0.005
	Shallow	B13-8058	0.4 J	1.2 J	< 0.02	< 0.01	0.03	< 1.00	0.024 J	12.4	< 3.00	0.130	0.919	9.23	< 0.005	0.068	0.092	0.080	2.16	< 0.50	0.040	7.40	< 0.01	10.0	0.577	0.016	< 0.01	0.010	0.014	5.20	2.30	4.00	265	0.100	1.38	9.07	0.007 J
	Shallow	B13-8060	1.8 J	1.6 J	< 0.02	0.02 J	0.03	< 1.00	0.049	9.50	< 3.00	0.210	1.17	10.6	< 0.005	0.064	0.050	0.068	2.10	< 0.50	0.045	7.55	< 0.01	10.0	0.536	0.023	0.060	0.007 J	0.009 J	7.70	2.60	4.30	206	0.100	1.27	10.6	< 0.005
	Industrial/Port	B13-8064	0.63 J	1.0 J	< 0.02	< 0.01	0.02	< 1.00	0.007 J	25.4	< 3.00	0.150	1.23	8.63	< 0.005	0.066	0.106	0.051	3.34	< 0.50	0.043	7.51	< 0.01	10.0	0.619	0.019	0.050	0.005 J	0.019	14.4	2.80	4.30	39.3	0.160	1.27	8.60	< 0.005
	Industrial/Port	B13-8065	0.78 J	0.66 J	< 0.02	0.02 J	0.03	< 1.00	< 0.005	19.6	< 3.00	0.170	1.20	7.95	< 0.005	0.073	0.093	0.052	4.00	< 0.50	0.049	8.03	< 0.01	10.2	0.639	0.013 J	0.050	< 0.005	0.009 J	12.8	2.60	18.6	31.9	0.170	1.19	9.76	< 0.005
	Industrial/Port	B13-8066	0.64 J	0.6 J	0.04 J	0.02 J	0.03	< 1.00	< 0.005	28.9	< 3.00	0.170	1.25	8.86	< 0.005	0.076	0.105	0.060	3.42	< 0.50	0.077	7.68	< 0.01	9.79	0.600	0.018	0.060	0.007 J	0.013	12.1	2.80	2.80	56.2	0.130	1.22	9.02	< 0.005
	Shallow	B13-8068	0.35 J	1.1 J	< 0.02	< 0.01	0.03	< 1.00	0.043	16.3	< 3.00	0.100	1.05	7.69	< 0.005	0.063	0.138	0.077	2.64	< 0.50	0.040	5.83	< 0.01	10.2	0.577	0.020	0.020	0.008 J	0.005 J	6.20	2.20	5.10	101	0.090	1.17	9.23	0.006 J
	Industrial/Port	B13-8069	0.62 J	0.52 J	< 0.02	0.01 J	0.03	< 1.00	0.016 J	21.8	< 3.00	0.150	1.34	8.54	< 0.005	0.066	0.114	0.047	3.21	0.7 J	0.055	6.06	< 0.01	10.0	0.584	0.016	0.050	< 0.005	0.030	14.1	2.70	3.90	75.3	0.120	1.24	8.96	< 0.005
	Marina	B13-8073	1.3 J	1.6 J	< 0.02	< 0.01	0.04	< 1.00	0.058	44.4	< 3.00	0.150	1.03	10.4	< 0.005	0.055	0.108	0.044	4.12	0.6 J	0.018	5.86	< 0.01	9.75	0.441	0.018	0.020	0.008 J	< 0.005	6.60	2.10	10.1	43.9	0.120	1.26	7.84	< 0.005
	Freshwater-Influence	B13-8074	1.4 J	2.4 J	< 0.02	0.02 J	0.02	< 1.00	0.029	16.9	4.1 J	0.150	1.20	9.16	< 0.005	0.063	0.161	0.104	3.69	< 0.50	0.052	6.33	< 0.01	9.19	0.621	0.015	0.080	< 0.005	< 0.005	11.4	2.60	7.70	36.1	0.160	1.13	8.62	0.005 J
	Freshwater-Influence	B13-8075	1.5 J	2.90	0.02 J	0.01 J	0.02	< 1.00	< 0.005	18.5	4.2 J	0.160	1.24	8.07	< 0.005	0.052	0.213	0.106	3.22	< 0.50	0.048	5.92	< 0.01	9.04	0.588	0.017	0.080	< 0.005	< 0.005	12.6	2.60	9.10	48.3	0.140	1.23	8.60	< 0.005
	Freshwater-Influence	B13-8076	1.4 J	2.60	< 0.02	0.02 J	0.03	< 1.00	0.040	17.7	5 J	0.150	1.24	9.45	0.005 J	0.055	0.172	0.104	3.09	< 0.50	0.054	6.21	< 0.01	9.05	0.546	0.034	0.080	< 0.005	< 0.005	8.90	2.50	8.90	38.7	0.140	1.19	8.50	0.005 J
	Freshwater-Influence	B13-8077	1.8 J	2.80	< 0.02	0.02 J	0.02	< 1.00	0.062	15.8	4.1 J	0.150	1.21	8.48	0.006 J	0.056	0.190	0.096	3.41	< 0.50	0.046	5.43	< 0.01	9.06	0.563	0.018	0.080	< 0.005	0.010	12.4	2.50	9.40	29.9	0.140	1.15	8.89	< 0.005
	Deep	B13-8078	2.1 J	0.8 J	< 0.02	0.02 J	0.03	< 1.00	0.038	12.8	< 3.00	0.180	1.35	8.46	< 0.005	0.058	0.062	0.042	2.38	< 0.50	0.033	2.83	< 0.01	10.0	0.477	0.015	0.060	0.005 J	0.005 J	9.30	2.30	5.30	27.9	0.090	1.25	8.39	< 0.005
	Deep	B13-8087	0.82 J	1.3 J	< 0.02	< 0.01	0.02	< 1.00	0.059	47.8	< 3.00	0.110	1.22	8.12	< 0.005	0.059	0.093	0.032	2.69	< 0.50	0.020	2.86	< 0.01	9.95	0.521	0.007 J	0.01 J	0.009 J	< 0.005	5.50	2.10	5.30	31.7	0.130	1.20	6.48	< 0.005
	Industrial/Port	B13-8090	0.31 J	1.1 J	< 0.02	< 0.01	0.03	< 1.00	0.042	30.1	< 3.00	0.090	1.09	10.9	< 0.005	0.068	0.103	0.076	2.71	< 0.50	0.079	7.59	< 0.01	10.4	0.639	0.031	0.01 J	0.011	< 0.005	6.40	2.20	12.3	42.9	0.110	1.21	7.92	< 0.005
	Deep	B13-8093	0.76 J	0.96 J	< 0.02	< 0.01	0.03	< 1.00	0.033	22.5	< 3.00	0.130	1.20	7.82	< 0.005	0.058	0.070	0.042	2.56	< 0.50	0.042	3.04	< 0.01	10.4	0.505	0.018	0.030	0.006 J	< 0.005	6.80	2.30	5.80	50.0	0.120	1.41	8.82	0.005 J
	Industrial/Port	B13-8095	0.97 J	1.1 J	< 0.02	< 0.01	0.03	< 1.00	0.053	51.0	< 3.00	0.170	1.11	9.09	< 0.005	0.056	0.056	0.061	3.05	< 0.50	0.040	4.62	< 0.01	10.0	0.550	0.017	0.030	0.006 J	< 0.005	6.00	2.30	6.80	20.9	0.100	1.10	7.93	< 0.005
	Industrial/Port	B13-8096	0.74 J	0.96 J	< 0.02	< 0.01	0.02	< 1.00	0.040	18.8	< 3.00	0.160	1.22	8.02	< 0.005	0.059	0.071	0.044	3.24	< 0.50	0.035	3.89	< 0.01	10.4	0.556	0.020	0.030	0.007 J	< 0.005	5.80	2.30	7.10	29.3	0.100	1.29	8.27	< 0.005
	Industrial/Port	B13-8098	0.38 J	1.1 J	< 0.02	< 0.01	0.03	< 1.00	0.048	15.6	< 3.00	0.170	1.07	9.31	< 0.005	0.061	0.058	0.052	3.01	< 0.50	0.032	4.54	< 0.01	9.94	0.544	0.012 J	0.040	< 0.005	< 0.005	6.20	2.30	5.80	23.1	0.120	1.23	9.10	< 0.005
	Industrial/Port	B13-8099	0.43 J	1.0 J	< 0.02	< 0.01	0.02	< 1.00	0.038	23.6	< 3.00	0.170	1.22	8.14	< 0.005	0.057	0.066	0.054	3.18	0.5 J	0.034	4.99	< 0.01	10.0	0.516	0.024	0.030	0.006 J	< 0.005	7.80	2.30	6.90	38.5	0.090	1.16	10.0	0.006 J
	Industrial/Port	B13-8100	0.44 J	0.98 J	< 0.02	< 0.01	0.02	< 1.00	0.040	21.3	< 3.00	0.150	1.31	6.96	< 0.005	0.053	0.084	0.039	2.73	< 0.50	0.031	3.00	< 0.01	10.1	0.488	0.016	0.030	0.006 J	< 0.005	7.30	2.40	5.40	27.5	0.090	1.19	10.4	< 0.005
San Diego Bay South	Marina	B13-8013	1.6 J	1.1 J	< 0.02	< 0.01	0.06	< 1.00	0.042	28.1	< 3.00	0.220	1.27	13.7	< 0.005	0.077	0.068	0.116	5.21	0.8 J	0.035	16.5	< 0.01	10.1	0.696	0.020	0.040	0.008 J	0.015	7.40	3.30	17.5	752	0.110	1.40	13.8	0.0160
	Marina	B13-8014	1.8 J	1.3 J	< 0.02	0.01 J	0.04	< 1.00	0.036	5.30	< 3.00	0.220	1.15	13.6	< 0.005	0.054	0.121	0.085	3.37	0.7 J	0.013	15.8	< 0.01	10.1	0.637	0.028	0.050	0.007 J	0.013	8.30	3.10	9.20	179	0.120	1.35	11.0	0.006 J
	Shallow	B13-8017	0.8 J	1.1 J	0.0800	< 0.01	0.04	< 1.00	0.007 J	14.2	< 3.00	0.170	1.22	10.5	< 0.005	0.076	0.155	0.080	2.88	< 0.50	0.021	10.6	< 0.01	10.1	0.625	0.032	0.050	0.006 J	< 0.005	14.3	3.20	3.40	322	0.160	1.36	10.8	0.009 J
	Shallow	B13-8018	1.3 J	1.2 J	< 0.02	< 0.01	0.02	< 1.00	0.051	6.20	3.2 J	0.190	1.15	11.9	< 0.005	0.078	0.077	0.087	2.26	1.10	0.017	17.1	< 0.01	9.73	0.569	0.020	< 0.01	< 0.005	< 0.005	12.3	3.00	3.90	120	0.190	1.27	12.1	< 0.005
	Shallow	B13-8020	0.86 J	0.98 J	0.160	< 0.01	0.03	< 1.00	0.019 J	24.3	< 3.00	0.180	1.14	8.78	< 0.005	0.069	0.108	0.081	2.86	< 0.50	0.040	7.75	< 0.01	9.92	0.642	0.034	0.040	0.007 J	0.034	14.0	3.10	2.90	386	0.140	1.33	9.02	0.009 J
	Freshwater-Influence	B13-8028	1.8 J	1.4 J	< 0.02	< 0.01	0.03	< 1.00	0.046	10.7	< 3.00	0.240	1.05	10.8	< 0.005	0.070	0.079	0.094	2.89	0.6 J	0.015	11.5	< 0.01	10.3	0.648	0.021	0.050	0.008 J	0.020	9.20	2.90	7.10	77.9	0.090	1.14	13.1	< 0.005
	Freshwater-Influence	B13-8029	0.72 J	0.97 J	0.04 J	0.02 J	0.03	< 1.00	0.011 J	16.2	< 3.00	0.150	1.22	11.2	< 0.005	0.082	0.089	0.092	2.74	< 0.50	0.025	12.5	< 0.01	10.6	0.652	0.026	0.050	< 0.005	0.010	11.1	3.20	3.30	145	0.170	1.21	10.6	< 0.005
	Freshwater-Influence	B13-8030	2.0 J	1.5 J	< 0.02	0.01 J	0.03	< 1.00	0.045	10.1	< 3.00	0.190	1.20	11.2	< 0.005	0.071	0.079	0.097	2.80	0.6 J	0.017	11.7	< 0.01	10.1	0.622	0.023	0.050	0.008 J	0.018	9.50	2.90	6.70	68.2	0.120	1.19	11.9	< 0.005
	Freshwater-Influence	B13-8031	0.86 J	1.2 J	< 0.02	< 0.01	0.03	< 1.00	0.043	13.1	< 3.00	0.110	0.92	10.8	< 0.005	0.080	0.086	0.106	2.64	< 0.50	0.012	8.22	< 0.01	10.5	0.631	0.022	0.01 J	0.012	0.014	7.60	2.50	3.90	68.3	0.120	1.15	10.2	< 0.005
	Freshwater-Influence	B13-8033	0.6 J	1.1 J	< 0.02	< 0.01	0.03	< 1.00	0.037	9.40	< 3.00	0.130	0.97	10.0	< 0.005	0.069	0.057	0.090	2.63	< 0.50	0.033	7.22	< 0.01	10.3	0.597	0.019	0.040	0.009 J	< 0.005	6.80	2.60	5.80	87.6	0.110	1.09	9.29	0.007 J
	Freshwater-Influence	B13-8036	2.2 J	2.2 J	< 0.02	0.02 J	0.03	< 1.00	0.045	13.7	< 3.00	0.190	1.17	10.5	< 0.005	0.071	0.051	0.089	2.89	0.5 J	0.016	10.5	< 0.01	10.4	0.634	0.021	0.060	0.009 J	0.012	6.90	2.80	6.80	72.3	0.120	1.03	10.3	< 0.005
	Freshwater-Influence	B13-8038	2.3 J	1.4 J	< 0.02	0.01 J	0.03	< 1.00	0.045	15.5	< 3.00	0.190	1.08	11.0	< 0.005	0.072	0.076	0.087	2.78	< 0.50	0.013	10.8	< 0.01	10.1	0.610	0.020	0.060	0.009 J	0.006 J	7.70	2.80	5.30	75.9	0.120	1.24	11.6	< 0.005
	Freshwater-Influence	B13-8040	2.4 J	1.3 J	< 0.02	0.02 J	0.04	< 1.00	0.040	8.30	< 3.00	0.220	1.36	14.5	< 0.005	0.077	0.038	0.108	2.91	1.40	0.031	15.9	< 0.01	10.6	0.650	0.035	0.060	0.010	0.007 J	7.20	2.90	5.80	91.5	0.120	1.28	13.2	< 0.005

Notes:
mg/l = milligrams per liter
ug/l = micrograms per liter
ng/l = nanograms per liter
Data reported to the method detection limit
< = not detected at or above the stated level
J = estimated result, below the reporting limit
PAH = Polycyclic Aromatic Hydrocarbons
Total PAHs were calculated by the sum of all tested PAHs. Non-detects were treated as 0 and estimated results were treated as the reported value for summing purposes.

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Table 3-3.
RHMP 2013 Water Chemistry Summary

Harbor	Strata	Sample ID	Total Trace Metals (µg/L)																			
			Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Tin	Titanium	Vanadium	Zinc
Dana Point Harbor	Marina	B13-8259	0.0456	0.268	0.0650	12.1	41.1	0.084	3.47	< 0.01	7.85	0.367	0.022	0.01 J	< 0.005	0.009 J	14.9	2.14	37.2
	Deep	B13-8263	0.036	0.552	0.0300	4.90	57.2	0.094	3.42	< 0.01	7.82	0.350	0.011 J	0.020	< 0.005	< 0.005	17.9	2.35	18.7
	Shallow	B13-8265	0.039	0.358	0.0180	8.20	36.4	0.074	2.91	< 0.01	7.54	0.291	0.013 J	0.01 J	< 0.005	< 0.005	15.0	2.15	22.4
	Marina	B13-8267	0.041	0.458	0.0470	8.15	83.5	0.153	4.54	< 0.01	6.86	0.360	0.013 J	0.020	< 0.005	0.0130	19.0	2.42	35.3
Oceanside Harbor	Marina	B13-8233	0.032	0.245	0.0240	6.78	40.9	0.050	15.6	< 0.01	8.54	0.277	0.011 J	0.020	< 0.005	0.007 J	15.8	2.25	18.8
	Deep	B13-8236	0.034	0.291	0.0330	6.05	49.5	0.069	9.48	< 0.01	7.94	0.262	0.007 J	0.020	< 0.005	< 0.005	18.0	2.43	20.6
	Deep	B13-8239	0.026	0.283	0.0320	3.44	44.6	0.063	4.42	< 0.01	8.50	0.262	0.020	0.020	< 0.005	< 0.005	17.1	2.39	10.4
Mission Bay	Deep	B13-8145	0.025	0.274	0.0700	4.83	13.7	0.055	2.06	< 0.01	8.67	0.250	0.009 J	0.090	< 0.005	0.017	11.4	2.18	18.3
	Marina	B13-8146	0.029	0.484	0.0740	6.54	7.5	0.046	1.97	< 0.01	8.43	0.399	0.013 J	0.100	< 0.005	0.010	10.8	2.15	32.0
	Marina	B13-8151	0.024	0.357	0.0830	2.57	47	0.121	2.93	< 0.01	8.05	0.287	0.015	0.100	< 0.005	0.018	14.3	2.44	11.3
	Deep	B13-8152	0.014	0.252	< 0.005	0.357	32.8	0.066	1.97	< 0.01	8.22	0.209	0.008 J	< 0.01	< 0.005	0.006 J	14.6	2.13	< 0.0025
	Shallow	B13-8156	0.018	0.333	0.0210	0.621	40.8	0.096	2.77	< 0.01	8.72	0.267	0.025	< 0.01	< 0.005	0.009 J	13.7	2.31	1.99
	Shallow	B13-8157	0.020	0.249	0.0730	0.622	71.4	0.137	8.27	< 0.01	8.43	0.310	0.013 J	< 0.01	< 0.005	0.008 J	16.1	2.60	< 0.0025
	Shallow	B13-8159	0.017	0.571	0.255	1.15	265	0.576	21.3	< 0.01	7.34	0.517	0.033	< 0.01	< 0.005	0.036	30.0	4.47	2.26
	Freshwater-Influence	B13-8160	0.022	0.936	0.300	1.28	396	0.794	29.6	< 0.01	7.12	0.667	0.033	< 0.01	< 0.005	0.034	42.3	4.84	1.16
	Freshwater	B13-8163	0.020	0.101	0.0700	0.838	15	0.057	17.7	< 0.01	9.06	0.292	0.020	< 0.01	< 0.005	< 0.005	14.4	2.71	< 0.0025
San Diego Bay North	Deep	B13-8085	0.045	0.255	0.0420	2.06	41.6	0.144	4.57	< 0.01	9.51	0.411	0.013 J	0.020	0.0100	0.009 J	13.5	2.22	4.31
	Marina	B13-8102	0.049	0.206	0.0480	7.99	17.1	0.071	4.01	< 0.01	9.39	0.351	0.022	0.020	0.0110	< 0.005	13.3	2.19	19.8
	Shallow	B13-8105	0.051	0.509	0.0890	2.38	135	0.395	7.17	< 0.01	8.75	0.506	0.021	0.020	0.0120	< 0.005	19.2	2.66	7.25
	Marina	B13-8106	0.039	0.253	0.0440	4.63	31.7	0.104	4.17	< 0.01	9.40	0.354	0.011 J	0.01 J	0.008 J	< 0.005	12.7	2.19	11.6
	Deep	B13-8108	0.050	0.250	0.0500	7.16	30.1	0.110	4.50	< 0.01	9.50	0.370	0.008 J	0.01 J	0.010	< 0.005	14.2	2.20	17.4
	Deep	B13-8109	0.059	0.199	0.0640	2.76	18.6	0.128	5.58	< 0.01	9.78	0.489	0.01 J	0.030	0.008 J	0.022	9.62	2.42	7.79
	Deep	B13-8111	0.058	0.343	0.0670	2.47	65.6	0.223	7.16	< 0.01	9.76	0.494	0.015	0.01 J	< 0.005	0.018	13.6	2.59	6.01
	Deep	B13-8112	0.060	0.377	0.0940	2.66	73.8	0.255	7.86	< 0.01	9.40	0.523	0.018	0.01 J	0.006 J	0.013	13.1	2.72	6.01
	Marina	B13-8113	0.047	0.243	0.0440	11.4	31.2	0.104	4.48	< 0.01	9.17	0.337	0.015	< 0.01	0.005 J	0.011	13.2	2.21	23.2
	Marina	B13-8116	0.053	0.306	0.0630	9.58	39.6	0.179	5.59	< 0.01	9.24	0.382	0.019	0.020	0.0110	< 0.005	12.8	2.31	25.4
	Marina	B13-8117	0.053	0.250	0.0640	9.89	24.7	0.100	4.34	< 0.01	9.55	0.331	0.006 J	0.020	0.0140	< 0.005	13.5	2.21	23.8
	Deep	B13-8118	0.054	0.140	0.0560	2.58	12.4	0.118	5.05	< 0.01	10.0	0.467	0.013 J	0.030	0.008 J	< 0.005	7.47	2.26	5.70
	Marina	B13-8121	0.050	0.505	0.0780	5.44	106	0.438	6.99	0.01 J	8.65	0.418	0.006 J	< 0.01	0.007 J	0.019	16.1	2.59	13.3
	Deep	B13-8122	0.058	0.207	0.0590	2.73	14.9	0.121	4.90	< 0.01	9.80	0.451	0.009 J	0.030	0.005 J	0.023	8.41	2.27	6.18
	Shallow	B13-8123	0.061	0.369	0.0820	2.60	76.7	0.261	7.72	< 0.01	9.04	0.502	0.021	0.01 J	0.006 J	0.006 J	15.0	2.69	5.76
	Shallow	B13-8124	0.063	0.460	0.0900	3.64	84.3	0.296	8.60	< 0.01	9.43	0.534	0.020	0.01 J	< 0.005	0.009 J	14.3	2.65	8.27
	Marina	B13-8127	0.059	0.265	0.0700	7.97	35.6	0.126	5.30	< 0.01	9.22	0.378	< 0.005	< 0.01	< 0.005	0.008 J	10.4	2.34	21.7
	Shallow	B13-8128	0.067	0.442	0.0820	6.17	66.3	0.238	10.9	< 0.01	9.32	0.504	0.009 J	< 0.01	0.006 J	0.012	14.2	2.59	16.1
	Freshwater-Influence	B13-8500	0.056	0.425	0.0890	2.78	78	0.301	8.25	< 0.01	9.16	0.510	0.006 J	0.020	0.008 J	0.013	13.9	2.68	6.25
San Diego Bay Central	Deep	B13-8045	0.071	0.148	0.103	3.17	36.2	0.113	10.4	< 0.01	10.5	0.652	0.019	0.020	0.010	< 0.005	9.02	2.47	5.21
	Industrial/Port	B13-8049	0.073	0.325	0.0860	3.37	30.4	0.155	10.8	< 0.01	10.0	0.683	0.018	0.060	< 0.005	0.027	16.6	3.09	3.44
	Industrial/Port	B13-8050	0.068	0.345	0.097	3.44	42.1	0.187	11.1	< 0.01	9.90	0.680	0.027	0.070	< 0.005	0.023	18.0	3.13	3.58
	Shallow	B13-8052	0.065	0.635	0.139	2.88	165	0.369	11.2	< 0.01	9.55	0.643	0.022	0.060	0.0120	0.033	21.6	3.25	6.06
	Industrial/Port	B13-8053	0.075	0.367	0.095	3.17	54.9	0.104	10.0	< 0.01	9.50	0.683	0.025	< 0.01	< 0.005	0.011	11.7	2.89	5.53
	Industrial/Port	B13-8056	0.062	0.332	0.0920	3.25	40.8	0.196	10.9	< 0.01	8.73	0.610	0.021	0.060	< 0.005	0.025	17.6	3.07	3.72
	Shallow	B13-8058	0.070	0.849	0.181	3.40	233	0.466	12.5	< 0.01	9.74	0.693	0.034	0.020	0.012	0.063	21.9	3.04	6.51
	Shallow	B13-8060	0.066	0.526	0.119	2.65	129	0.335	10.6	< 0.01	9.62	0.622	0.019	0.050	0.010	0.025	17.1	3.04	5.59
	Industrial/Port	B13-8064	0.069	0.331	0.0590	3.72	18.1	0.145	10.1	< 0.01	10.2	0.767	0.022	0.060	0.006 J	0.014	12.6	2.90	4.86
	Industrial/Port	B13-8065	0.069	0.194	0.0490	4.27	16.0	0.141	9.84	< 0.01	10.1	0.646	0.021	0.060	< 0.005	0.019	11.6	2.70	18.6
	Industrial/Port	B13-8066	0.067	0.240	0.0630	4.01	24.5	0.153	9.82	< 0.01	9.80	0.708	0.024	0.060	< 0.005	0.013	15.2	2.79	3.97
	Shallow	B13-8068	0.064	0.301	0.105	3.42	73.8	0.265	9.47	< 0.01	10.0	0.635	0.023	0.020	0.0120	0.033	12.2	2.50	6.25
	Industrial/Port	B13-8069	0.066	0.296	0.0670	3.73	33.6	0.208	9.33	< 0.01	9.11	0.626	0.021	0.060	< 0.005	0.023	16.8	2.88	4.67
	Marina	B13-8073	0.051	0.224	0.0740	4.80	31.4	0.161	8.93	< 0.01	9.25	0.440	0.023	0.030	0.0100	0.010	10.3	2.25	11.4
	Freshwater-Influence	B13-8074	0.059	0.267	0.118	4.10	17.3	0.160	8.21	< 0.01	8.74	0.665	0.027	0.080	< 0.005	0.017	14.4	2.66	10.2
	Freshwater-Influence	B13-8075	0.059	0.273	0.122	3.54	18.2	0.171	6.51	< 0.01	8.76	0.637	0.019	0.080	< 0.005	0.014	11.0	2.63	9.80
	Freshwater-Influence	B13-8076	0.056	0.278	0.120	3.38	20.8	0.179	8.00	< 0.01	8.78	0.576	0.026	0.080	< 0.005	0.019	14.4	2.63	9.75
	Freshwater-Influence	B13-8077	0.058	0.452	0.108	3.71	15.4	0.149	7.95	< 0.01	8.74	0.647	0.017	0.080	< 0.005	0.023	11.7	2.54	8.55
	Deep	B13-8078	0.054	0.174	0.0400	2.71	16.5	0.139	5.56	< 0.01	10.1	0.493	0.019	0.060	0.009 J	< 0.005	7.52	2.37	5.95
	Deep	B13-8087	0.052	0.235	0.0620	2.99	19.7	0.120	5.87	< 0.01	9.75	0.507	0.012 J	0.020	0.008 J	< 0.005	9.06	2.21	6.37
	Industrial/Port	B13-8090	0.063	0.224	0.097	3.47	30.9	0.228	9.03	< 0.01	10.0	0.659	0.019	0.01 J	0.008 J	0.031	8.91	2.45	12.5
	Deep	B13-8093	0.059	0.241	0.0600	2.84	28.4	0.169	6.37	< 0.01	9.68	0.499	0.018	0.030	0.008 J	0.015	9.15	2.41	6.17
	Industrial/Port	B13-8095	0.057	0.184	0.0580	3.36	13.6	0.116	6.89	< 0.01	9.79	0.528	0.013 J	0.030	0.007 J	0.019	8.32	2.35	7.03
	Industrial/Port	B13-8096	0.059	0.214	0.0640	3.12	16.9	0.132	6.39	< 0.01	10.1	0.524	0.018	0.020	0.007 J	0.008 J	8.42	2.27	6.58
	Industrial/Port	B13-8098	0.061	0.160	0.0730	3.18	12.5	0.110	7.27	< 0.01	9.54	0.514	0.009 J	0.030	0.0100	0.012	8.68	2.44	6.34
	Industrial/Port	B13-8099	0.055	0.448	0.0700	3.79	23.4	0.132	6.94	< 0.01	9.85	0.571	0.015	0.030	0.008 J	0.023	9.64	2.40	7.31
	Industrial/Port	B13-8100	0.058	0.200	0.0640	3.05	15.6	0.130	5.83	< 0.01	9.85	0.508	0.019	0.020	0.006 J	0.017	8.26	2.29	6.34
San Diego Bay South	Marina	B13-8013	0.080	1.091	0.286	8.60	504	0.504	26.2	< 0.01	9.64	0.896	0.028	0.050	0.016	0.083	45.8	4.91	20.1
	Marina	B13-8014	0.064	0.374	0.128	4.60	107	0.143	18.8	< 0.01	10.4	0.717	0.026	0.050	0.011	0.009 J	15.5	3.47	10.5
	Shallow	B13-8017	0.076	0.614	0.154	3.50	161	0.275	13.3	< 0.01	8.92	0.799	0.038	0.060	0.006 J	0.057	26.2	3.73	4.80
	Shallow	B13-8018	0.088	0.289	0.133	2.81	80.3	0.119	18.7	< 0.01	10.1	0.689	0.032	0.01 J	< 0.005	0.012	13.7	3.27	4.92
	Shallow	B13-8020	0.071	0.764	0.169	3.65	161	0.332	12.2	< 0.01	8.70	0.803	0.030	0.070	0.008 J	0.051	35.3	3.89	4.53
	Freshwater-Influence	B13-8028	0.082	0.235	0.108	3.44	44.7	0.108	13.4	< 0.01	10.7	0.704	0.025	0.060	0.012	0.010	10.5	2.98	7.40
	Freshwater-Influence	B13-8029	0.081	0.361	0.125	3.10	69.3	0.177	14.3	< 0.01	9.37	0.695	0.031	0.060	0.005 J	0.026	17.0	3.44	3.13
	Freshwater-Influence	B13-8030	0.081	0.225	0.112	3.24	41.4	0.100	13.8	< 0.01	10.5	0.701	0.025	0.040	0.010	< 0.005	10.2	2.94	7.92
	Freshwater-Influence	B13-8031	0.074	0.195	0.106	3.11	50.9	0.118	10.9	< 0.01	10.2	0.650	0.029	0.020	0.012	0.017	9.91	2.60	4.82
	Freshwater-Influence	B13-8033	0.072	0.309	0.105	3.03	55.2	0.177	10.5	< 0.01	10.3	0.644	0.020	0.040	0.006 J	0.015	11.8	2.86	6.10
	Freshwater-Influence	B13-8036	0.078	0.232	0.103	3.15	40.1	0.098	12.7	< 0.01	10.4	0.675	0.029	0.050	0.009 J	0.006 J	11.1	2.92	6.61
	Freshwater-Influence	B13-8038	0.076	0.223	0.103	3.27	44	0.100	13.0	< 0.01	10.2	0.667	0.024	0.050	0.011	< 0.005	10.2	3.00	5.79
	Freshwater-Influence	B13-8040	0.083	0.193	0.123	3.28	57	0.157	18.0	< 0.01	10.6	0.696	0.021	0.050	0.010	< 0.005	10.6	3.02	6.09

3.1.2.1 Primary Indicators: Dissolved and Total Copper

Across the 2013 RHMP study area, concentrations of dissolved and total copper at 17% and 19% of the stations exceeded their respective RHMP thresholds which are equivalent to the EPA acute CTR Continuous Maximum Criteria or CMC (Table 3-4). The percentage of stations with copper concentrations greater than the threshold values is summarized in Table 3-5 among strata. The marina stratum had the greatest number of exceedances, with concentrations of dissolved and total copper above the acute CTR threshold at 67% of the stations. The remaining four strata had dissolved and total copper concentrations that were mostly below the threshold values of 4.8 and 5.8 µg/L for dissolved and total copper, respectively.. A graphed comparison of surface water copper concentrations among strata and harbors is shown with box plots in Figure 3-6. The RHMP threshold equivalent to the EPA CTR acute CMC, as well as the chronic CTR values referred to as the Continuous Chronic Criteria (CCC) are shown on the figure for comparison purposes.

Table 3-4.
Percentage of Stations with Results Exceeding Threshold Values for Surface Water Metals

Indicator		Threshold Value (µg/L)	Pre-set Target[a] (%)	RHMP Data – % of Stations Exceeding Threshold Values	
				2008	2013
Copper	Dissolved	4.8	42	21	17
	Total	5.8	49	28	19
Nickel	Dissolved	74	0	0	0
	Total	75	0	0	0
Zinc	Dissolved	90	0	0	0
	Total	95	1	0	0

Notes:
[a] Pre-set target values were derived for the 2008 RHMP effort (Weston, 2005b).
µg/L = micrograms per liter; % = percent

Table 3-5.
Percentage of Stations Exceeding Thresholds for Copper by Stratum

Copper	Historical Baseline (%)	Deep (%)	Freshwater-Influenced (%)	Marina (%)	Industrial/ Port (%)	Shallow (%)
Number of stations		*16*	*15*	*15*	*14*	*15*
Dissolved	42	12	0	67	0	7
Total	49	12	0	67	0	13

Regional harbor copper concentrations showed an overall improvement when compared with historical baseline conditions. Based on the selected historic values, dissolved copper concentrations exceeded the RHMP-established threshold value of 4.8 µg/L at 42% of the stations sampled, and results at 49% exceeded the threshold value for total copper (5.8 µg/L).

The 2013 results show an improvement, with less than 20% of the stations having concentrations exceeding dissolved and total copper thresholds values, respectively (Figure 3-7, Appendix K). The number of exceedances in 2013 was also less than that in 2008, which ranged from 21 to 28% for dissolved and total copper, respectively.

The total copper concentration should exceed the dissolved copper concentration by a fairly consistent percentage in ambient clear marine waters. As a QA/QC measure, comparison of total and dissolved copper across all samples collected is graphically shown for reference in Appendix F. Total copper consistently exceeded the dissolved fraction by 3 to 67% across all samples, except for two stations where the dissolved fraction exceeded the total by 5% or less, well within a range of typical analytical variability.

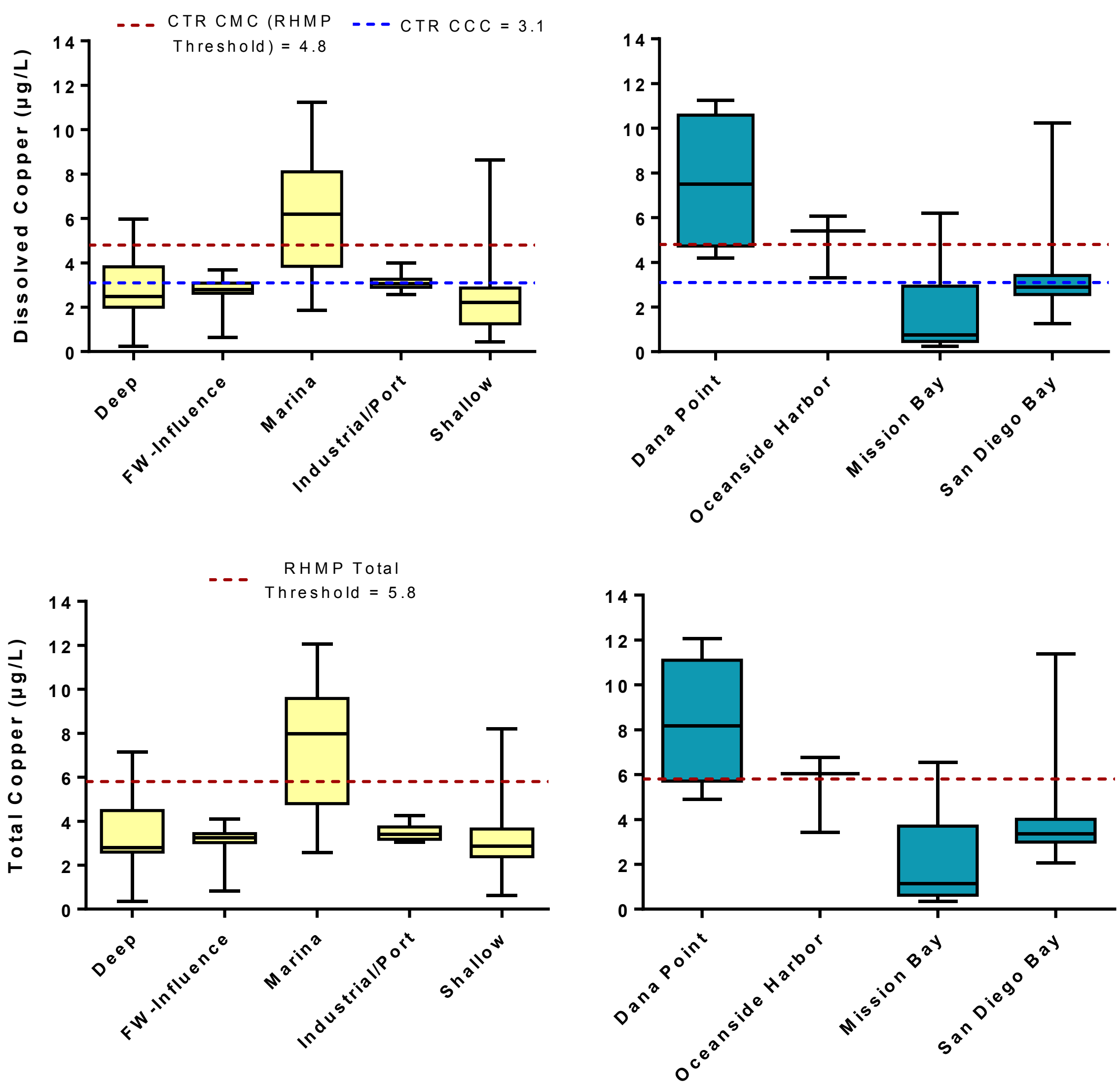

Figure 3-6. Comparison of Surface Water Copper Concentrations Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of average values

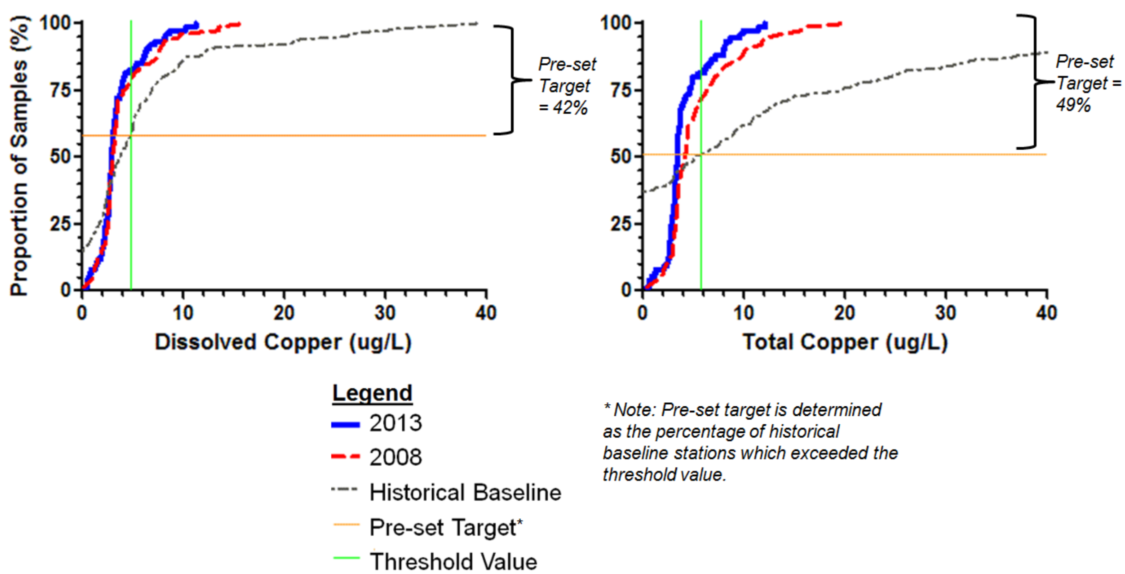

Figure 3-7. Cumulative Distribution Curves for Dissolved and Total Copper in Surface Waters

Figures 3-8a through 3-8f present copper concentration values on maps for all harbors categorized for a variety of benchmarks, including the analytical Method Detection Limit (MDL), Reporting Limit (RL), California Toxics Rule Criterion Maximum Concentration (acute, CTR CMC), and the California Toxics Rule Criterion Continuous Concentration (chronic, CTR CCC).

Figure 3-8a. Distribution of Dissolved Copper Concentrations in Surface Waters for Dana Point Harbor

Figure 3-8b. Distribution of Dissolved Copper Concentrations in Surface Waters for Oceanside Harbor

Figure 3-8c Distribution of Dissolved Copper Concentrations in Surface Waters for Mission Bay

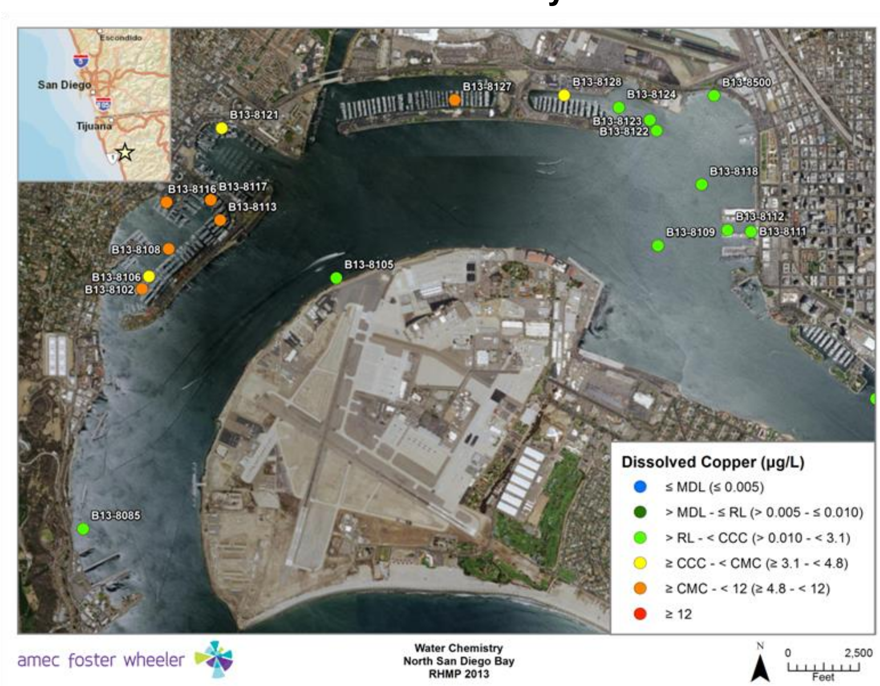

Figure 3-8d. Distribution of Dissolved Copper Concentrations In Surface Waters for Northern San Diego Bay

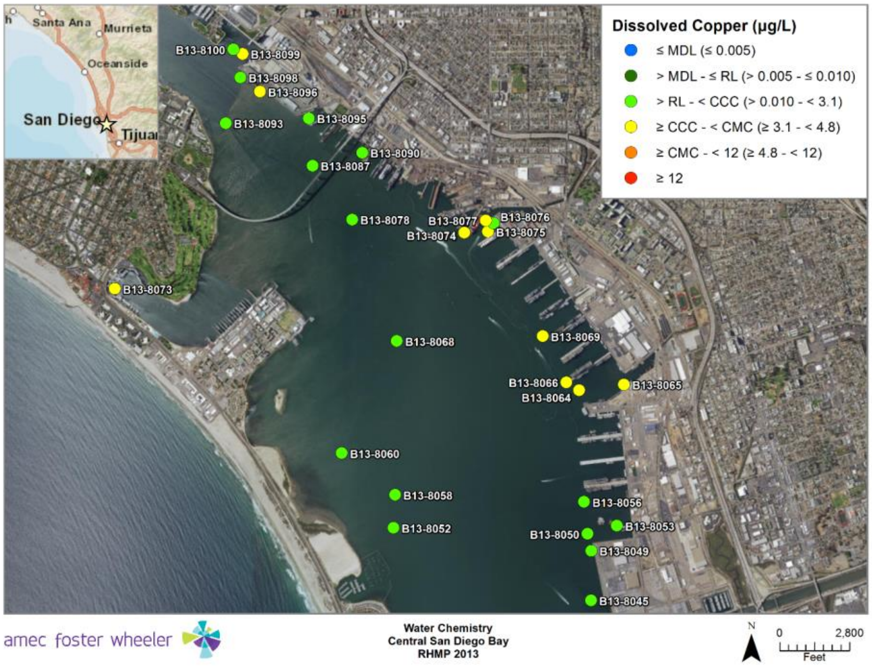

Figure 3-8e. Distribution of Dissolved Copper Concentrations in Surface Waters for Central San Diego Bay

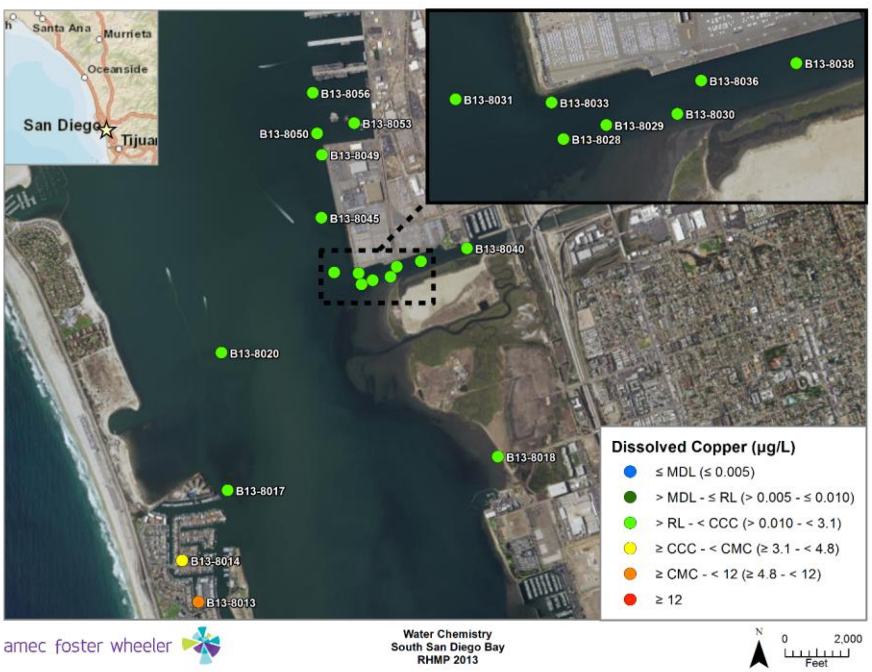

Figure 3-8f. Distribution of Dissolved Copper Concentrations in Surface Waters for Southern San Diego Bay

3.1.2.2 Secondary Indicators

Secondary indicators for the 2013 RHMP water chemistry included dissolved and total zinc and nickel, which are discussed below.

Zinc
At all sample stations, concentrations of dissolved and total zinc were well below acute threshold values of 90 and 95 µg/L, respectively. Concentrations at all sample stations were also below the dissolved marine chronic CTR value of 81 µg/L (Figure 3-9). The highest concentrations of zinc were recorded in the marina stratum, and within Dana Point Harbor.

Historically, dissolved and total zinc concentrations exceeded the threshold values at only 1% of the stations. During the 2013 sampling effort, 100% of stations had dissolved and total concentrations below acute threshold values, consistent with the 2008 RHMP and historical conditions (Table 3-4).

As with copper, a comparison of total and dissolved zinc across all samples collected is graphically shown for reference in Appendix F as a QA/QC measure. A consistent pattern was observed among all samples, with total zinc generally exceeding the dissolved fraction, ranging from 0% to 69% across all samples. In the few stations (8) where dissolved exceeded total concentrations, the differences were within 25%, with greater differences associated with the lower concentrations of zinc.

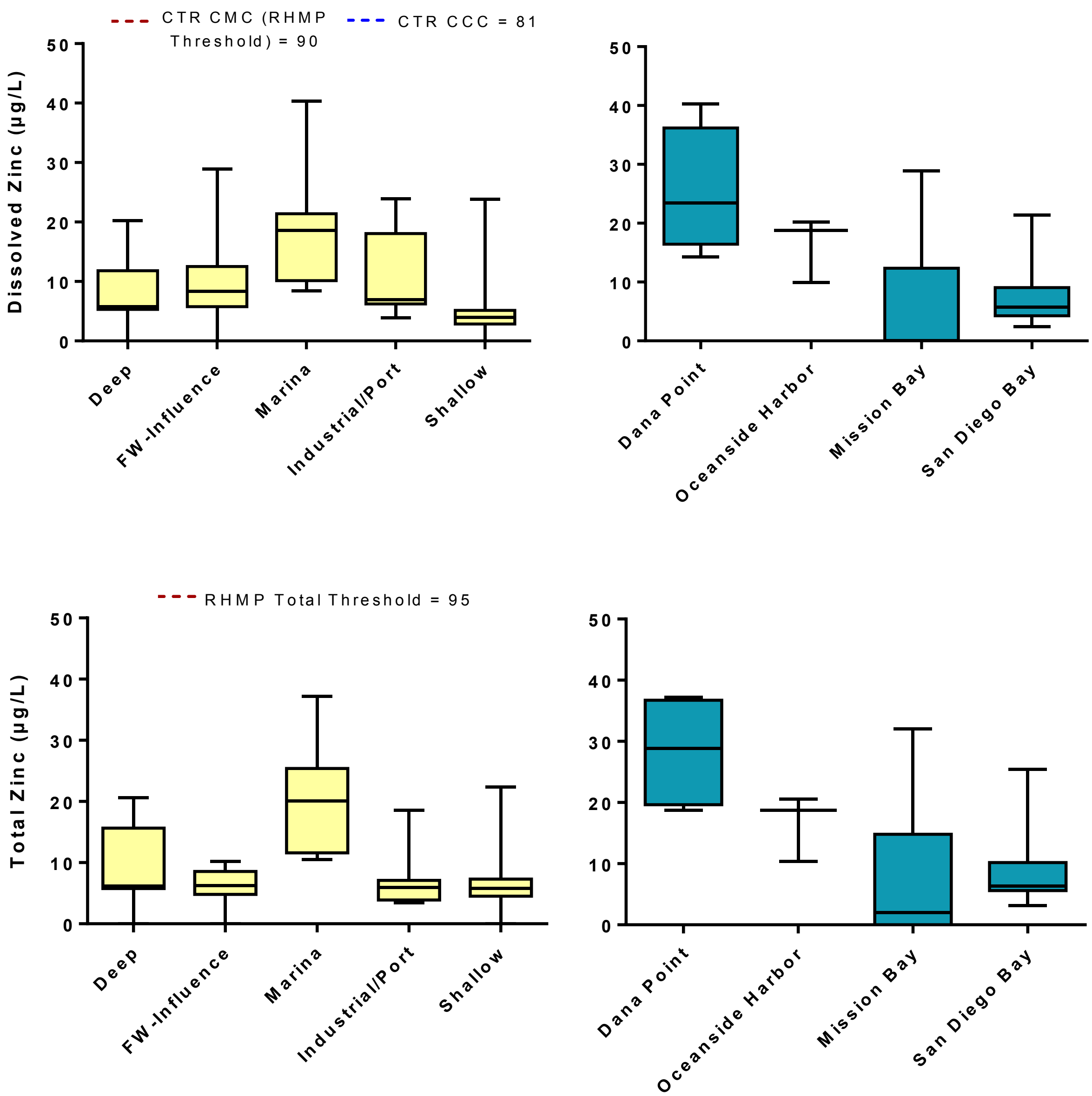

Figure 3-9. Comparisons of Total and Dissolved Zinc Concentrations Among Strata and Harbors in Surface Waters

Box plots showing median, 25th percent quartiles, and range of average values

Nickel

All stations had concentrations of dissolved and total nickel well below threshold values used for RHMP (74 and 75 µg/L, respectively), as well as below the dissolved marine chronic CTR value of 8.2 µg/L. There were no appreciable differences in nickel concentrations among the different strata across all harbors (Figure 3-10).

Pre-set target percentages were 0% for dissolved and total nickel (i.e., no historical stations exceeded acute CTR thresholds). As such, no differences were observed between historical results and present-day conditions for dissolved and total nickel when using this threshold methodology (Table 3-4).

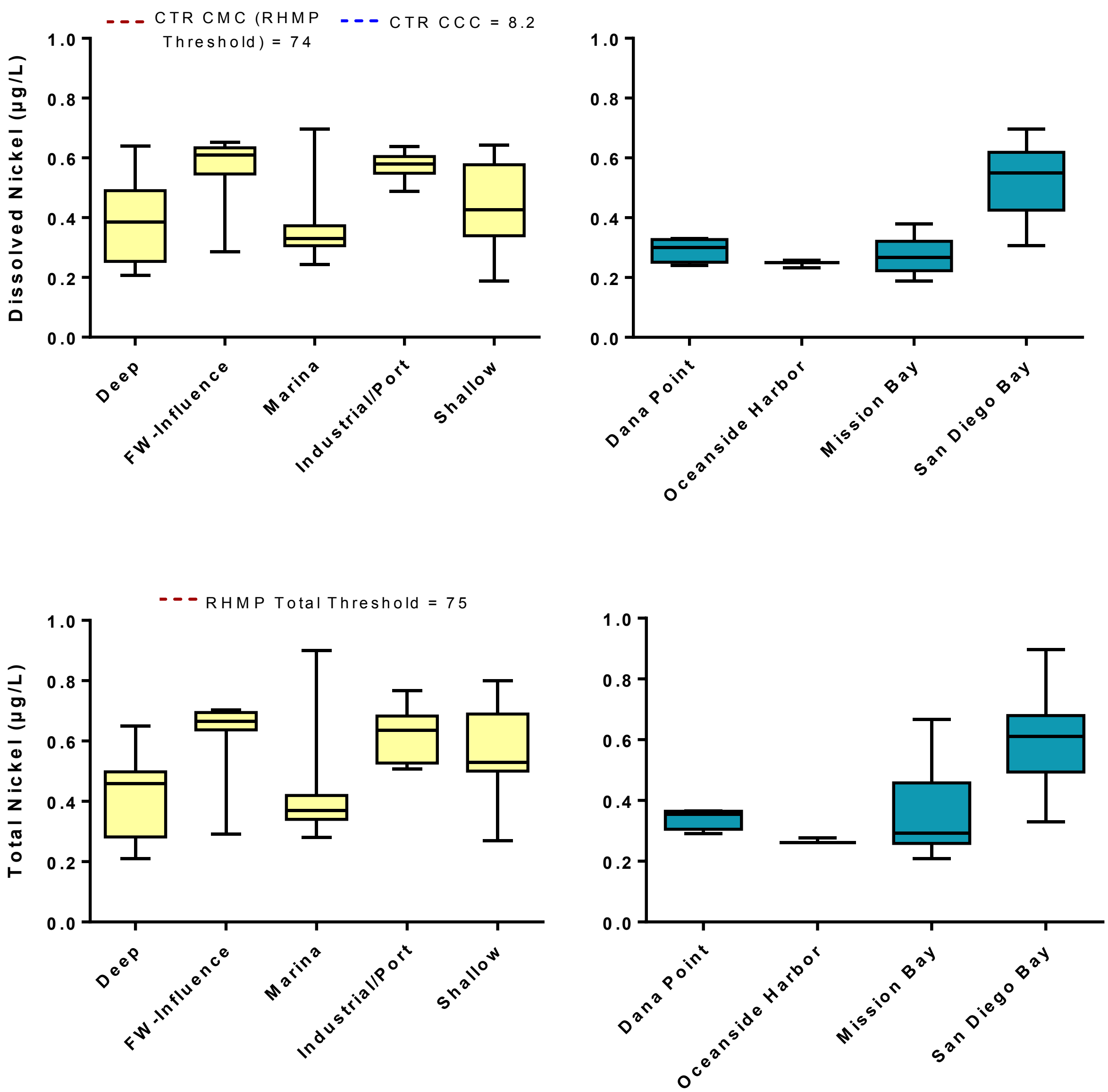

Figure 3-10. Comparisons of Total and Dissolved Nickel Concentrations Among Strata and Harbors in Surface Waters

Box plots showing median, 25th percent quartiles, and range of average values

3.1.2.3 Other Contaminants of Concern in Surface Waters

Other Dissolved and Total Metals

All other dissolved and total metals had concentrations below their respective acute and chronic CTR values among all harbors and strata (see Appendix F).

Total PAHs

Total PAH concentrations varied substantially among stations (Figure 3-11). A single outlier value was noted in a marina stratum station (Mission Bay Station B13-8146 within Quivira Basin). This station had a total PAH concentration of 223 nanograms per liter (ng/L) relative to <50 ng/L for most other stations region-wide.

Although PAHs were detected in surface waters within the harbors, summed and individual PAH concentrations were all below currently available threshold values for the protection of aquatic life referenced in the latest USEPA ecological risk guidelines for the mid-Atlantic (http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/marine/screenbench.htm, 2015) and the latest Canadian Environmental Protection Division Guidelines (http://www.env.gov.bc.ca/wat/wq/BCguidelines/pahs/pahs_over.html, 1981) (see Appendix F). Widely accepted aquatic wildlife criteria for total PAHs are not currently available for Region 9.

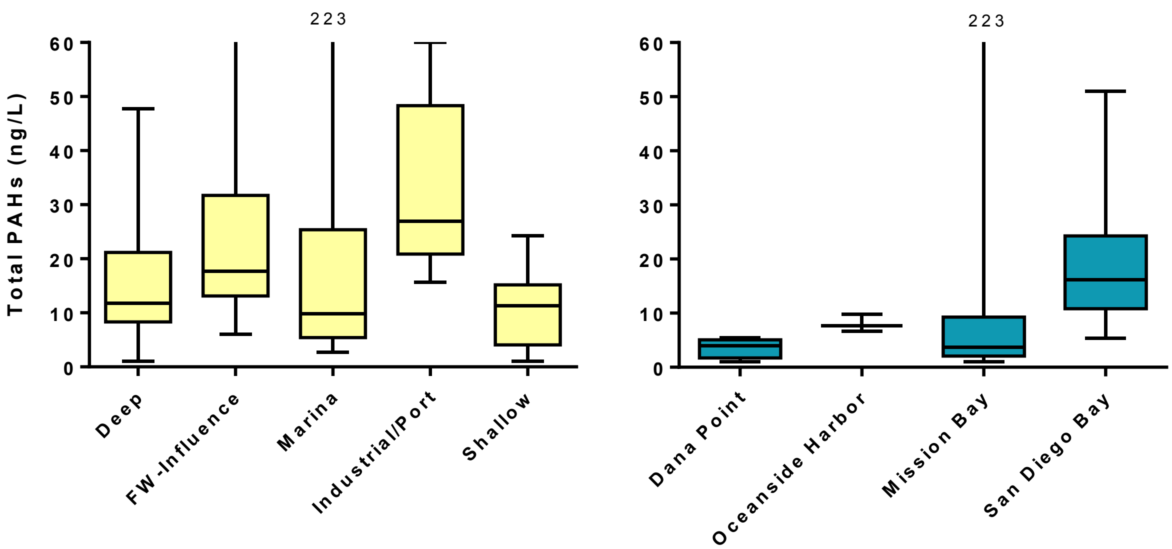

Figure 3-11. Comparison of Total PAHs Among Strata and Harbors in Surface Waters

Box plots showing median, 25th percent quartiles, and range of average values

General Chemistry
Results for general chemistry parameters of ammonia, nitrate, DOC, TOC, methylene blue MBAS, O&G, and total orthophosphate as P were relatively consistent with limited variability across all strata and harbors (Table 3-3, Appendix F). A brief summary of results follows. Mean ammonia and nitrate concentrations across all harbors and strata were 0.03 $\pm$ 0.03 milligrams per liter (mg/L) and 0.01 $\pm$ 0.00 mg/L, respectively. Mean DOC concentrations ranged from 0.54 $\pm$ 0.02 mg/L in the deep stratum to 0.99 $\pm$ 0.01 mg/L in the freshwater-influenced stratum, and mean TOC concentrations ranged from 0.54 $\pm$ 0.03 mg/L in the deep stratum to 2.33 $\pm$ 0.89 mg/L in the industrial/port stratum. Mean MBAS concentrations across all strata were 0.03 $\pm$ 0.02 mg/L, total orthophosphate as P mean concentrations were 0.03 $\pm$ 0.01 mg/L across all strata, while O&G was <1.0 mg/L at every station across strata.

3.2 Sediment Quality

The overall quality of surface sediment was evaluated using a MLOE technique, as provided by the *Water Quality Control Plan for Enclosed Bays and Estuaries—Part 1, Sediment Quality* (SWRCB and Cal/EPA, 2009) and updated SQO guidance provided in Bay et al. (2014). Sediment samples were tested for multiple indicators known as individual LOEs. LOEs included chemistry, toxicity, and benthic community condition to measure contaminant exposure and the potential effects on organisms.

The integration of these three LOEs constitutes the sediment quality triad (Long and Chapman, 1985), which provides a better understanding of surface sediment conditions and ecological health. Section 2.3.2 provides more details on the integrated SQO LOEs.

3.2.1 Sediment Chemistry

Sediment samples from each station were analyzed for trace metals, SEM-AVS, organic compounds (including PAHs, PCB congeners, organochlorine pesticides, pyrethroid insecticides, and PBDEs), total organic carbon, and total organic nitrogen. A comprehensive list of analytes submitted for analysis and associated reporting limits (RLs) and method detection limits (MDLs) is provided in Appendix B.

3.2.1.1 Sediment Chemistry Indicators

Sediment chemistry indicators (including several trace metals and organic compounds) were compared with the ER-L and effects ER-M screening guideline values. For this project, threshold values for most of the secondary constituents were set at the ER-L value, except for sediment copper[10].

During the 2013 RHMP, the majority of stations (93%) had one or more ER-L exceedances for the applicable constituents. This is an improvement from the 2008 study period, when 100% of stations had at least one ER-L exceedance. Table 3-6 compares the percentage of stations with at least one ER-L exceedance per stratum during 2008 and 2013.

[10] The threshold value for sediment copper was set at 175 mg/kg to compensate for naturally occurring deposition. This is known as the ambient threshold limit (ATL) in RHMP studies.

Table 3-6.
Percentage of Stations with at Least One ER-L Exceedance by Stratum in RHMP 2008 and 2013

Study	Percentage of Stations with at Least One ER-L Exceedance by Stratum					Total
	Deep (%)	Freshwater-Influenced (%)	Marina (%)	Industrial/Port (%)	Shallow (%)	
2008 RHMP	100	100	100	100	100	100
2013 RHMP	94	93	100	100	80	93

Figures 3-12a through 3-12f display the spatial distribution of ER-L exceedances. Stations with a greater number of ER-L exceedances were generally located in the industrial/port stratum, followed by the marina stratum.

Figure 3-12a. Spatial Distribution of ER-L Exceedances per Station in Dana Point Harbor

Figure 3-12b. Spatial Distribution of ER-L Exceedances per Station in Oceanside Harbor

Figure 3-12c. Spatial Distribution of ER-L Exceedances per Station in Mission Bay

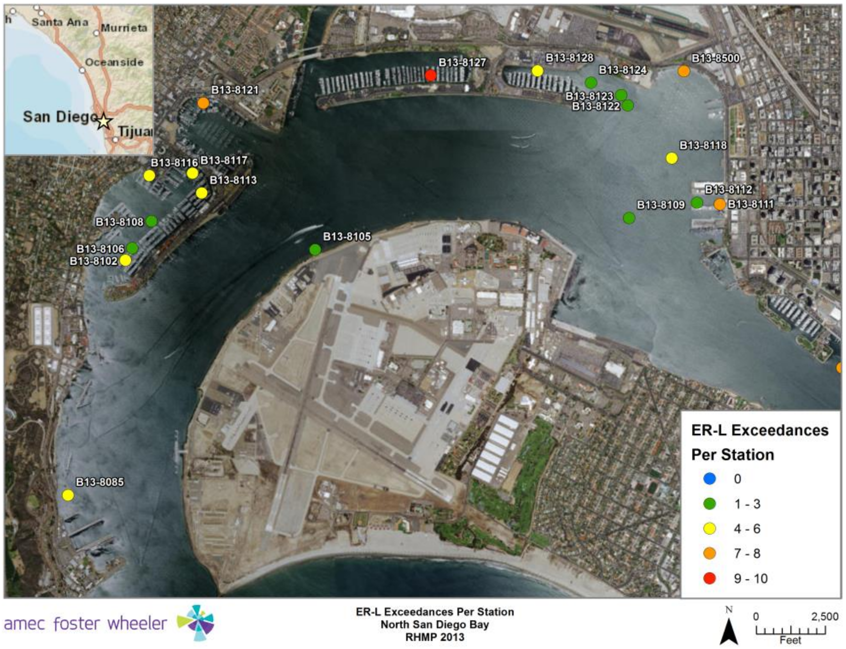

Figure 3-12d. Spatial Distribution of ER-L Exceedances per Station in Northern San Diego Bay

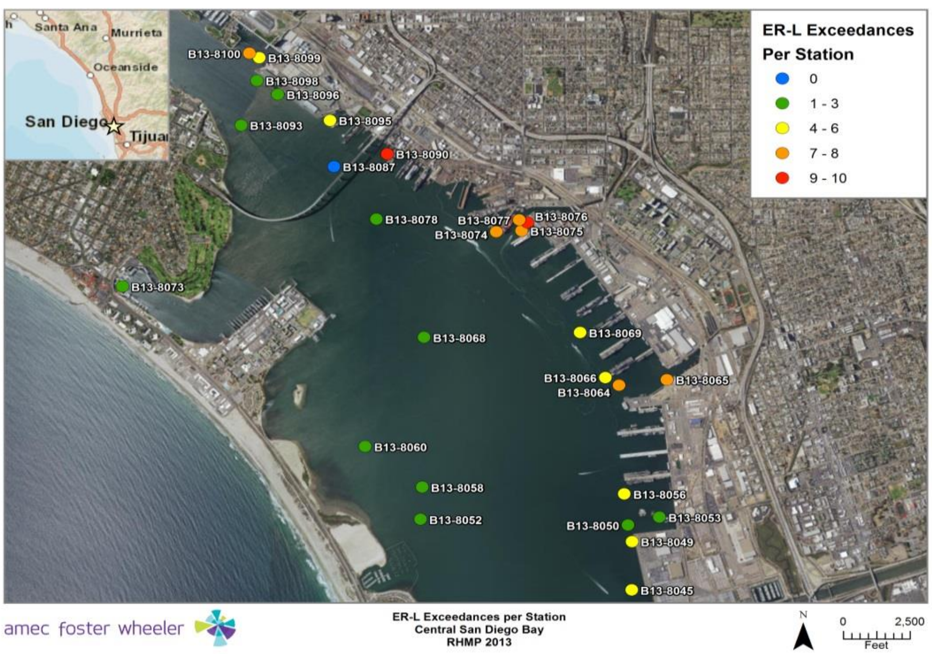

Figure 3-12e. Spatial Distribution of ER-L Exceedances per Station in Central San Diego Bay

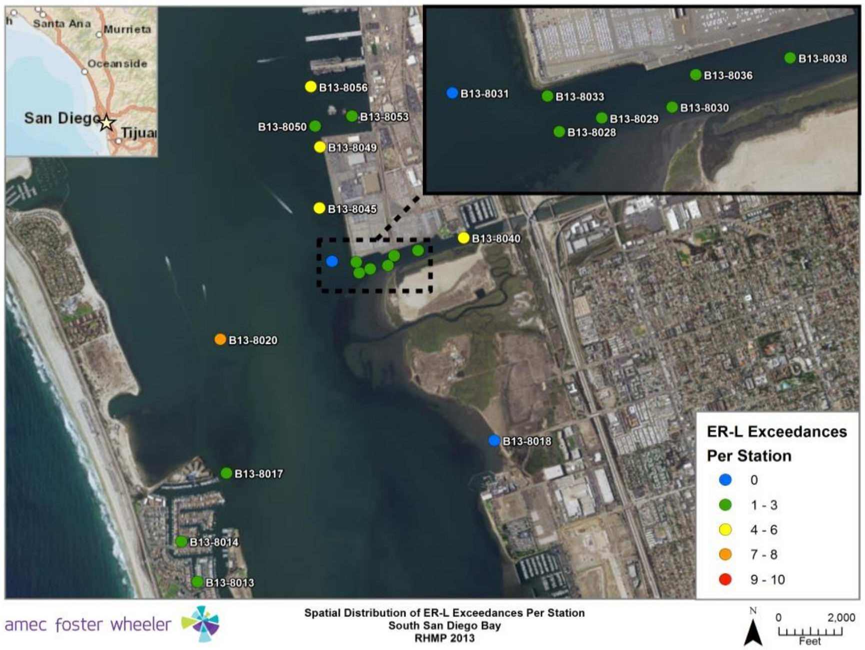

Figure 3-12f. Spatial Distribution of ER-L Exceedances per Station in Southern San Diego Bay

During the 2013 RHMP, 20% of stations had one or more ER-M exceedances, an improvement from the 2008 RHMP when 27% of stations had one or more ER-M exceedances. Table 3-7 compares the percentage of stations with at least one ER-M exceedance per stratum between 2008 and 2013.

Table 3-7.
Percentage of Stations with at Least One ER-M Exceedance by Stratum in RHMP 2008 and 2013

Study	Count of ER-M Exceedances by Stratum					Total
	Deep (%)	Freshwater-Influenced (%)	Marina (%)	Industrial/Port (%)	Shallow (%)	
2008 RHMP	27	20	44	33	7	27
2013 RHMP	6	20	67	7	0	20

Figures 3-13a through 3-13f display the spatial distribution of ER-M exceedances throughout the harbors. Similar to the ER-L exceedances, the greatest number of ER-M exceedances occurred within the marina stratum, followed by the industrial/port stratum.

Raw sediment chemistry results are provided in Table 3-8. A summary of results across strata showing the percentage of stations with results exceeding threshold values for individual sediment chemistry indicators is provided in Table 3-9. Results are compared between 2008 and 2013 and the historical baseline exceedance frequency. The results for sediment are detailed further below.

Figure 3-13a. Spatial Distribution of ER-M Exceedances per Station in Dana Point Harbor

Figure 3-13b. Spatial Distribution of ER-M Exceedances per Station in Oceanside Harbor

Figure 3-13c. Spatial Distribution of ER-M Exceedances per Station in Mission Bay

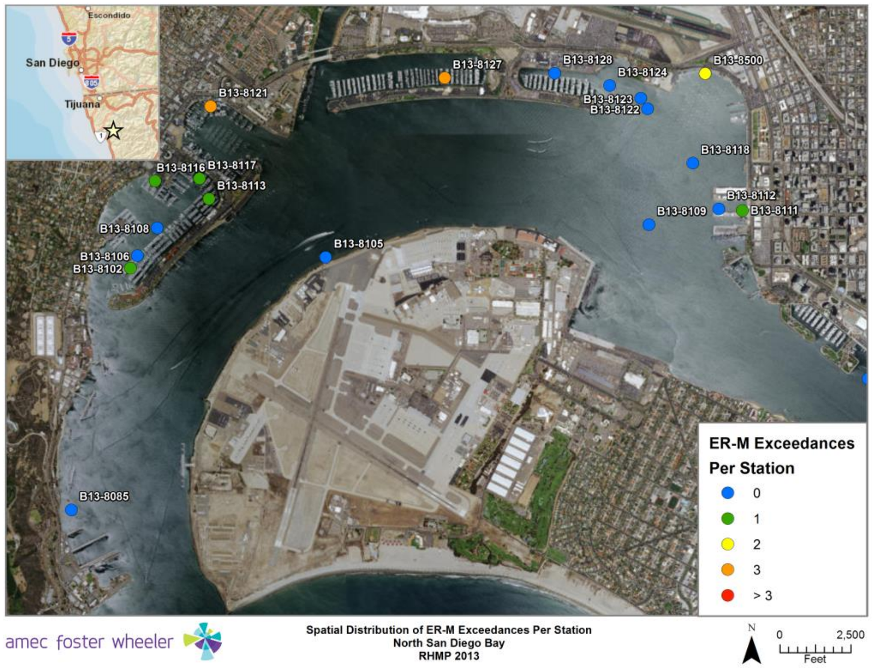

Figure 3-13d. Spatial Distribution of ER-M Exceedances per Station in Northern San Diego Bay

Figure 3-13e. Spatial Distribution of ER-M Exceedances per Station in Central San Diego Bay

Figure 3-13f. Spatial Distribution of ER-M Exceedances per Station in Southern San Diego Bay

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Table 3-8.
RHMP 2013 Sediment Chemistry Summary

			General Chemistry				AVS-SEM Values and Calculations										Metals (mg/kg)															
Harbor	Strata	Station ID	Ammonia-N (mg/kg)	Percent Solids (%)	Total Nitrogen (%)	Total Organic Carbon (%)	Acid Volatile Sulfides (mg/kg)	Acid Volatile Sulfides (umol/dry g)	Sum of SEM (umol/dry g)	SEM:AVS Ratio	SEM:AVS Ratio norm. to fOC	CSI Score	CSI Category	ER-L Exceedances	ER-M Exceedances	Mean ER-M Quotient	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Copper	Iron	Lead	Mercury	Nickel	Selenium	Silver	Phosphorus	Zinc
ER-L			--	--	--	--	--					--	--	--	--	--	--	--	8.20	--	--	1.20	81.0	34.0	--	46.7	0.15	20.9	--	1.00	--	150
ER-M			--	--	--	--	--					--	--	--	--	--	--	--	70.0	--	--	9.60	370	270	--	218	0.71	51.6	--	3.70	--	410
Dana Point Harbor	Marina	B13-8259	2.31	46.7	0.11	1.31	59.1	1.84	3.26	1.77	108	1.71	Low Exposure	3	1	0.19	28164	0.30	9.73	219	0.66	0.20	51.6	293	24258	17.9	0.07	16.7	0.63	0.14	762	225
	Deep	B13-8263	3.18	61.2	0.03	1.63	58.1	1.81	0.70	0.38	-68.4	1.05	Minimal Exposure	1	0	0.07	12028	0.21	4.57	81.1	0.29	0.38	34.3	37.4	12887	8.25	0.02	15.0	0.35	0.07	606	73.5
	Shallow	B13-8265	1.78	55.6	0.05	1.72	103	3.21	1.67	0.52	-89.5	1.55	Minimal Exposure	2	0	0.12	20313	0.29	7.76	141	0.47	0.27	49.8	113	17697	10.7	0.03	17.4	0.84	0.14	968	120
	Marina	B13-8267	4.22	40.9	0.12	2.59	173	5.40	3.56	0.66	-71.1	1.98	Low Exposure	6	1	0.28	32302	0.48	12.0	188	0.75	0.35	67.3	402	27688	27.0	0.07	22.7	0.66	0.22	935	275
Oceanside Harbor	Marina	B13-8233	3.95	44.0	0.13	2.72	175	5.45	4.31	0.79	-41.9	1.76	Low Exposure	6	1	0.28	41528	0.37	12.4	165	0.77	0.27	65.9	364	42546	22.4	0.32	23.9	0.44	0.22	977	317
	Deep	B13-8236	4.36	49.2	0.08	2.49	74.9	2.33	2.07	0.88	-10.8	1.60	Minimal Exposure	3	0	0.16	35385	0.26	9.41	150	0.63	0.25	55.0	145	35802	14.8	0.15	20.3	0.33	0.12	729	185
	Deep	B13-8239	6.26	51.5	0.08	2.11	405	12.6	0.54	0.04	-573	1.05	Minimal Exposure	1	0	0.09	21140	0.18	6.83	135	0.43	0.27	41.6	46.2	26811	7.89	0.03	16.9	0.33	0.06	574	106
Mission Bay	Deep	B13-8145	5.41	57.7	0.06	1.31	32.0	1.00	1.33	1.34	25.5	1.53	Minimal Exposure	2	0	0.11	15663	0.20	5.83	67.0	0.30	0.15	26.2	105	18608	13.4	0.11	7.72	0.29	0.10	732	91.7
	Marina	B13-8146	2.97	53.0	0.12	1.61	8.09	0.25	3.61	14.3	209	1.76	Low Exposure	3	1	0.19	20272	0.28	7.26	72.5	0.39	0.36	32.7	132	21032	19.6	0.19	9.22	0.41	0.15	893	486
	Marina	B13-8151	7.46	31.9	< 0.01	1.00	100	3.11	1.51	0.48	-161	1.70	Low Exposure	4	0	0.14	30565	0.37	9.81	114	0.59	0.25	50.9	102	32936	28.1	0.18	15.6	0.64	0.19	706	160
	Deep	B13-8152	1.87	76.1	0.04	2.99	0.08 J	0.00	0.08	31.4	2.5	1.20	Minimal Exposure	1	0	0.03	2830	0.04	1.37	13.1	0.05 J	0.02	4.88	1.84	3441	1.96	0.00	1.14	0.03 J	< 0.01	172	10.2
	Shallow	B13-8156	5.70	41.2	0.53	6.39	24.4	0.76	0.76	1.00	0.0	1.03	Minimal Exposure	0	0	0.08	19157	0.16	6.63	90.1	0.39	0.23	37.5	31.6	24942	15.7	0.08	11.1	0.35	0.14	563	89.8
	Shallow	B13-8157	5.86	47.3	0.09	2.09	180	5.62	0.67	0.12	-237	1.00	Minimal Exposure	0	0	0.08	32719	0.23	8.20	121	0.58	0.20	44.1	28.4	31320	17.6	0.05	12.8	0.28	0.12	588	98.8
	Shallow	B13-8159	6.08	30.9	0.14	2.42	190	5.93	1.14	0.19	-198	1.31	Minimal Exposure	3	0	0.13	52121	0.50	16.3	120	1.18	0.24	55.8	48.4	44488	42.8	0.08	19.3	0.51	0.22	803	152
	Freshwater-Influence	B13-8160	9.62	34.7	0.10	2.10	86	2.68	1.19	0.44	-71.0	1.31	Minimal Exposure	2	0	0.11	30271	0.44	13.8	93.3	0.85	0.30	41.7	42.7	34072	36.5	0.08	14.8	0.51	0.21	748	145
	Freshwater-Influence	B13-8163	7.87	45.6	0.12	2.24	137	4.29	1.20	0.28	-138	1.74	Low Exposure	4	0	0.15	27114	0.63	10.2	97.3	0.82	0.33	28.9	34.6	24265	27.4	0.06	11.2	0.51	0.13	537	133
San Diego Bay North	Deep	B13-8085	9.07	42.2	0.11	2.26	570	17.76	0.87	0.05	-748	1.42	Minimal Exposure	4	0	0.15	27355	0.33	9.86	108	0.51	0.48	47.7	81.7	30817	21.6	0.22	17.4	0.57	0.58	788	157
	Marina	B13-8102	5.56	44.9	< 0.01	1.52	24.1	0.75	2.70	3.59	128	2.04	Low Exposure	4	1	0.27	32515	0.30	10.8	107	0.58	0.36	58.1	197	33519	34.2	0.76	16.4	0.43	0.72	746	237
	Shallow	B13-8105	2.66	68.7	< 0.01	0.02	22.3	0.70	0.57	0.82	-613	1.26	Minimal Exposure	2	0	0.11	11845	0.30	3.26	45.5	0.18	0.24	25.1	39.2	11184	14.7	0.11	6.15	0.11	0.33	297	70.1
	Marina	B13-8106	2.89	60.5	0.01	0.67	12.0	0.37	1.68	4.48	195	1.72	Low Exposure	2	0	0.16	16892	0.16	6.39	59.8	0.31	0.17	31.8	104	19483	20.2	0.46	8.91	0.17	0.38	447	134
	Deep	B13-8108	1.57	65.6	< 0.01	0.34	5.16	0.16	1.16	7.20	293	1.27	Minimal Exposure	2	0	0.12	12500	0.14	5.10	35.5	0.22	0.12	21.9	69.9	12636	14.3	0.47	5.68	0.11	0.28	337	83.1
	Deep	B13-8109	0.48	64.7	0.31	0.50	5.96	0.19	1.06	5.71	175	1.05	Minimal Exposure	2	0	0.10	14475	0.17	5.51	51.9	0.29	0.12	27.2	46.0	16031	20.6	0.23	7.22	0.15	0.35	313	92.5
	Deep	B13-8111	3.12	42.8	0.28	1.30	7.42	0.23	2.96	12.8	210	2.16	Low Exposure	7	1	0.37	44068	0.44	14.7	135	0.80	0.26	77.9	147	40012	49.2	1.19	20.5	0.43	1.02	837	240
	Deep	B13-8112	5.20	53.8	< 0.01	1.00	19.4	0.61	1.39	2.30	78.7	1.52	Minimal Exposure	2	0	0.15	27654	0.33	7.78	103	0.47	0.14	42.5	72.6	24583	24.8	0.36	11.9	0.22	0.61	474	132
	Marina	B13-8113	1.31	51.8	0.07	0.70	1.46	0.05	2.59	56.8	363	1.84	Low Exposure	4	1	0.30	30384	0.27	10.8	103	0.54	0.13	48.2	171	32261	27.3	1.33	13.1	0.21	0.40	537	183
	Marina	B13-8116	1.55	67.6	0.24	0.16	2.87	0.09	2.15	24.0	1287	2.39	Moderate Exposure	5	1	0.26	12989	0.35	5.08	136	0.23	0.09	21.8	137	13878	29.7	0.84	5.98	0.13	0.30	269	123
	Marina	B13-8117	1.26	43.5	0.29	0.99	1.27	0.04	3.56	89.9	356	2.00	Low Exposure	4	1	0.42	42692	0.28	16.8	113	0.72	0.16	72.1	236	44681	43.9	1.93	18.1	0.35	0.53	827	257
	Deep	B13-8118	0.47	54.0	0.48	1.09	4.29	0.13	2.21	16.5	191	1.77	Low Exposure	4	0	0.21	31357	0.33	11.2	98.8	0.55	0.18	55.5	99.1	31527	36.0	0.62	14.6	0.26	0.64	666	169
	Marina	B13-8121	1.64	49.7	0.06	1.34	3.80	0.12	3.97	33.5	287	2.66	Moderate Exposure	8	3	0.82	34658	0.63	15.3	119	0.59	0.22	66.2	296	33104	84.4	3.55	15.7	0.30	0.76	705	257
	Deep	B13-8122	0.26	69.8	0.22	0.30	4.61	0.14	0.86	6.01	240	1.05	Minimal Exposure	1	0	0.08	14145	0.11	4.34	70.9	0.19	0.14	28.2	32.1	14983	12.0	0.17	6.19	0.10	0.27	277	80.9
	Shallow	B13-8123	1.62	67.8	< 0.01	0.22	2.71	0.08	0.90	10.6	369	1.05	Minimal Exposure	2	0	0.10	17781	0.17	5.82	70.3	0.25	0.13	34.1	42.7	16825	18.9	0.24	7.26	0.14	0.42	384	95.0
	Shallow	B13-8124	1.62	64.7	< 0.01	0.40	5.70	0.18	1.02	5.75	211	1.14	Minimal Exposure	2	0	0.11	18916	0.19	5.59	80.3	0.27	0.16	38.0	48.1	17806	18.7	0.24	8.02	0.11	0.45	383	106
	Marina	B13-8127	6.16	37.4	0.30	1.82	87.4	2.73	4.00	1.47	70.1	2.24	Low Exposure	9	3	0.42	62749	0.43	18.3	165	1.08	0.29	121	382	57535	69.6	0.77	27.2	0.48	1.11	986	431
	Shallow	B13-8128	1.56	52.0	0.05	0.91	10.1	0.31	2.60	8.29	251	2.09	Low Exposure	6	0	0.24	36031	0.27	9.85	145	0.56	0.17	88.4	134	33075	37.2	0.50	15.5	0.22	0.67	565	226
	Freshwater-Influence	B13-8500	2.32	61.8	0.35	1.64	32.3	1.01	1.02	1.02	1.0	2.57	Moderate Exposure	7	2	0.72	17403	0.41	6.10	60.9	0.35	0.43	36.6	62.7	16509	50.4	0.21	10.4	0.20	0.73	471	182
San Diego Bay Central	Deep	B13-8045	0.49	47.9	0.45	0.93	17.2	0.54	1.90	3.55	147	1.55	Minimal Exposure	4	0	0.16	38437	0.27	9.03	100	0.61	0.20	50.4	130	34117	24.7	0.22	14.1	0.29	0.54	488	164
	Industrial/Port	B13-8049	13.3	43.1	0.07	1.22	64.4	2.01	2.73	1.36	59	1.95	Low Exposure	4	0	0.22	43380	0.36	10.3	94.6	0.77	0.19	62.4	173	38324	37.1	0.38	16.9	0.40	0.72	593	216
	Industrial/Port	B13-8050	4.03	54.3	0.01	1.61	16.5	0.52	2.14	4.15	101	1.70	Low Exposure	3	0	0.15	29117	0.26	7.04	67.9	0.52	0.14	43.8	110	27413	27.3	0.31	12.2	0.27	0.52	438	151
	Shallow	B13-8052	5.14	60.8	0.33	0.58	17.1	0.53	1.52	2.86	171	1.38	Minimal Exposure	2	0	0.12	21562	0.16	6.56	41.6	0.38	0.11	35.6	60.4	19661	21.6	0.29	8.70	0.14	0.60	381	128
	Industrial/Port	B13-8053	0.87	69.3	< 0.01	0.41	22.2	0.69	0.64	0.92	-13.6	1.00	Minimal Exposure	1	0	0.07	20135	0.14	3.36	118	0.28	0.09	26.9	48.8	21362	9.06	0.09	8.92	0.11	0.38	246	83.8
	Industrial/Port	B13-8056	6.85	43.9	0.06	1.86	4.58	0.14	3.12	21.8	160	2.07	Low Exposure	5	0	0.23	43659	0.45	9.35	101	0.78	0.24	63.8	148	38458	38.0	0.43	17.2	0.42	0.81	598	226
	Shallow	B13-8058	0.39	62.8	0.34	0.47	5.66	0.18	1.33	7.51	245	1.05	Minimal Exposure	2	0	0.10	17641	0.15	5.49	45.8	0.30	0.14	29.5	51.6	16906	17.6	0.24	7.35	0.13	0.58	327	106
	Shallow	B13-8060	5.52	59.0	0.35	1.44	7.61	0.24	1.55	6.53	91.1	1.38	Minimal Exposure	2	0	0.14	24385	0.22	6.96	55.7	0.45	0.16	40.2	63.3	21220	22.5	0.34	10.1	0.15	0.68	394	133
	Industrial/Port	B13-8064	3.34	41.3	0.07	1.53	93.4	2.91	3.17	1.09	16.9	2.00	Low Exposure	8	0	0.30	52326	0.61	11.3	133	0.89	0.26	82.9	202	45772	58.1	0.69	21.7	0.46	1.09	698	262
	Industrial/Port	B13-8065	4.43	44.6	0.23	2.62	12.1	0.38	3.92	10.4	135	2.27	Low Exposure	8	0	0.33	45137	1.14	11.7	132	0.77	0.47	82.4	242	41879	73.2	0.64	19.0	0.47	1.12	777	355
	Industrial/Port	B13-8066	5.10	43.0	0.06	1.93	25.1	0.78	3.52	4.50	142	2.00	Low Exposure	5	0	0.27	48585	0.68	10.8	117	0.84	0.25	76.0	177	42906	51.0	0.67	19.8	0.40	0.99	698	241
	Shallow	B13-8068	0.33	70.5	0.34	0.27	8.67	0.27	0.86	3.19	219	1.05	Minimal Exposure	1	0	0.07	9917	0.15	3.82	26.3	0.16	0.12	17.0	33.7	8920	12.4	0.16	4.06	0.10	0.39	212	70.9
	Industrial/Port	B13-8069	2.69	47.2	0.04	1.46	6.13	0.19	3.83	20.0	249	1.93	Low Exposure	5	0	0.26	35634	0.53	9.80	90.5	0.59	0.26	58.7	145	32108	41.7	0.66	15.3	0.35	0.94	576	194
	Marina	B13-8073	0.39	68.6	0.25	0.99	87.6	2.73	1.31	0.48	-143	1.22	Minimal Exposure	2	0	0.10	9765	0.17	3.97	22.0	0.17	0.17	18.0	65.3	9221	16.4	0.29	4.25	0.09	0.28	190	96.6
	Freshwater-Influence	B13-8074	3.10	44.7	0.04	1.66	10.7	0.33	2.93	8.76	156	2.60	Moderate Exposure	8	0	0.37	39344	1.24	12.6	109	0.81	0.38	68.5	187	36675	60.5	0.59	18.2	0.32	0.98	531	337
	Freshwater-Influence	B13-8075	1.89	46.1	0.05	1.99	75.0	2.34	2.77	1.18	21.5	2.81	Moderate Exposure	8	1	0.45	30890	2.01	11.3	103	0.72	0.45	64.0	195	33451	64.4	0.55	18.2	0.35	0.93	514	292
	Freshwater-Influence	B13-8076	7.72	40.3	< 0.01	0.10	63.3	1.97	3.22	1.63	1250	2.58	Moderate Exposure	9	0	0.38	39541	0.81	12.2	107	0.79	0.38	74.5	204	36339	59.1	0.64	19.6	0.45	1.15	705	287
	Freshwater-Influence	B13-8077	1.91	54.3	0.03	1.69	7.11	0.22	2.16	9.74	115	2.74	Moderate Exposure	8	1	0.45	29658	0.91	9.33	105	0.61	0.54	45.4	118	28233	57.3	0.62	13.3	0.32	0.66	394	236
	Deep	B13-8078	4.95	61.3	0.36	0.71	4.68	0.15	1.42	9.70	179	1.38	Minimal Exposure	2	0	0.13	21140	0.22	6.46	56.1	0.39	0.11	36.0	67.7	20457	22.7	0.30	9.26	0.16	0.52	400	121
	Deep	B13-8087	0.24	74.3	0.24	0.57	2.13	0.07	0.52	7.83	79.6	1.00	Minimal Exposure	0	0	0.04	7390	0.16	5.30	19.8	0.14	0.03	12.2	19.4	9900	8.96	0.07	3.29	0.07	0.08	244	44.8
	Industrial/Port	B13-8090	2.01	34.5	0.78	2.43	108	3.35	3.47	1.04	5.0	2.39	Moderate Exposure	10	2	0.69	45467	0.85	15.2	126	0.84	0.50	93.6	268	46494	78.1	0.96	26.8	0.62	1.59	928	350
	Deep	B13-8093	0.36	66.5	0.26	1.50	3.89	0.12	1.06	8.75	62.7	1.05	Minimal Exposure	2	0	0.09	13609	0.21	6.73	37.3	0.26	0.07	26.8	37.8	15443	17.7	0.18	6.11	0.13	0.25	299	97.4
	Industrial/Port	B13-8095	0.81	39.2	0.66	1.78	39.0	1.22	3.31	2.72	117	2.03	Low Exposure	5	0	0.28	42220	0.53	13.0	115	0.77	0.27	79.9	180	40460	56.6	0.67	20.8	0.42	0.97	784	266
	Industrial/Port	B13-8096	0.36	67.5	0.23	0.38	3.83	0.12	0.96	8.02	221	1.05	Minimal Exposure	2	0	0.08	13360	0.22	4.41	41.9	0.24	0.07	22.9	43.5	14014	15.4	0.17	6.06	0.09	0.26	268	74.3
	Industrial/Port	B13-8098	0.31	67.6	0.20	0.84	3.31	0.10	0.80	7.71	82.5	1.08	Minimal Exposure	1	0	0.06	11424	0.18	3.97	30.8	0.20	0.05	19.5	37.4	12119	13.4	0.13	4.93	0.09	0.20	228	61.4
	Industrial/Port	B13-8099	0.59	51.8	0.44	1.14	25.0	0.78	1.79	2.30	89.1	2.01	Low Exposure	4	0	0.19	28818	0.44	8.13	86.4	0.49	0.17	49.2	98.9	29195	34.2	0.41	13.3	0.23	0.58	529	168
	Industrial/Port	B13-8100	0.86	42.1	0.56	1.58	26.0	0.81	4.35	5.37	224	2.23	Low Exposure	7	0	0.29	42172	0.44	12.3	124	0.74	0.27	73.1	158	38790	51.6	0.62	19.0	0.39	0.92	732	239
San Diego Bay South	Marina	B13-8013	3.45	46.3	0.48	1.71	102	3.19	2.95	0.93	-13.9	1.71	Low Exposure	3	0	0.21	34658	0.32	6.96	82.1	0.68	0.20	52.6	209	31583	24.5	0.20	15.5	0.35	0.73	517	288
	Marina	B13-8014	5.00	63.7	0.24	1.03	76.6	2.39	0.88	0.37	-146	1.00	Minimal Exposure	1	0	0.06	15468	0.17	2.89	46.4	0.27	0.16	20.5	45.3	13611	6.83	0.06	6.07	0.10	0.22	326	92.2
	Shallow	B13-8017	3.51	45.0	0.05	1.51	16.6	0.52	2.18	4.23	110	1.38	Minimal Exposure	3	0	0.13	31736	0.29	7.08	55.5	0.52	0.17	40.8	70.1	26185	20.8	0.22	11.4	0.24	0.51	434	161
	Shallow	B13-8018	2.10	73.8	< 0.01	0.14	24.4	0.76	0.36	0.47	-290	1.09	Minimal Exposure	0	0	0.03	5847	0.12	1.93	11.3	0.11	0.15	11.2	11.5	4524	5.01	0.03	2.66	0.09	0.10	104	36.4
	Shallow	B13-8020	10.6	28.5	0.04	1.65	25.8	0.80	4.08	5.08	199	2.00	Low Exposure	8	0	0.31	66619	0.51	14.7	144	1.10	0.35	92.8	163	57144	49.0	0.63	25.0	0.44	1.42	914	343
	Freshwater-Influence	B13-8028	6.70	57.1	0.45	1.25	15.8	0.49	1.43	2.90	74.8	1.38	Minimal Exposure	1	0	0.11	28893	0.22	6.81	85.1	0.47	0.17	36.5	79.2	26888	16.3	0.14	11.5	0.18	0.40	394	135
	Freshwater-Influence	B13-8029	2.70	60.6	< 0.01	1.51	2.52	0.08	1.42	18.1	89.1	1.22	Minimal Exposure	1	0	0.09	24650	0.22	4.95	80.7	0.38	0.18	29.9	63.7	22458	14.0	0.12	9.64	0.22	0.33	297	106
	Freshwater-Influence	B13-8030	4.01	66.1	0.32	0.57	101	3.14	0.84	0.27	-402	1.00	Minimal Exposure	1	0	0.08	22803	0.16	5.47	80.3	0.37	0.15	28.5	51.8	21535	11.2	0.08	9.59	0.14	0.28	298	104
	Freshwater-Influence	B13-8031	0.08	65.8	0.37	1.32	1.30	0.04	0.16	3.86	8.8	1.00	Minimal Exposure	0	0	0.05	30895	0.13	6.81	70.4	0.44	0.11	32.2	17.3	27974	4.73	0.02	11.6	0.15	0.06	288	53.2
	Freshwater-Influence	B13-8033	1.46	47.8	0.49	1.14	88.0	2.74	1.56	0.57	-104	1.55	Minimal Exposure	3	0	0.15	34929	0.29	7.98	92.8	0.57	0.23	46.0	101	32280	23.5	0.18	14.1	0.28	0.52	502	175
	Freshwater-Influence	B13-8036	4.05	60.4	0.26	0.47	129	4.03	1.04	0.26	-635	1.38	Minimal Exposure	1	0	0.10	26430	0.25	6.16	102	0.43	0.21	32.9	68.3	25781	15.1	0.11	10.9	0.26	0.35	351	128
	Freshwater-Influence	B13-8038	8.71	59.3	0.30	0.64	27.2	0.85	1.35	1.59	78.7	1.38	Minimal Exposure	1	0	0.11	28704	0.22	6.80	95.8	0.47	0.22	35.4	67.0	26915	15.4	0.11	11.5	0.22	0.37	410	131
	Freshwater-Influence	B13-8040	8.44	43.3	0.58	1.67	107	3.32	2.58	0.77	-44.8	1.91	Low Exposure	4	0	0.20	50671	0.50	9.66	133	0.91	0.47	58.2	131	44924	34.5	0.18	20.1	0.42	0.67	607	259

Notes:

All values reported in dry weight
-- = No applicable ER-L/ER-M
ug/kg = micrograms per dry kilogram
mg/kg = milligrams per dry kilogram
umol/g = micromoles per gram
< Data reported to the method detection limit
J = estimated result, below the reporting limit, but above the MDL
% = percent

ER-L = Effects Range-Low; ER-M = Effects Range-Median
SQO CSI = Sediment Quality Objective Chemical Score Index
PAH = Polycyclic Aromatic Hydrocarbons
PCB = Polychlorinated Biphenyl
PBDE = Polybrominated diphenyl ethers
1 = The specific compounds comprising the sums of the PAH, PCB, PBDE, and pyrethroid groups are listed in Table 2-3.
2 = Total Detectable DDTs in the sum of 2,4'-DDD, 4,4'-DDD, 2,4'-DDE, 4,4'-DDE, 2,4'-DDT, and 4,4'-DDT
3 = Total Chlordanes in the sum of alpha-chlordane and gamma-chlordane.

amec foster wheeler

Table 3-8.
RHMP 2013 Sediment Chemistry Summary

Harbor	Strata	Station ID	Total PAHs[1] (µg/kg)	Total PCBs[1] (µg/kg)	Pesticides (µg/kg)						Total PBDEs[1] (µg/kg)	% Fines (Silt + Clay)
					2,4'-DDD & 4,4'-DDD	2,4'-DDE & 4,4'-DDE	2,4'-DDT & 4,4'-DDT	Total Detectable DDTs[2]	Total Chlordanes[3] (µg/kg)	Total Pyrethroids[1] (µg/kg)		
ER-L			4022	22.7	--	--	--	1.58	0.50	--	--	--
ER-M			44792	180	--	--	--	46.1	6.00	--	--	--
Dana Point Harbor	Marina	B13-8259	148	1.08	< 0.05	1.07	< 0.05	1.07	< 0.05	< 0.25	1.01	79.0
	Deep	B13-8263	155	< 0.10	< 0.05	1.56	< 0.05	1.56	< 0.05	< 0.25	1.41	60.6
	Shallow	B13-8265	102	1.54	< 0.05	1.80	< 0.05	1.80	< 0.05	0.37	1.85	68.8
	Marina	B13-8267	849	5.55	< 0.05	2.66	< 0.05	2.66	1.20	1.19	0.56	83.5
Oceanside Harbor	Marina	B13-8233	97.3	3.19	< 0.05	1.73	< 0.05	1.73	< 0.05	< 0.25	0.51	79.3
	Deep	B13-8236	77.6	< 0.10	< 0.05	0.63	< 0.05	0.63	< 0.05	< 0.25	0.55	68.9
	Deep	B13-8239	40.3	< 0.10	< 0.05	0.80	< 0.05	0.80	< 0.05	< 0.25	0.46	63.0
Mission Bay	Deep	B13-8145	126	1.90	< 0.05	0.87	< 0.05	0.87	1.16	< 0.25	0.41	44.9
	Marina	B13-8146	397	< 0.10	< 0.05	0.92	< 0.05	0.92	< 0.05	< 0.25	< 0.05	54.1
	Marina	B13-8151	200	3.69	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.76	65.3
	Deep	B13-8152	29.5	< 0.10	< 0.05	0.22	< 0.05	0.22	1.70	< 0.25	0.26	4.28
	Shallow	B13-8156	1322	< 0.10	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.53	66.0
	Shallow	B13-8157	38.8	< 0.10	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.41	54.2
	Shallow	B13-8159	111	< 0.10	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	1.04	87.3
	Freshwater-Influence	B13-8160	70.1	< 0.10	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	1.59	1.09	80.3
	Freshwater-Influence	B13-8163	342	< 0.10	< 0.05	1.76	< 0.05	1.76	4.29	0.780	0.74	60.7
San Diego Bay North	Deep	B13-8085	667	8.79	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.17	68.2
	Marina	B13-8102	1405	15.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.18	80.7
	Shallow	B13-8105	632	103	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.24	22.8
	Marina	B13-8106	679	13.9	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.61	54.8
	Deep	B13-8108	184	8.22	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.13	42.5
	Deep	B13-8109	502	4.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	< 0.05	37.3
	Deep	B13-8111	2926	99.0	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.20	80.9
	Deep	B13-8112	2605	14.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	3.99	60.0
	Marina	B13-8113	292	14.4	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.19	76.9
	Marina	B13-8116	1371	32.7	< 0.05	2.06	< 0.05	2.06	4.01	1.91	1.20	43.4
	Marina	B13-8117	495	17.2	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.67	12.1	84.0
	Deep	B13-8118	716	10.4	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.07 J	65.1
	Marina	B13-8121	4276	411	2.62	5.00	1.13	8.75	< 0.05	< 0.25	13.0	74.0
	Deep	B13-8122	146	9.67	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	< 0.05	18.7
	Shallow	B13-8123	424	10.2	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.130	33.1
	Shallow	B13-8124	401	16.2	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.15	35.3
	Marina	B13-8127	407	26.5	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	7.70	93.9
	Shallow	B13-8128	607	51.4	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	18.1	60.6
	Freshwater-Influence	B13-8500	1644	132	40.8	5.52	< 0.05	46.3	34.1	19.1	31.3	46.0
San Diego Bay Central	Deep	B13-8045	146	1.62	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	8.94	65.3
	Industrial/Port	B13-8049	261	15.2	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	6.09	77.8
	Industrial/Port	B13-8050	208	4.88	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	6.50	61.8
	Shallow	B13-8052	68.9	3.49	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	< 0.05	55.3
	Industrial/Port	B13-8053	141	1.31	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.14	14.0
	Industrial/Port	B13-8056	988	25.7	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	17.3	73.5
	Shallow	B13-8058	96.2	0.79	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	< 0.05	34.1
	Shallow	B13-8060	130	6.73	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.08 J	60.7
	Industrial/Port	B13-8064	431	20.7	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	22.0	85.0
	Industrial/Port	B13-8065	1192	27.3	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.92	26.1	72.8
	Industrial/Port	B13-8066	425	15.6	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	10.0	80.5
	Shallow	B13-8068	60.7	< 0.10	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	< 0.05	18.8
	Industrial/Port	B13-8069	517	63.6	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	11.0	69.5
	Marina	B13-8073	29.8	0.26	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.07 J	27.8
	Freshwater-Influence	B13-8074	846	39.0	< 0.05	2.12	8.33	10.5	3.82	0.55	49.0	76.9
	Freshwater-Influence	B13-8075	1321	46.6	< 0.05	6.81	5.33	12.1	10.5	0.49	58.5	76.4
	Freshwater-Influence	B13-8076	1848	52.8	5.88	1.37	18.8	26.1	1.79	0.55	41.1	74.8
	Freshwater-Influence	B13-8077	1410	55.6	2.05	5.23	10.7	18.0	13.3	< 0.25	31.0	57.2
	Deep	B13-8078	316	9.87	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.06 J	50.4
	Deep	B13-8087	67.2	< 0.10	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.06 J	28.6
	Industrial/Port	B13-8090	3155	685	< 0.05	< 0.05	< 0.05	< 0.05	0.630	< 0.25	< 0.05	77.6
	Deep	B13-8093	176	10.0	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	< 0.05	34.5
	Industrial/Port	B13-8095	868	10.6	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.25	82.5
	Industrial/Port	B13-8096	438	0.40	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.20	35.9
	Industrial/Port	B13-8098	809	1.67	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.15	28.8
	Industrial/Port	B13-8099	1633	12.6	< 0.05	< 0.05	< 0.05	< 0.05	1.12	< 0.25	0.90	64.0
	Industrial/Port	B13-8100	1986	43.5	< 0.05	< 0.05	< 0.05	< 0.05	1.33	< 0.25	1.32	75.3
San Diego Bay South	Marina	B13-8013	449	8.08	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	2.31	0.36	74.2
	Marina	B13-8014	33.4	4.95	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.78	30.5
	Shallow	B13-8017	74.4	5.19	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	2.44	49.8
	Shallow	B13-8018	120	14.2	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	< 0.05	10.5
	Shallow	B13-8020	125	12.6	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	27.0	68.9
	Freshwater-Influence	B13-8028	176	7.55	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.06 J	47.8
	Freshwater-Influence	B13-8029	91.4	7.37	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	7.42	38.8
	Freshwater-Influence	B13-8030	251	4.02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	< 0.05	36.8
	Freshwater-Influence	B13-8031	4.30 J	0.57	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	< 0.05	72.3
	Freshwater-Influence	B13-8033	239	9.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.66	55.7
	Freshwater-Influence	B13-8036	617	4.98	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	14.0	44.0
	Freshwater-Influence	B13-8038	181	6.67	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.25	0.34	50.9
	Freshwater-Influence	B13-8040	204	8.58	< 0.05	0.91	< 0.05	0.91	0.18	< 0.25	0.13	73.3

Notes:

All values reported in dry weight
-- = No applicable ER-L/ER-M
ug/kg = micrograms per dry kilogram
mg/kg = milligrams per dry kilogram
umol/g = micromoles per gram
< Data reported to the method detection limit
J = estimated result, below the reporting limit, but above the MDL
% = percent

ER-L = Effects Range-Low; ER-M = Effects Range-Median
SQO CSI = Sediment Quality Objective Chemical Score Index
PAH = Polycyclic Aromatic Hydrocarbons
PCB = Polychlorinated Biphenyl
PBDE = Polybrominated diphenyl ethers
1 = The specific compounds comprising the sums of the PAH, PCB, PBDE, and pyrethroid groups are listed in Table 2-3.
2 = Total Detectable DDTs in the sum of 2,4'-DDD, 4,4'-DDD, 2,4'-DDE, 4,4'-DDE, 2,4'-DDT, and 4,4'-DDT
3 = Total Chlordanes in the sum of alpha-chlordane and gamma-chlordane.

Table 3-9.
Percentage of Stations with Results Exceeding Threshold Values for Sediment Chemistry Indicators

Indicator	Threshold Values	Pre-set Target (%)[b]	RHMP Data Mean (%)		Stratum (%)				
			2008	2013	Deep (%)	Freshwater-Influenced (%)	Marina (%)	Industrial/Port (%)	Shallow (%)
Number of Stations:			***75***		***16***	***15***	***15***	***14***	***15***
Mean ER-M Quotient[c]	0.2[a]	54	48	36	13	33	60	64	13
Arsenic	8.2 mg/kg	48	43	44	31	47	60	64	20
Cadmium	1.2 mg/kg	8	0	0	0	0	0	0	0
Chromium	81 mg/kg	17	1	8	0	0	7	21	13
Copper	175[d] mg/kg	32	20	21	0	20	53	36	0
Lead	46.7 mg/kg	25	11	20	6	33	13	43	7
Mercury	0.15 mg/kg	74	69	67	62	47	80	86	60
Nickel	20.9 mg/kg	20	3	8	0	0	20	14	7
Zinc	150 mg/kg	55	56	51	31	47	73	79	27
Total PAHs	4,022 µg/kg	21	12	1	0	0	7	0	0
Total Chlordanes	0.5[e] µg/kg	14	11*	17	13	40	13	21	0
Total DDTs	1.58[f] µg/kg	46	21	15	0	40	27	0	7
Total PCBs	22.7 µg/kg	53	37	21	6	33	20	36	13

Notes:
a The ER-M quotient threshold value of 0.2 is a unitless value representing a mean threshold for predicted adverse biological effects (Weston 2005b).
b Pre-set target values derived for the 2008 RHMP effort (Weston, 2005b). Value is the percentage of stations exceeding the historic threshold value.
c The mean ER-M Quotient is a unitless value.
d Historical baseline value for copper was not based on the ER-L, as described in Section 2.3.1.2.
e Historical baseline value for total chlordanes was based on the reporting limit available pre-2008 (2 µg/kg). In the 2013 RHMP, the ER-L is used as the Threshold Value for comparisons between 2008 and 2013.
f Historical baseline value for total DDTs in previous studies was based on the reporting limit available (2 µg/kg). In the 2013 RHMP, the ER-L is used as the Threshold Value for comparisons between 2008 and 2013.
* The available reporting limit for total chlordanes in 2008 was 1 µg/kg, above the current Threshold Value of 0.5 µg/kg.

3.2.1.2 Primary Indicator: Mean ER-M Quotient

The mean ER-M quotient provides an integrated value for a suite of sediment chemistry measurements (Wenning et al., 2005). Given its integrative nature and long history of use, this metric was chosen as the single primary indicator of sediment chemistry exposure potential for the RHMP. The mean ER-M quotient was calculated using concentrations of 13 analytes, listed in Table 2-5. The mean ER-M quotient threshold for predicted adverse biological effects is 0.2 based on a historical review of regional data (Weston, 2005b). In the 2013 RHMP results for 36% of stations exceeded this threshold value, compared to 48% in 2008. This is a considerable improvement from historical conditions, when results from 54% of stations exceeded the threshold value (Figure 3-14).

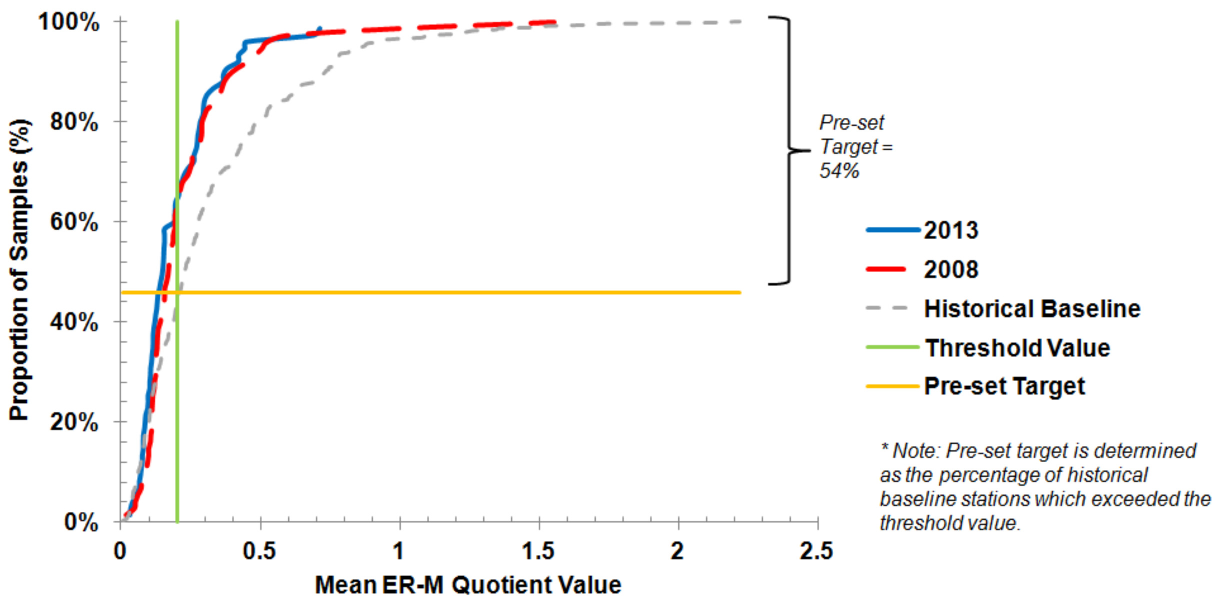


Figure 3-14. Cumulative Distribution Curves for Sediment ER-M Quotients Derived During the 2008 and 2013 RHMP Compared to Historic Data and the Pre-set RHMP Threshold Value

One or more stations had results that exceeded the mean ER-M quotient threshold of 0.2 across all strata; however, the industrial/port stratum had the greatest percentage (64%) of stations with exceedances, followed by the marina stratum (60% of stations). San Diego Bay had the greatest percentage of exceedances out of the four harbors (42%, 25 stations). All harbors had at least one or more stations with threshold exceedances using the mean ER-M quotient, except Mission Bay. Northern San Diego Bay had the station with the highest mean ER-M quotient (Station B13-8121 in the marina stratum located in America's Cup Harbor). Mean ER-M quotients across strata and harbors are graphically depicted in Figure 3-15. Refer to Table F-2 in Appendix F for individual mean ER-M quotient values.

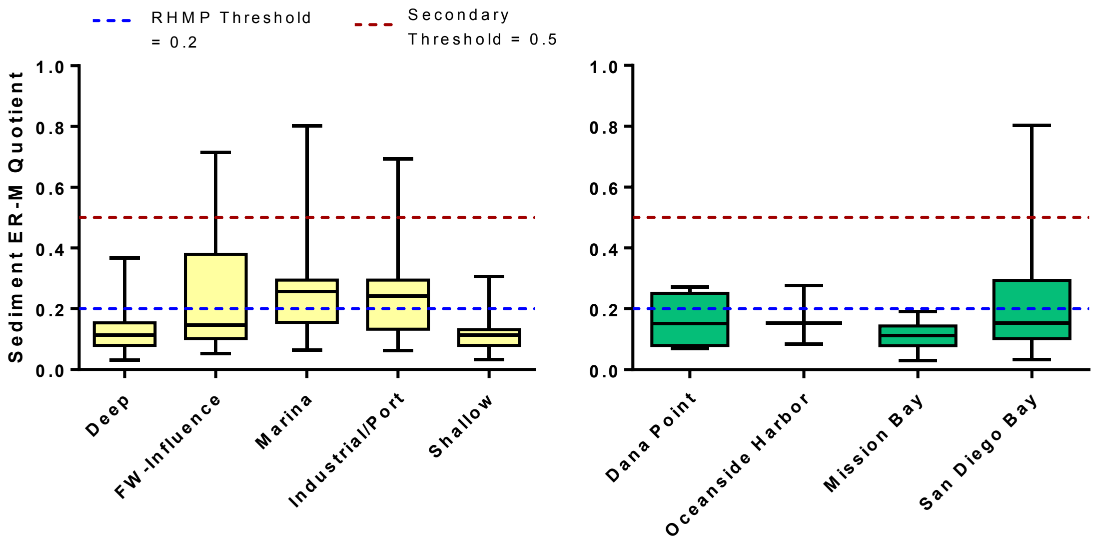


Figure 3-15. Comparisons of ER-M Quotients Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

3.2.1.3 Secondary Indicators

A total of 13 sediment chemistry analytes (listed in Table 2-4) were used to calculate the mean ER-M quotient; all of these chemicals (except silver[11]) were identified as secondary indicators of sediment chemistry conditions. Of these analytes, chemical-specific ER-M exceedances were noted for copper (five stations), mercury (eight stations), zinc (two stations), total PCBs (two stations), and total chlordanes (three stations). Further analyses comparing the differences among strata and harbors and historic conditions are provided below.

Sediment Metals

Arsenic

Arsenic concentrations exceeded the ER-L threshold value of 8.2 mg/kg across all strata and in all harbors; however, no stations had concentrations of arsenic that exceeded the ER-M value of 70 mg/kg. The fraction of total stations with concentrations exceeding the arsenic ER-L threshold value improved slightly between the historical baseline of 48% and the 2013 RHMP percentage of 44%. The fraction of stations exceeding ER-L values in 2008 (43%) was very similar to that observed in 2013. Note that natural background concentrations of arsenic in the San Diego region have also been found to be near or exceed the ER-L value (Harris et al. 2013).

[11] Silver was not identified as a secondary indicator because data were not consistently available to calculate the historical baseline (Weston, 2007).

The range of arsenic concentrations among strata and harbors in 2013 is displayed in Figure 3-16. The marina and industrial/port strata had the highest concentrations of arsenic compared to the other three strata.

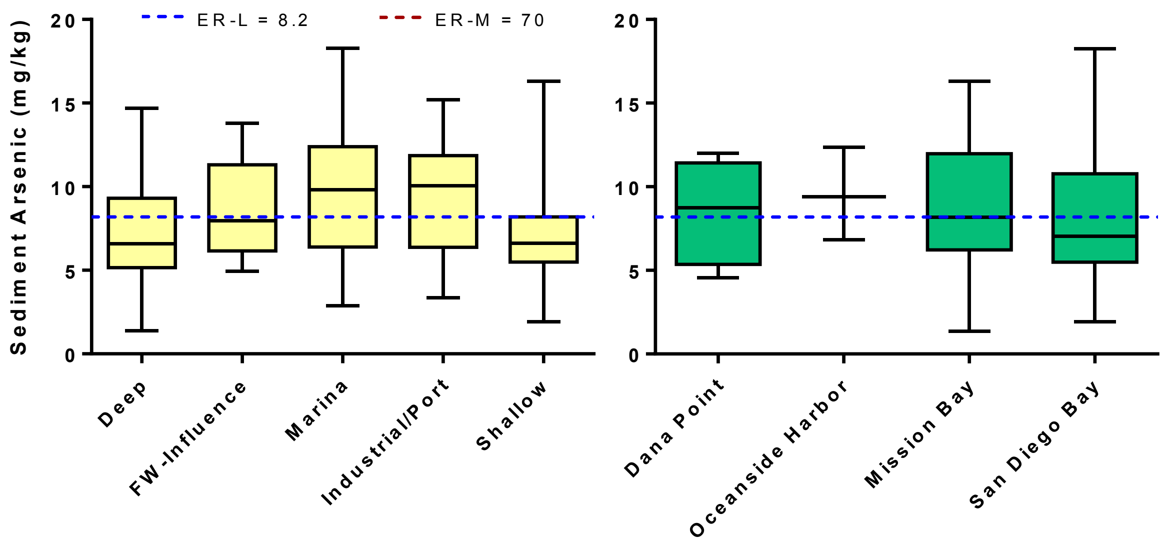


Figure 3-16. Comparisons of Sediment Arsenic Concentrations Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

Cadmium

Cadmium concentrations were below the ER-L threshold value of 1.2 mg/kg at 100% of stations during both the 2008 RHMP and 2013 RHMP. This is an improvement when compared to the historical baseline where 8% of the stations exceeded the ER-L threshold, indicating that conditions regarding cadmium concentrations have improved over time (Table 3-9). The distribution of cadmium among strata and harbors in 2013 is shown in Figure 3-17.

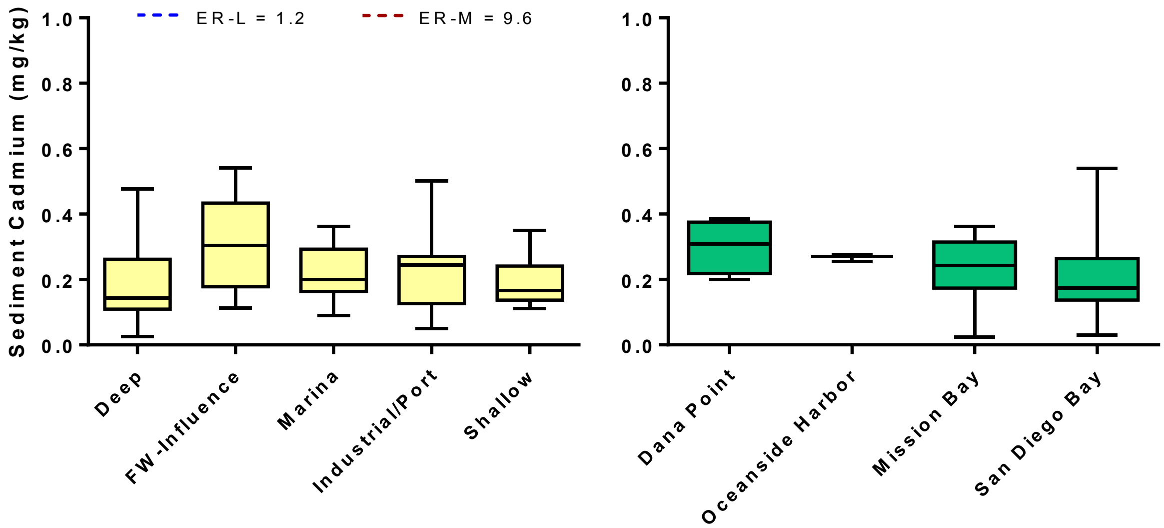


Figure 3-17. Comparisons of Sediment Cadmium Concentrations Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

Chromium

Chromium concentrations exceeded the ER-L threshold of 81.0 mg/kg at six stations (8% of total stations), primarily in the industrial/port strata (three stations) and shallow strata (two stations), all within San Diego Bay (Table 3-9). There were no exceedances of the ER-M value of 370 mg/kg. The percentage of stations with concentrations of chromium below the ER-L threshold value was an improvement over the pre-2008 historical baseline of 17%; however, 2013 had more exceedances than in 2008, when concentrations of chromium at only 1% of stations exceeded the threshold value. The distribution of chromium among strata and harbors in 2013 is displayed in Figure 3-18.

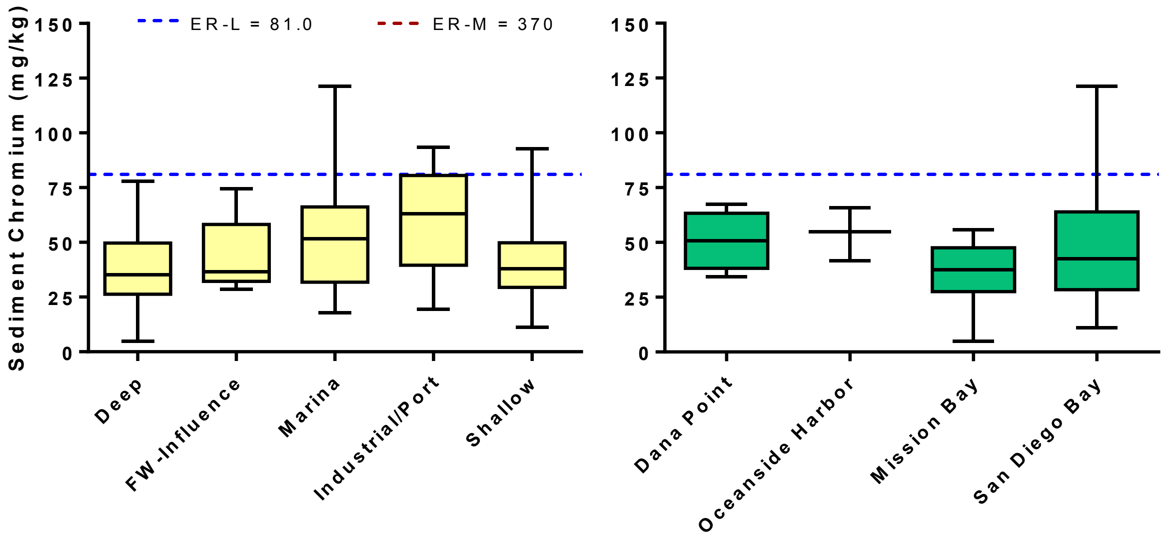


Figure 3-18. Comparisons of Sediment Chromium Concentrations Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

Copper

Concentrations of copper exceeded the ER-L value of 34.0 mg/kg at 67 (89%) of the stations across all strata and all harbors. Concentrations exceeded the ER-M value of 270 mg/kg at five stations (7%), all of which were within the marina stratum.

Although copper concentrations commonly exceeded the ER-L across all strata and harbors, elevated sediment copper levels can partly be attributed to high natural levels rather than being entirely due to anthropogenic influences (Schiff and Weisberg, 1999). Thus, the threshold level for sediment copper was set at 175 mg/kg, representing a concentration where anthropogenic enhancement is apparent as described in Section 2.3.1.2. Copper concentrations at 16 stations (21%) exceeded the 175-mg/kg threshold level; eight were among the industrial/port stratum in San Diego Bay, and eight were among the marina stratum within all harbors except Mission Bay (Figure 3-19). The historical baseline for the percentage of stations with results exceeding the copper threshold value is 32%. Sediment copper concentrations in 2013 are less than the pre-2008 historic baseline conditions, but similar to conditions during the 2008 RHMP (20%) (Table 3-9).

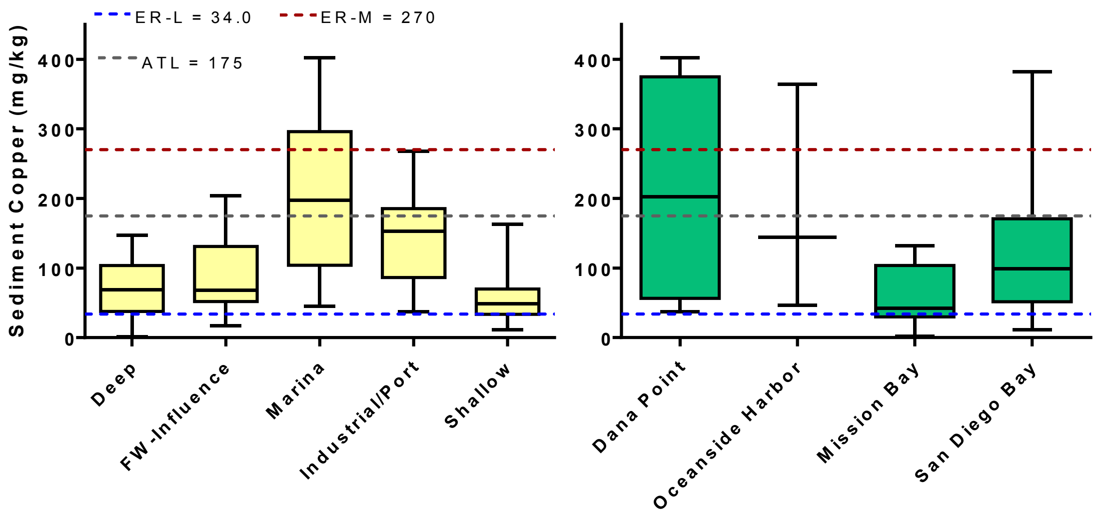


Figure 3-19. Comparisons of Sediment Copper Concentrations Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

The integrated and more regionally relevant CSI score used in the California SQO methodology can also be used as an alternative screening metric for several chemical constituents provided in Table 2-7, including copper. Using this methodology a total of 24 stations (32%) were within the minimal exposure (1) category (Figure 3-20). The majority of stations (51%) scored in the moderate exposure (3) category, most of which were among the marina and industrial/port strata. No stations were considered to be in the high exposure category (4).

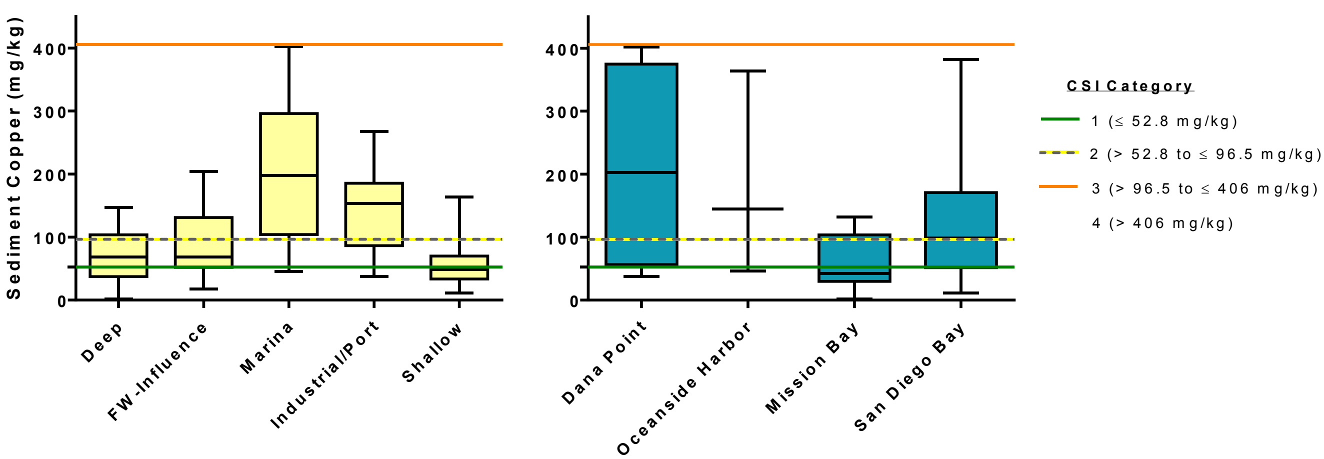


Figure 3-20. Comparisons of Sediment Copper Concentrations Compared to SQO CSI Thresholds

1 = Minimal Chemical Exposure; 2 = Low Exposure; 3 = Moderate Exposure; 4 =High Chemical Exposure

Box plots showing median, 25th percent quartiles, and range of values

The spatial distribution of sediment copper throughout the harbors is shown in Figures 3-21a through 3-21f.

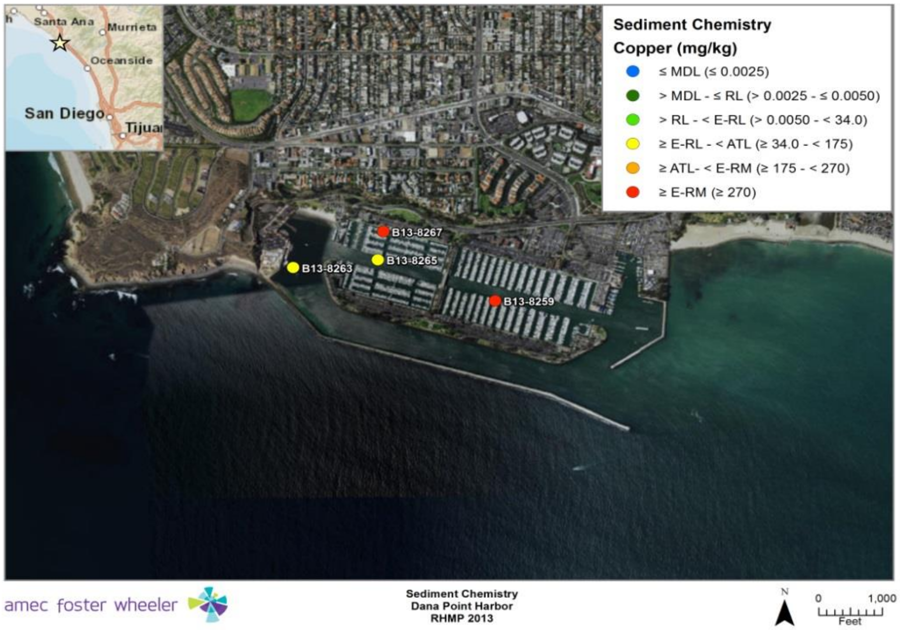


Figure 3-21a. Spatial Distribution of Sediment Copper Concentrations in Dana Point Harbor

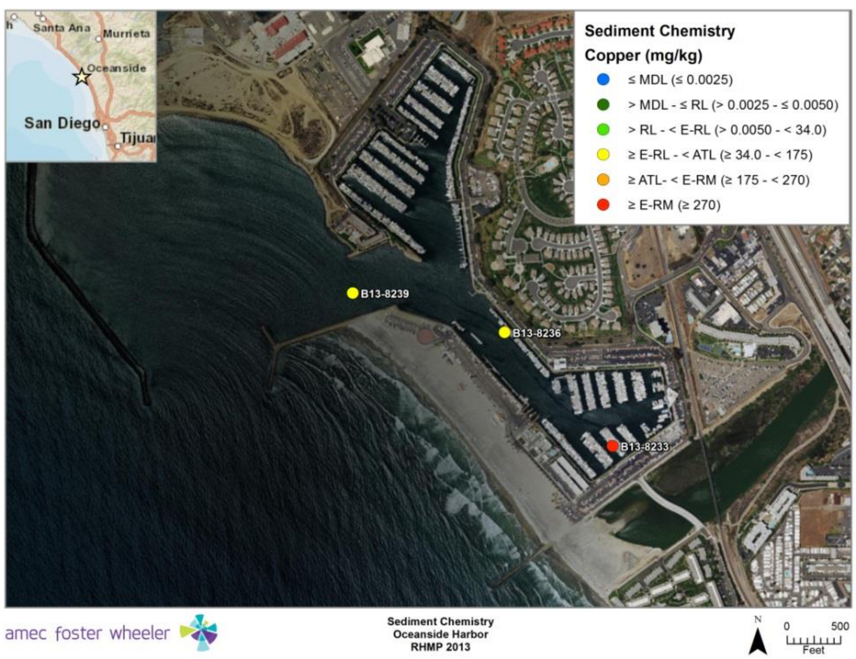


Figure 3-21b. Spatial Distribution of Sediment Copper Concentrations in Oceanside Harbor

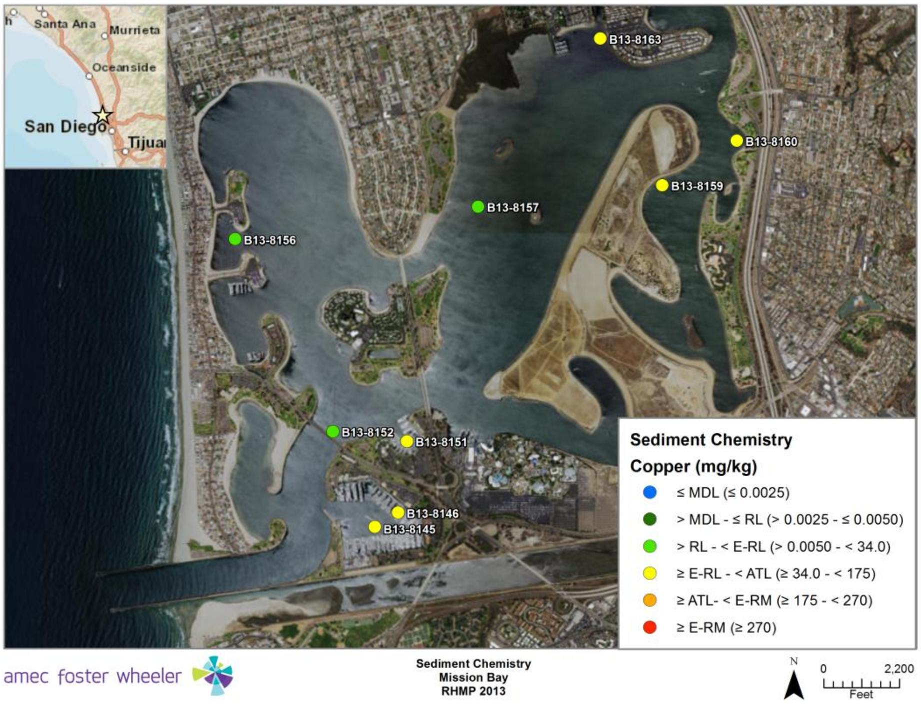


Figure 3-21c. Spatial Distribution of Sediment Copper Concentrations in Mission Bay

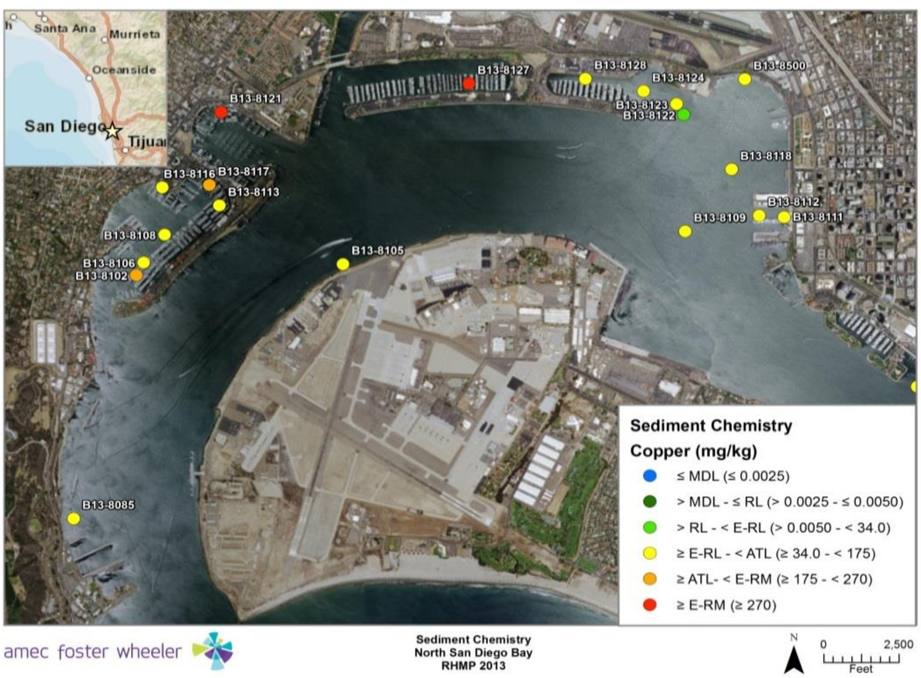


Figure 3-21d. Spatial Distribution of Sediment Copper Concentrations in Northern San Diego Bay

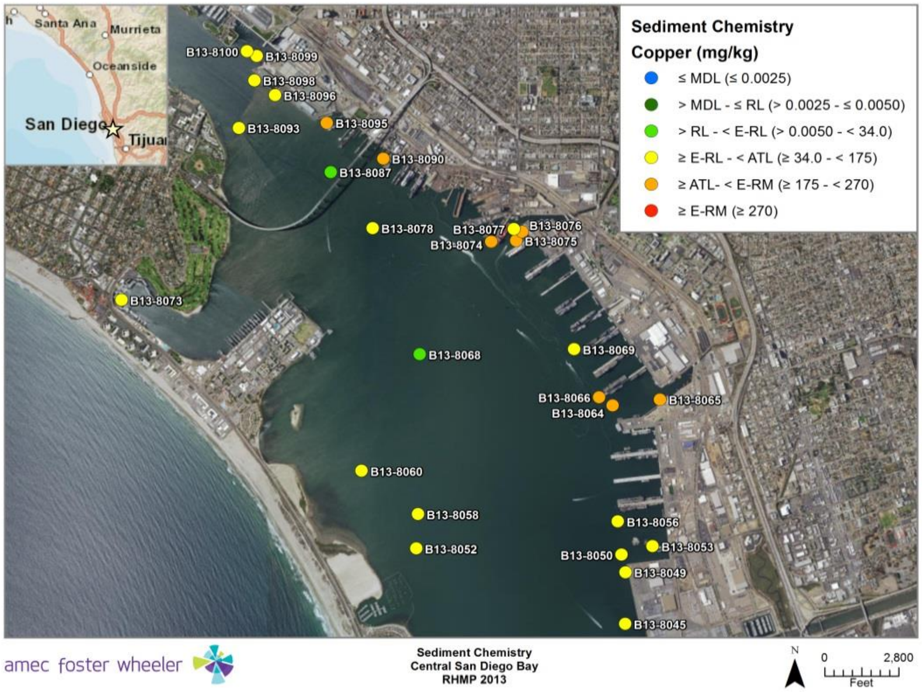


Figure 3-21e. Spatial Distribution of Sediment Copper Concentrations in Central San Diego Bay

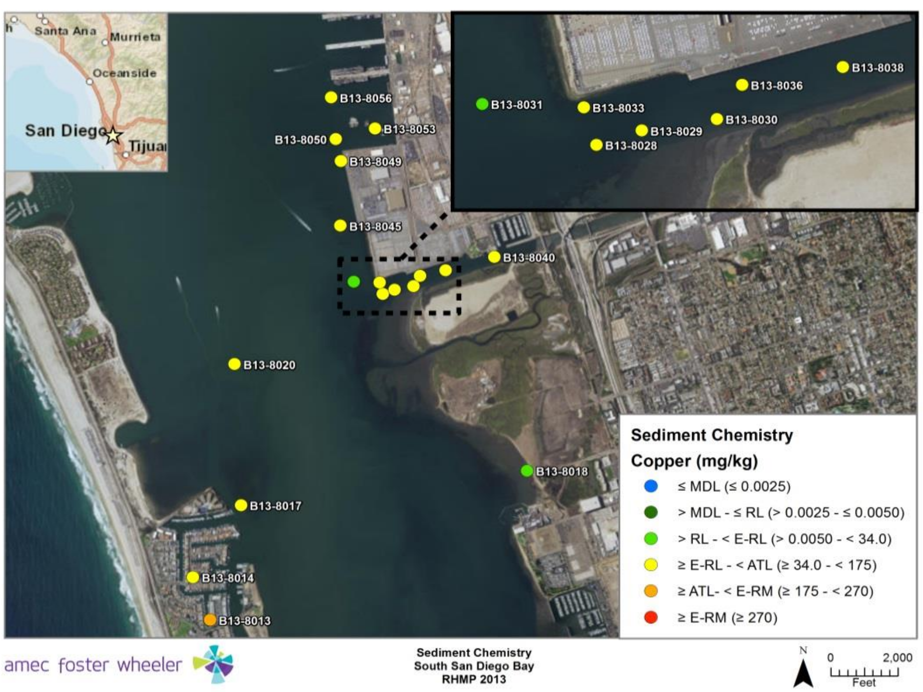


Figure 3-21f. Spatial Distribution of Sediment Copper Concentrations in Southern San Diego Bay

Lead

Concentrations of lead exceeded the ER-L threshold value of 46.7 mg/kg in fifteen (20%) of the stations across all strata, all within San Diego Bay; 10 of these sites were located in the industrial/port stratum. Refer to Figure 3-22 for more detail. There were no ER-M exceedances of 218 mg/kg.

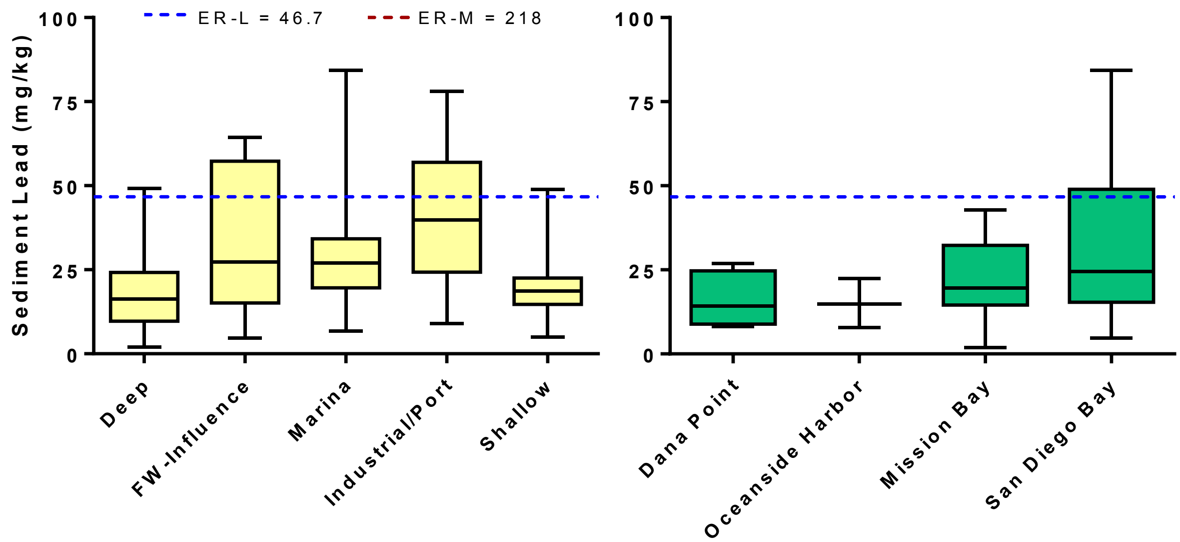


Figure 3-22. Comparisons of Sediment Lead Concentrations Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

Results for the 2013 RHMP indicate a slight improvement over historic concentrations where lead exceeded the ER-L threshold value at 25% of the stations. However, 2013 conditions had more exceedances than during the 2008 RHMP, when only 11% of stations had lead concentrations that exceeded the ER-L threshold value (Table 3-9).

Sediment lead concentrations were also incorporated into the calculation of the integrated CSI score based on lead alone. Based on lead alone, a total of 43 stations (57%) were within the minimal exposure (1) category, followed by 27 stations (36%) in the low exposure (2) category, and five stations (7%) in the moderate exposure (3) category, as shown in Figure 3-23.

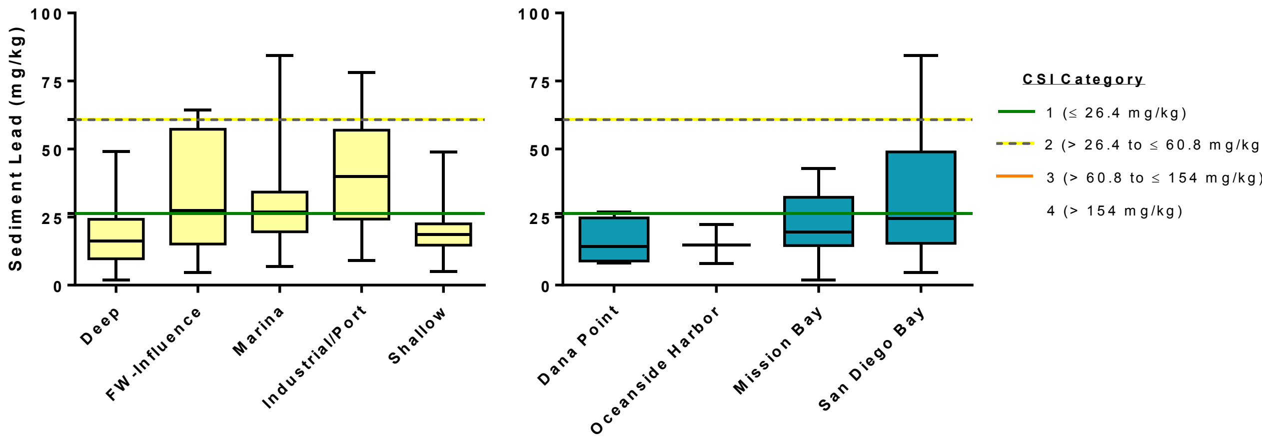


Figure 3-23. Comparisons of Lead Concentrations to SQO CSI Thresholds

1 = Minimal Chemical Exposure; 2 = Low Exposure; 3 = Moderate Exposure; 4 =High Chemical Exposure
Box plots showing median, 25th percent quartiles, and range of values

Mercury

Concentrations of mercury exceeded the ER-L threshold value of 0.15 mg/kg in 50 (67%) of the 2013 RHMP stations among all strata and all harbors (except Dana Point Harbor where no ER-L exceedances were observed). This represents an improvement over the historical baseline results where 74% of stations had concentrations of mercury that exceeded the threshold value, and is consistent with results from the 2008 RHMP where concentrations of mercury at 69% of stations exceeded the threshold value. Mercury concentrations exceeded the ER-M value of 0.71 mg/kg in just eight (11%) of the stations among three strata (marina, industrial/port, and deep) within San Diego Bay (mainly Northern San Diego Bay). Six of these eight stations were in the marina stratum. Plots showing the distribution of mercury concentrations among strata and harbors relative to the ER-L/threshold value and ER-M are shown in Figure 3-24.

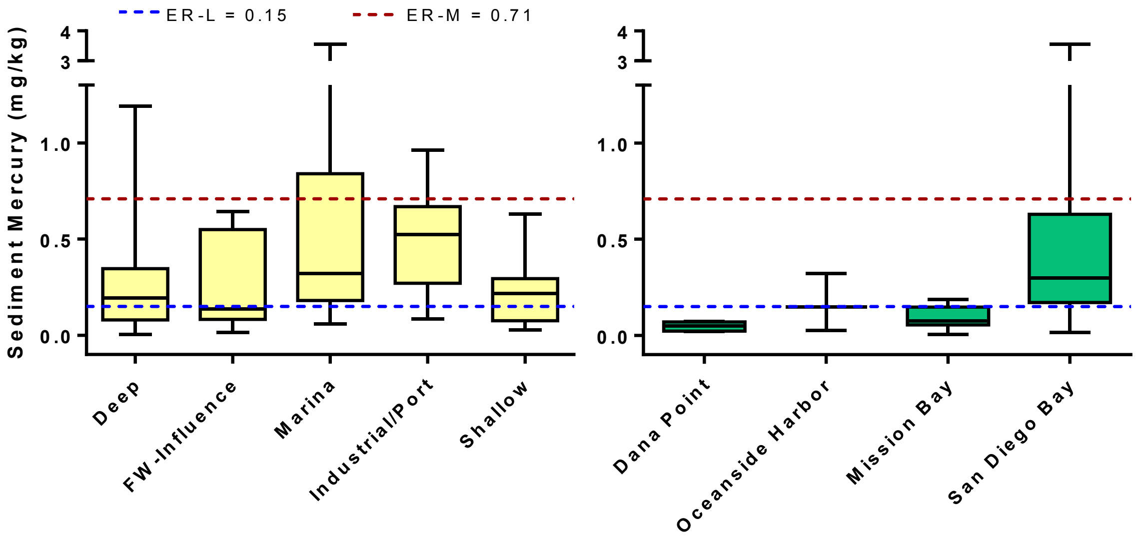


Figure 3-24. Comparisons of Sediment Mercury Concentrations Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

Sediment mercury concentrations were also incorporated into the calculation of the integrated SQO CSI score. Based on mercury alone, most stations (47%) were considered to be in the low exposure (2) category, followed by 31% of stations in the moderate exposure (3) category, as displayed in Figure 3-25. One station in Northern San Diego Bay (in the marina stratum) was considered to be in the high exposure (4) category.

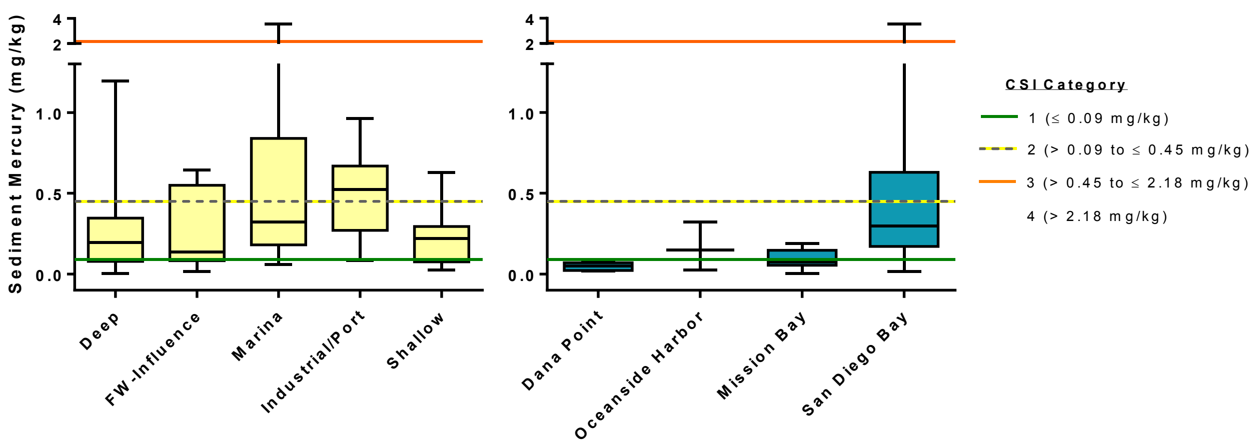


Figure 3-25. Comparisons of Sediment Mercury Concentrations to SQO CSI Thresholds

1 = Minimal Chemical Exposure; 2 = Low Exposure; 3 = Moderate Exposure; 4 =High Chemical Exposure
Box plots showing median, 25th percent quartiles, and range of values

The spatial distribution of sediment mercury concentrations throughout the harbors is shown in Figures 3-26a through 3-26f.

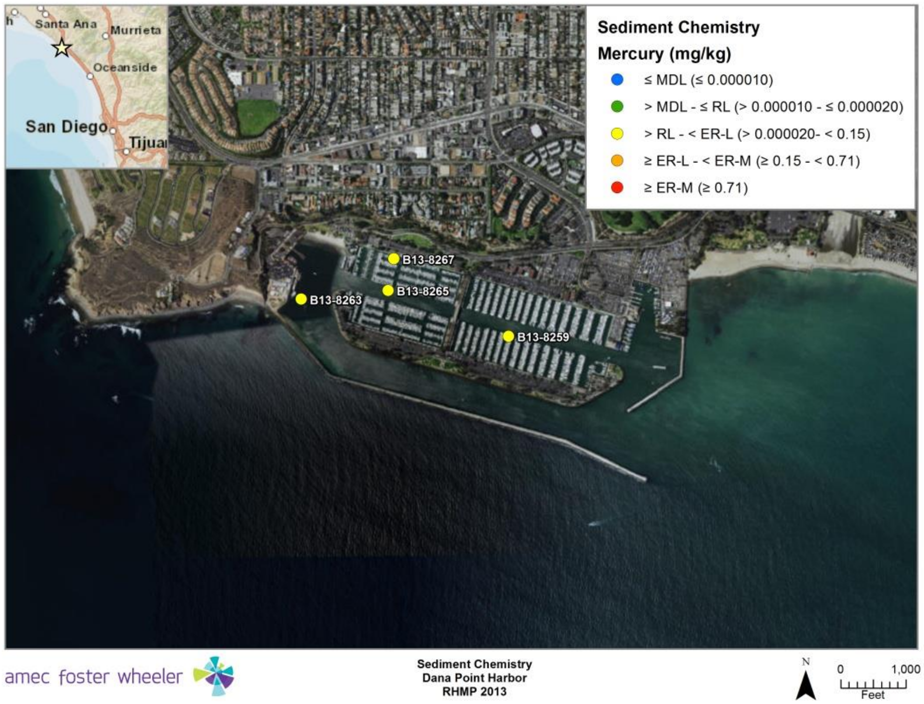


Figure 3-26a. Spatial Distribution of Sediment Mercury Concentrations in Dana Point Harbor

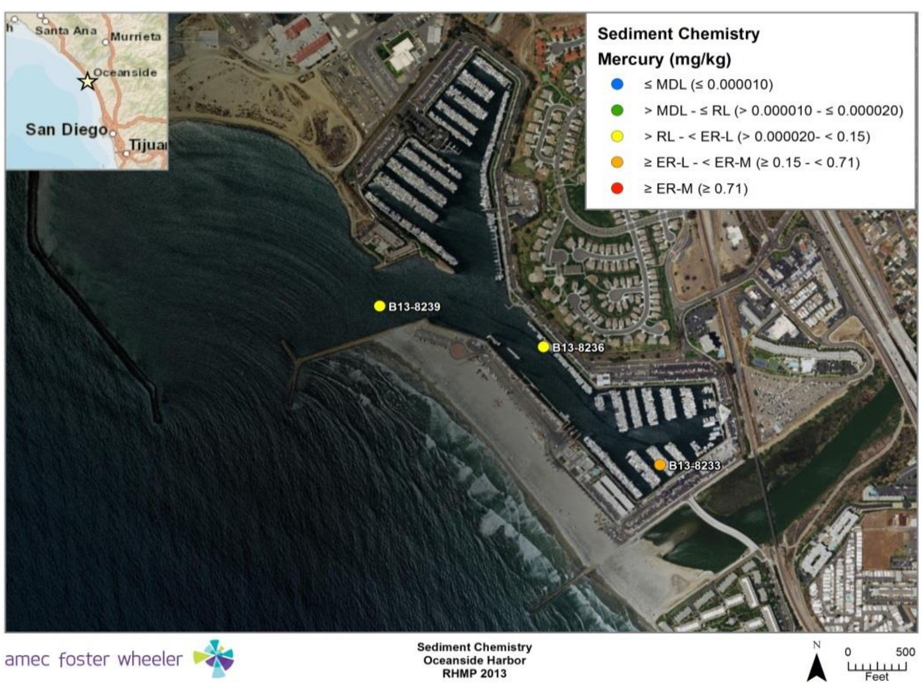


Figure 3-26b. Spatial Distribution of Sediment Mercury Concentrations in Oceanside Harbor

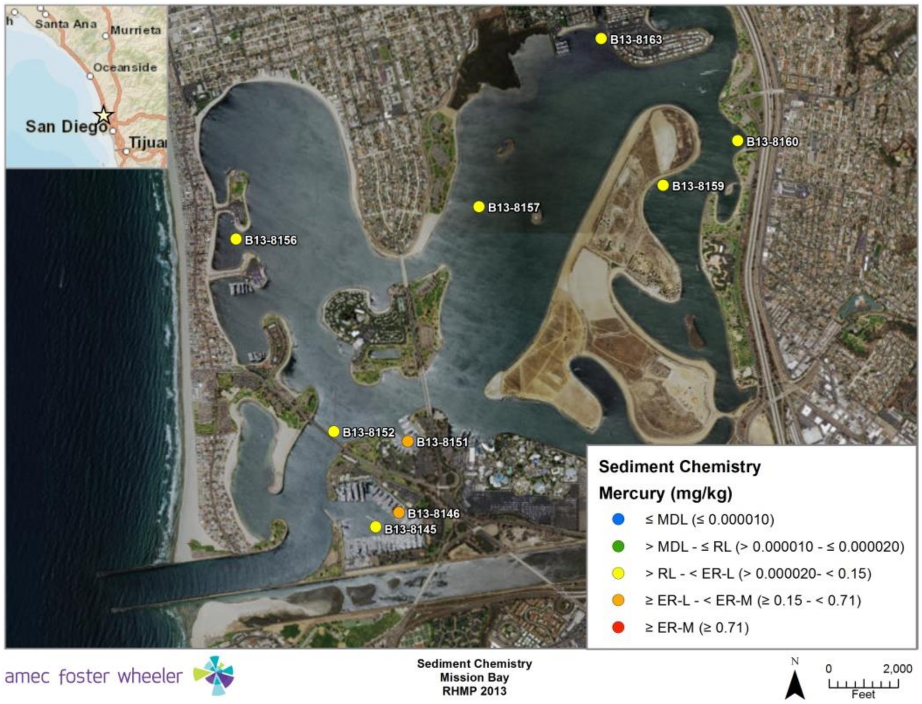


Figure 3-26c. Spatial Distribution of Sediment Mercury Concentrations in Mission Bay

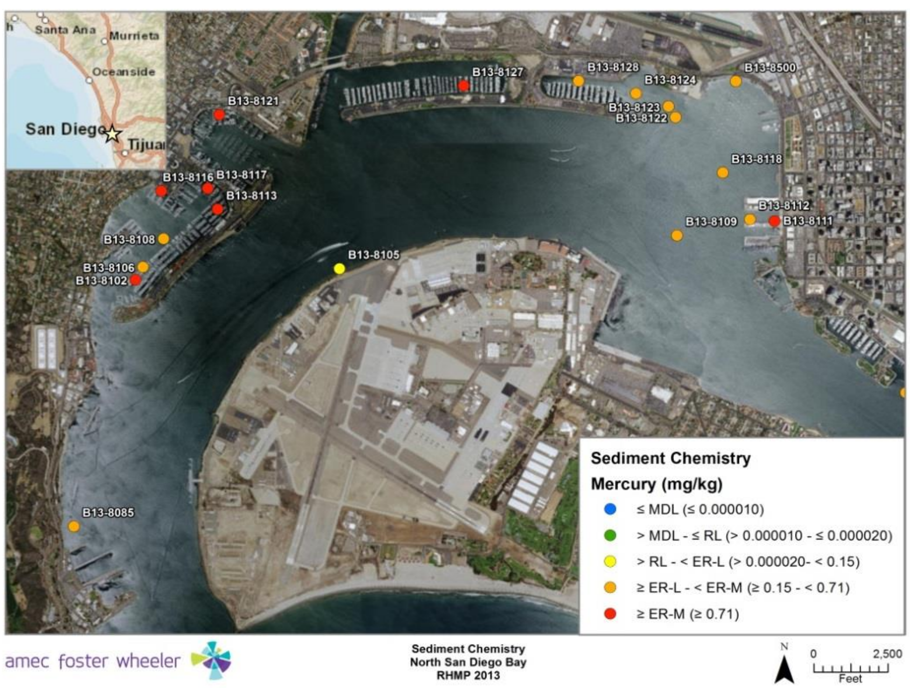


Figure 3-26d. Spatial Distribution of Sediment Mercury Concentrations in Northern San Diego Bay

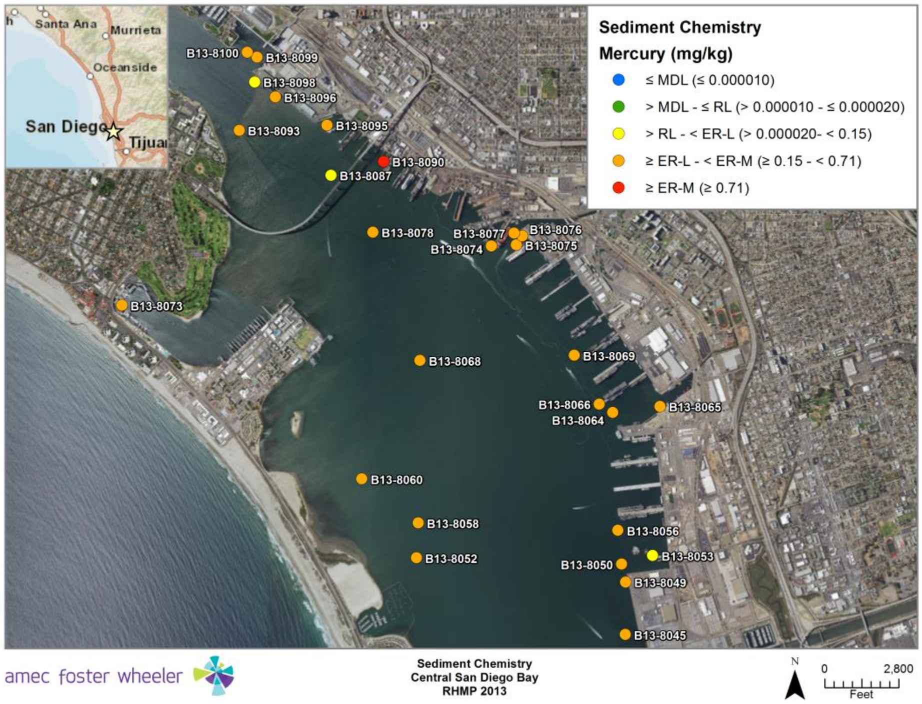


Figure 3-26e. Spatial Distribution of Sediment Mercury Concentrations in Central San Diego Bay

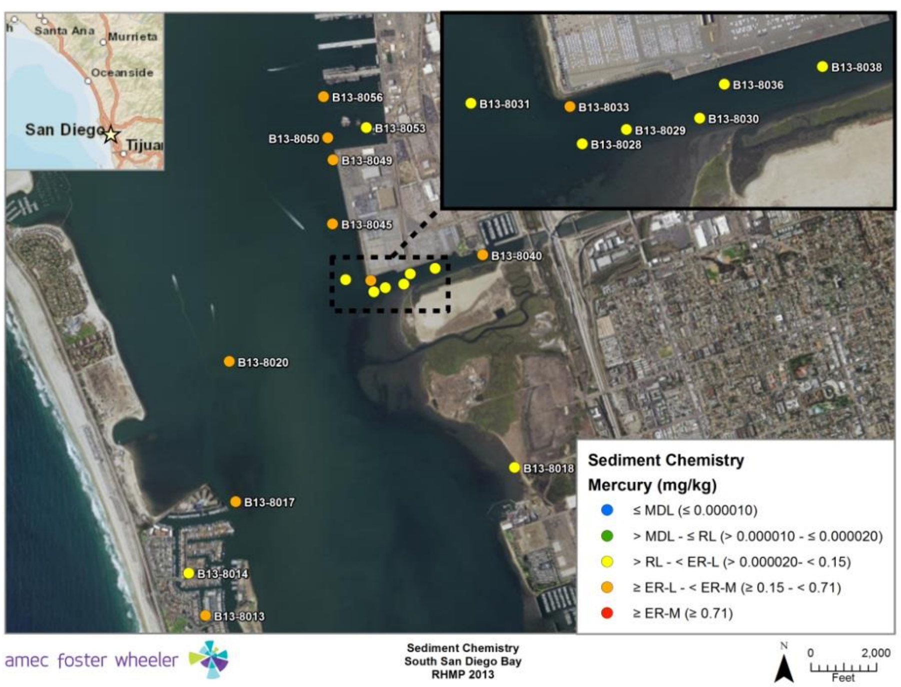


Figure 3-26f. Spatial Distribution of Sediment Mercury Concentrations in Southern San Diego Bay

Nickel

Nickel concentrations exceeded the ER-L threshold of 20.9 mg/kg at just six stations (8%); these exceedances were primarily in the marina stratum (three stations) and industrial/port stratum (two stations) among all harbors, except Mission Bay (Table 3-9). There were no exceedances of the ER-M value of 51.6 mg/kg.

The percentage of stations with concentrations of nickel exceeding the nickel ER-L threshold value was an improvement from the historical baseline of 20%; however, in 2013 there were slightly more exceedances than in the 2008 RHMP, when concentrations of nickel at only 3% of stations exceeded the ER-L threshold value. The distribution of nickel among strata and harbors is shown in Figure 3-27.

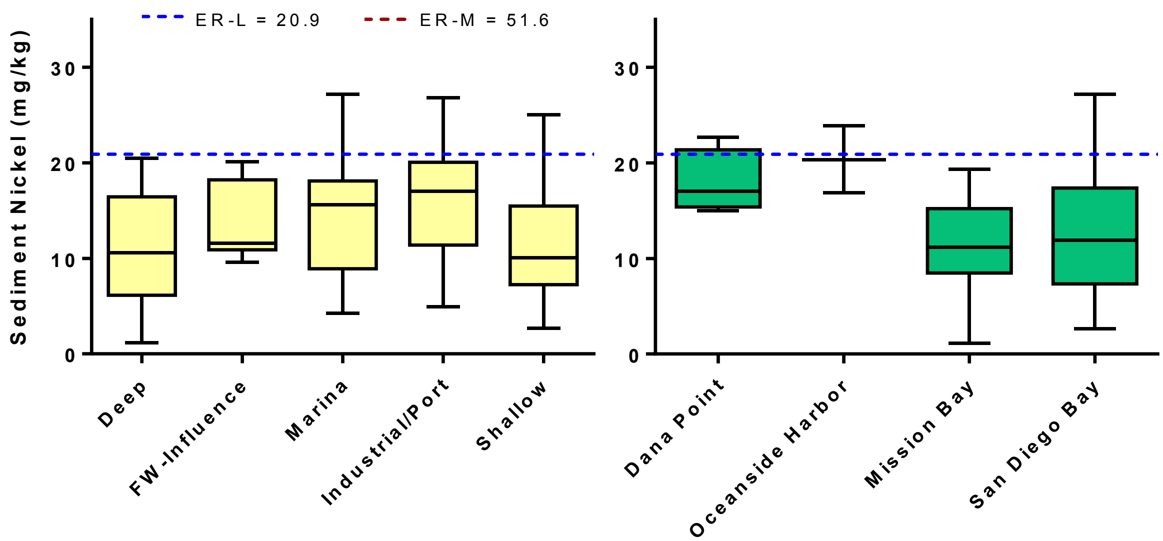


Figure 3-27. Comparisons of Sediment Nickel Concentrations Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

Silver

Silver concentrations exceeded the ER-L value of 1.0 mg/kg at seven stations (9%) in San Diego Bay, primarily in the industrial/port stratum (four stations). There were no exceedances of the ER-M value of 3.7 mg/kg. Although silver concentrations were used to calculate the mean ER-M quotient, a historical baseline and threshold values were not applicable because of limited reporting of this trace metal in older studies.

Zinc

Concentrations of zinc exceeded the ER-L threshold value of 150 mg/kg at 38 stations (51%) throughout all harbors. These exceedances were primarily observed in the industrial/port stratum (11 of 14 stations) and marina stratum (11 of 15 stations) (Figure 3-28).

Concentrations of zinc exceeded the ER-M value of 410 mg/kg at just two stations within the marina stratum. In the 2008 RHMP there were no ER-M exceedances for zinc.

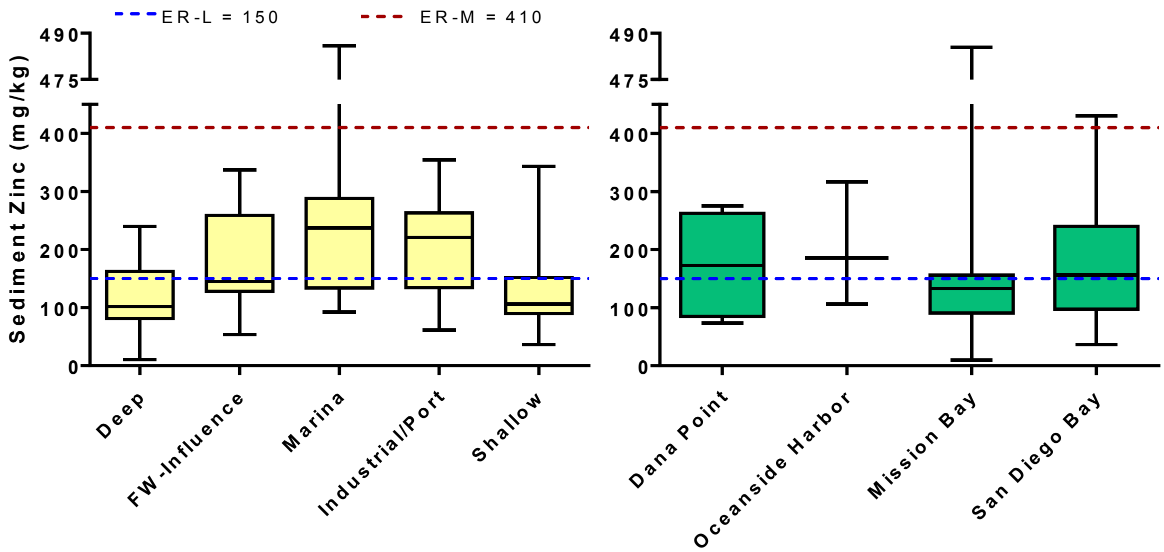


Figure 3-28. Comparisons of Sediment Zinc Concentrations Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

The current 2013 ER-L exceedance frequency for zinc is similar to that derived using the historic pre-2008 dataset (55%), as well as a 56% ER-L exceedance frequency during the 2008 RHMP (Table 3-9).

Sediment zinc concentrations were also incorporated into the calculation of the integrated CSI score. Based on zinc alone, stations were evenly distributed in the minimal exposure (1), low exposure (2), and moderate exposure (3) categories, as shown in Figure 3-29. Most of the stations scored as having moderate exposure potential were within the marina and industrial/port strata. No stations scored in the high exposure (4) category.

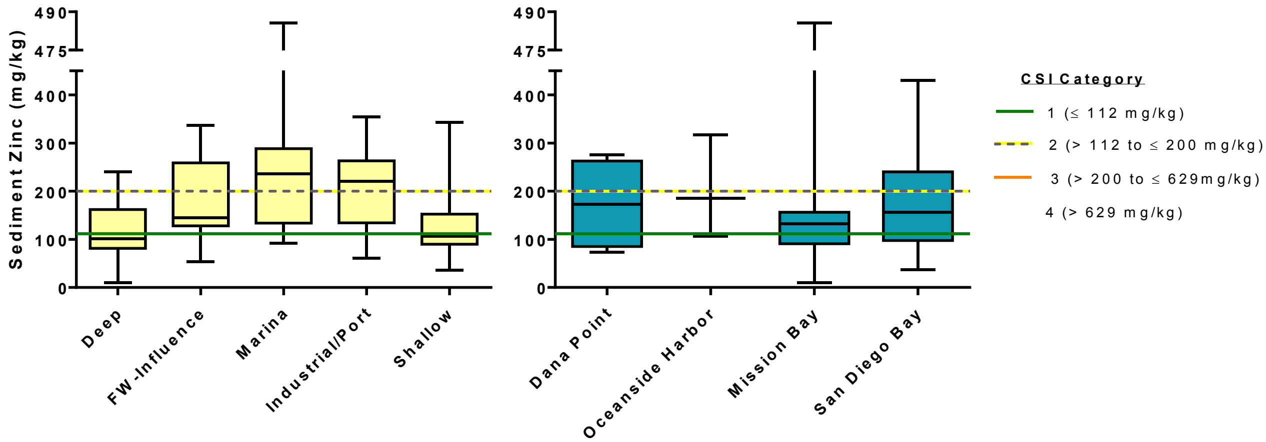


Figure 3-29. Comparisons of Sediment Zinc Concentrations Among Strata and Harbors Versus SQO CSI Thresholds

1 = Minimal Chemical Exposure; 2 = Low Exposure; 3 = Moderate Exposure; 4 =High Chemical Exposure
Box plots showing median, 25th percent quartiles, and range of values

The spatial distribution of zinc among harbors are detailed in Figures 3-30a through 3-30f.

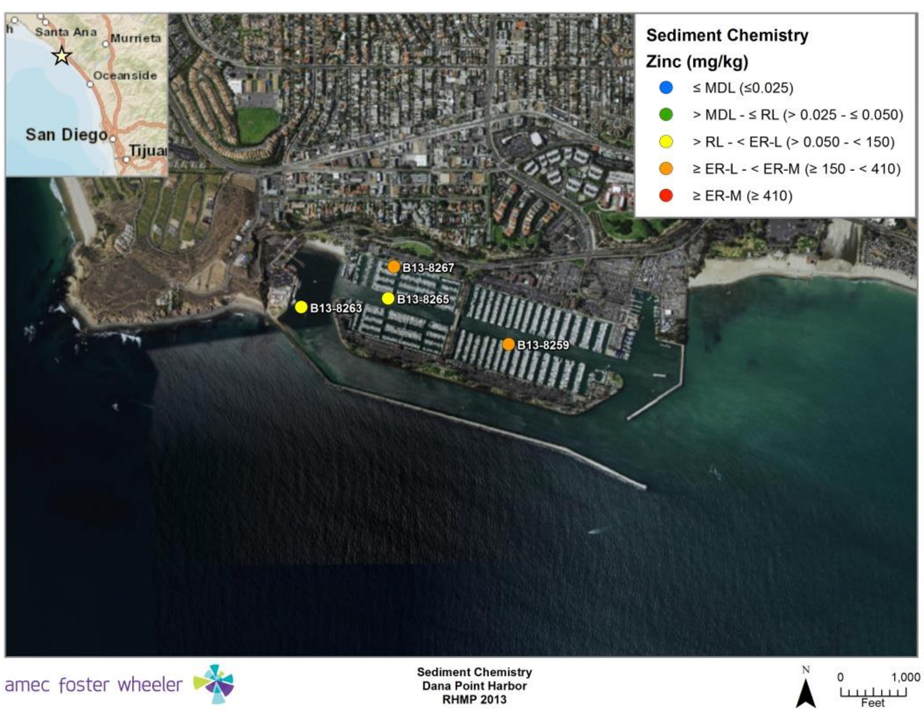


Figure 3-30a. Spatial Distribution of Sediment Zinc Concentrations in Dana Point Harbor

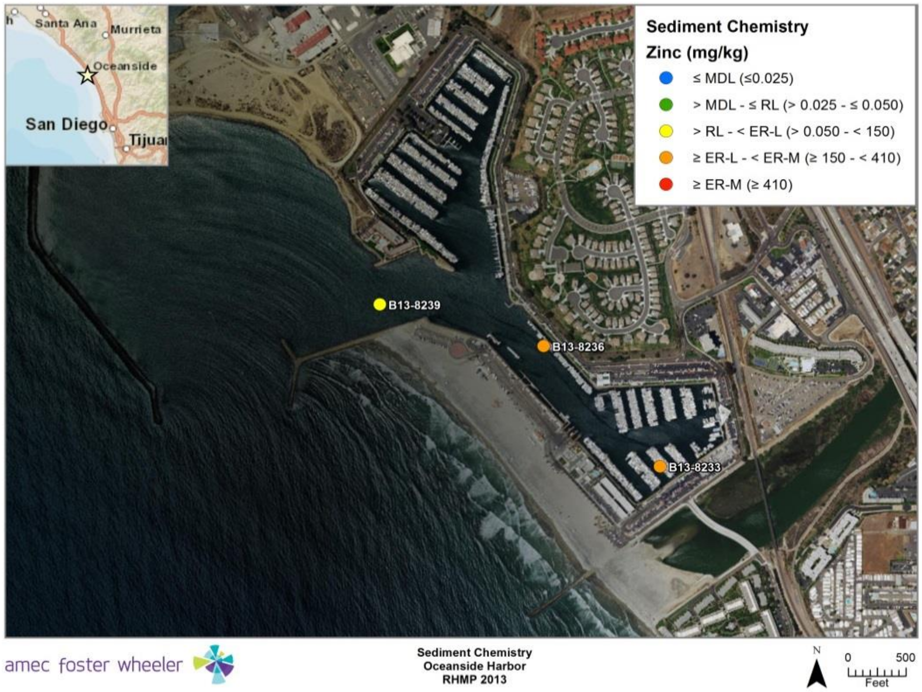


Figure 3-30b. Spatial Distribution of Sediment Zinc Concentrations in Oceanside Harbor

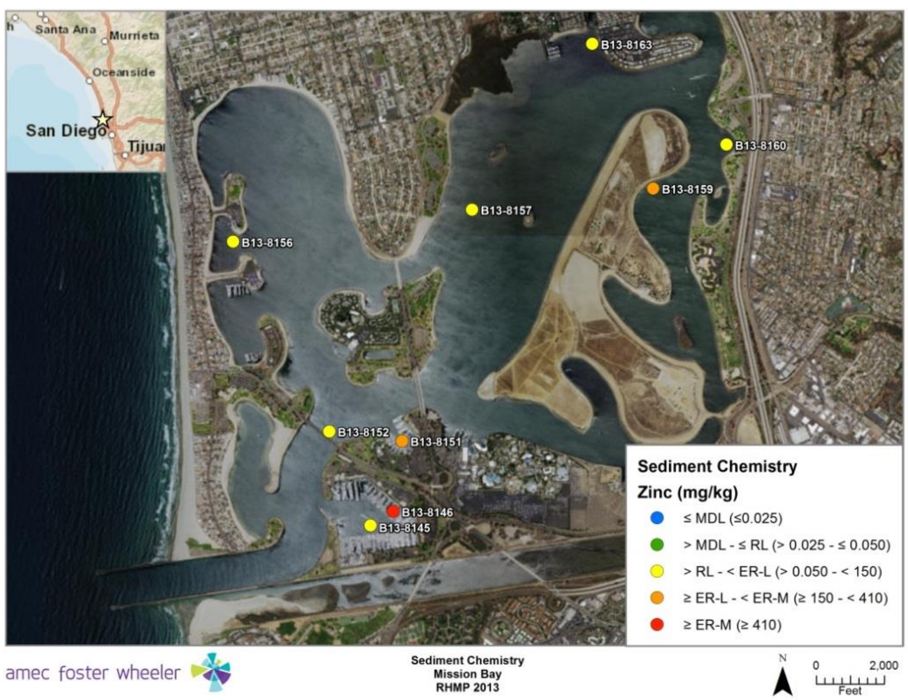


Figure 3-30c. Spatial Distribution of Sediment Zinc Concentrations in Mission Bay

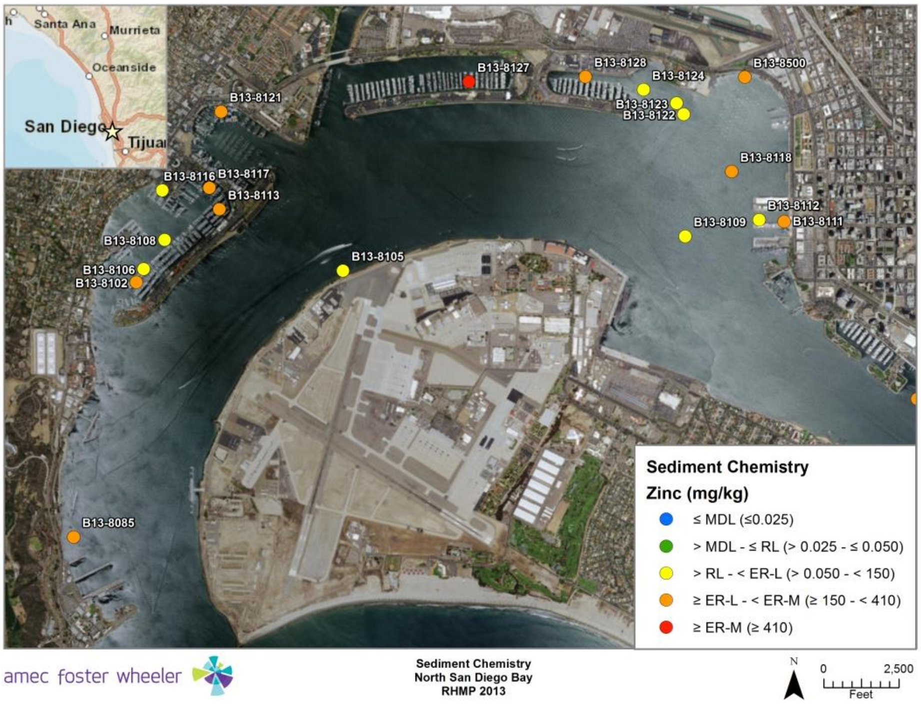


Figure 3-30d. Spatial Distribution of Sediment Zinc Concentrations in Northern San Diego Bay

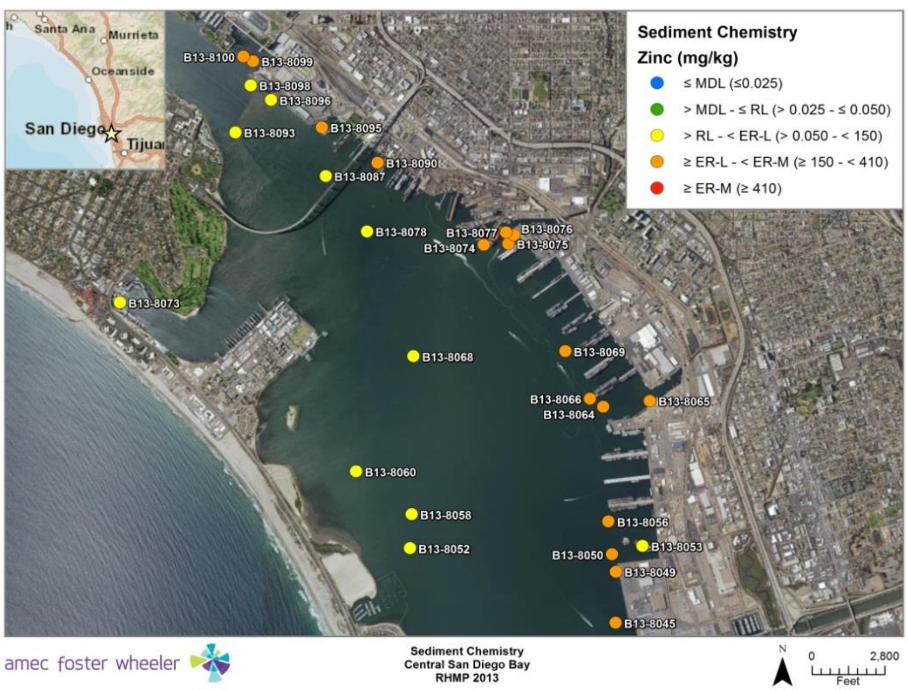


Figure 3-30e. Spatial Distribution of Sediment Zinc Concentrations in Central San Diego Bay

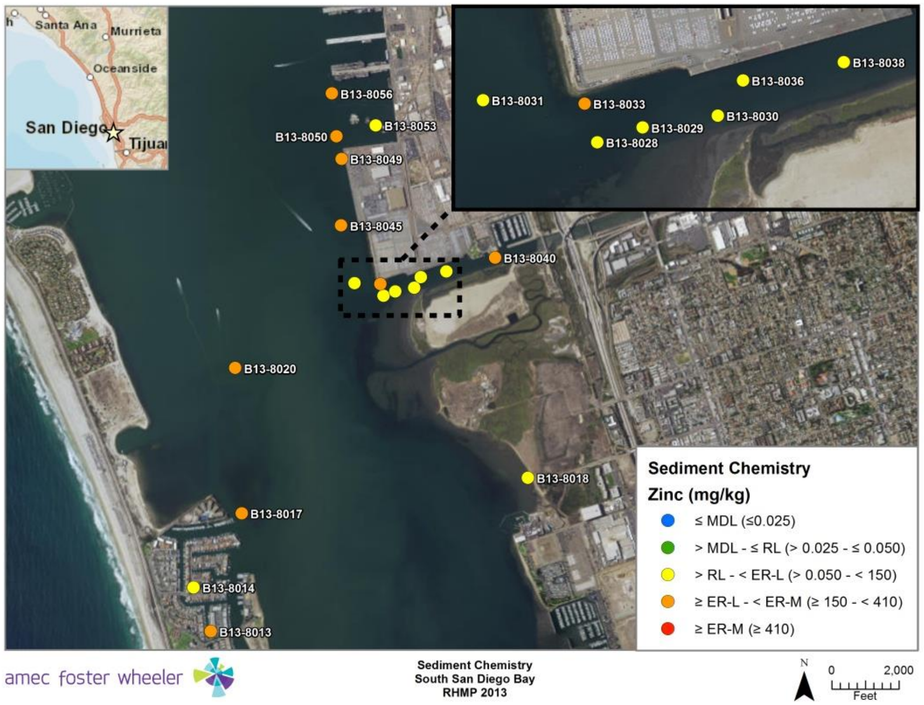


Figure 3-30f. Spatial Distribution of Sediment Zinc Concentrations in Southern San Diego Bay

Sediment Organics

Total PAHs

Concentrations of total PAHs (the sum of 25 isomers) slightly exceeded the ER-L threshold value of 4,022 µg/kg at just one station within the marina stratum; Site 8121 in North San Diego Bay located in Americas Cup Harbor (Figure 3-31). No stations had concentrations of total PAHs exceeding the ER-M value of 44,792 µg/kg.

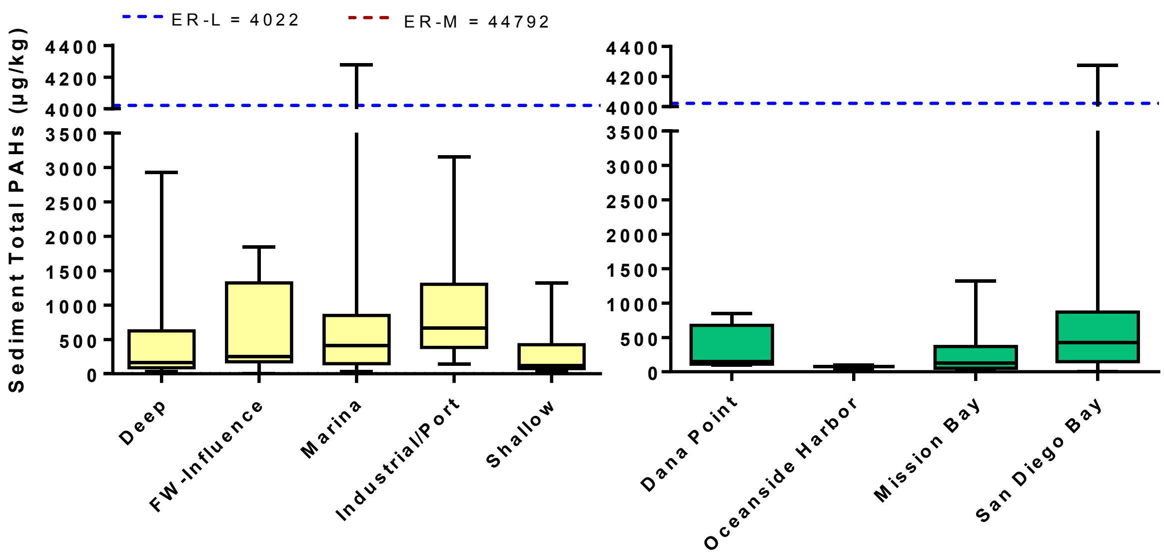


Figure 3-31. Comparisons of Sediment Total PAH Concentrations Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

During the 2013 RHMP, concentrations of total PAHs at only 1% of stations exceeded the ER-L threshold value, resulting in a considerable improvement when compared to historical conditions (21% exceedance) and conditions during the 2008 RHMP (12% exceedance) (Table 3-9). Maps that spatially show total PAH concentrations among the harbors are also provided in Appendix F for reference.

Sediment concentrations of low-molecular-weight PAHs (LPAHs) and high-molecular-weight PAHs (HPAHs) were incorporated separately into the calculation of the integrated SQO CSI score. The majority of stations (79%) scored within the minimal exposure category (1) for LPAHs alone. Stations within Dana Point Harbor, Oceanside Harbor, and Mission Bay were all in the minimal exposure category, as displayed in Figure 3-32. See Appendix F for individual LPAH concentrations.

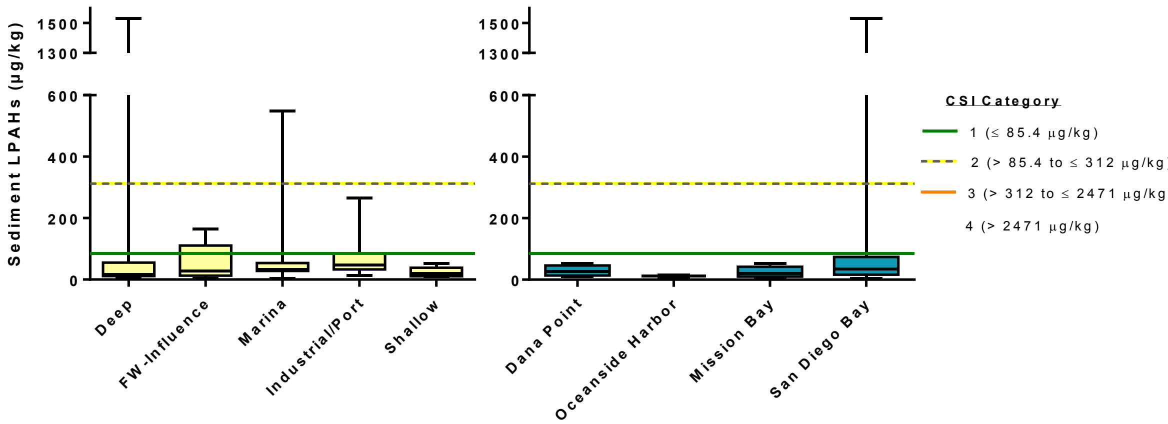


Figure 3-32. Comparisons of Sediment Total LPAHs Among Strata and Harbors Versus SQO CSI Thresholds

1 = Minimal Chemical Exposure; 2 = Low Exposure; 3 = Moderate Exposure; 4 =High Chemical Exposure
Box plots showing median, 25th percent quartiles, and range of values

Similarly, the majority of stations (65%) scored within the minimal exposure category (1) for HPAHs. Stations within Dana Point Harbor, Oceanside Harbor, and Mission Bay were all in the minimal exposure or low exposure categories, as displayed in Figure 3-33. See Appendix F for individual HPAH concentrations.

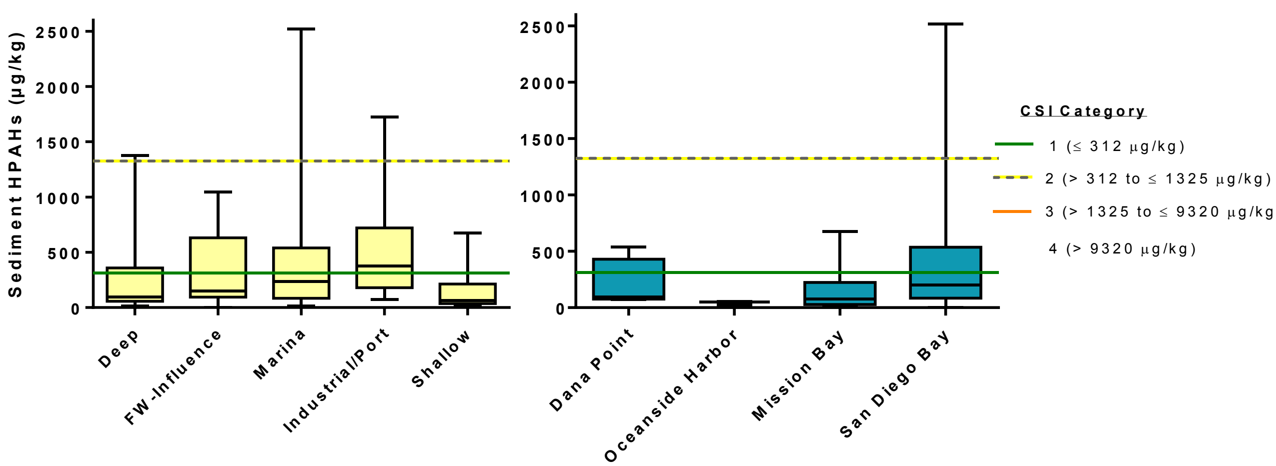


Figure 3-33. Comparisons of Sediment Total HPAHs Among Strata and Harbors Versus SQO CSI Thresholds

1 = Minimal Chemical Exposure; 2 = Low Exposure; 3 = Moderate Exposure; 4 =High Chemical Exposure
Box plots showing median, 25th percent quartiles, and range of values

Pesticides – Total Chlordanes

Total chlordanes represented the sum of alpha-chlordane and gamma-chlordane. A total of 17% of the 2013 RHMP stations had concentrations of total chlordanes that exceeded the ER-L target of 0.5 µg/kg, and three stations (4%) had concentrations that exceeded the ER-M of 6.0 µg/kg. All three of these stations exceeding the ER-M value were located in the freshwater-influenced stratum (Figure 3-34).

Note that the pre-set target value for total chlordanes (results at 14% of historical stations exceeded the threshold value) was based on reporting limits available at the time (2 µg/kg) as opposed to the ER-L value of 0.5 µg/kg. It is thus likely that the proportion of historic samples exceeding the ER-L is greater than currently reported given a much lower 0.05 µg/kg reporting limit in 2013.

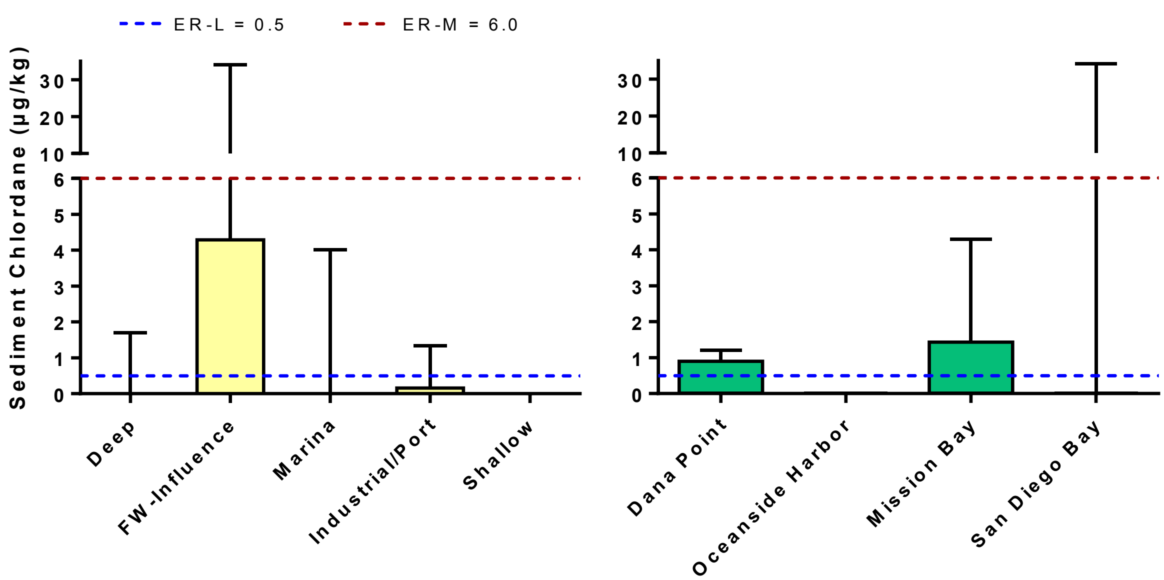


Figure 3-34. Comparisons of Sediment Total Chlordane Concentrations Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

Pesticides – Total DDTs

Total DDT concentrations exceeded the ER-L threshold value of 1.58 µg/kg at 11 stations (15%) throughout three strata (freshwater-influenced, marina, and shallow) and in all harbors. Exceedances were most frequent in the freshwater-influenced stratum (six stations) and the marina stratum (four stations). At all other stations, total DDT concentrations were well below the ER-L threshold value. One station within the freshwater-influenced stratum located in northern San Diego Bay had concentrations of total DDTs marginally exceeding the ER-M value of 46.1 µg/kg (Figure 3-35).

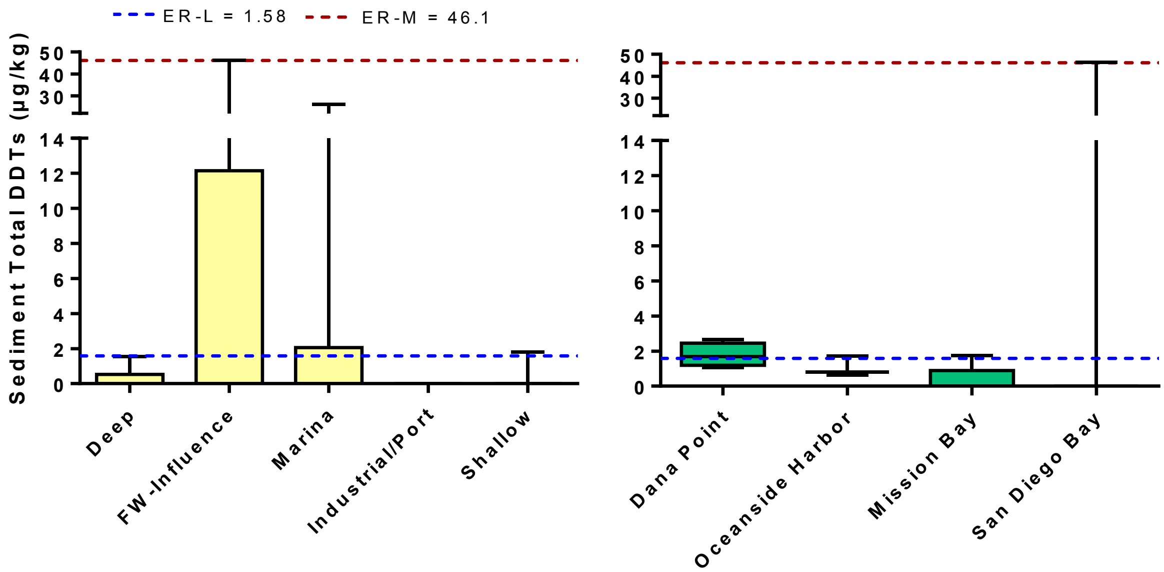


Figure 3-35. Comparisons of Sediment Total DDT Concentrations Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

The percentage of stations exceeding the total DDT ER-L threshold value exhibited a significant improvement over the historical baseline of 46%. The 2013 RHMP results also demonstrated a large improvement over the 2008 RHMP results, where 21% of stations had concentrations of DDT that exceeded the ER-L threshold value (Table 3-9).

Total PCBs

Concentrations of total PCBs (the sum of 209 PCB congeners) exceeded the ER-L threshold value of 22.7 mg/kg at 16 stations (21%), all within San Diego Bay. Exceedances occurred throughout all five strata, but were most frequent in the industrial/port and freshwater-influenced strata (five stations each), as shown in Figure 3-36. Concentrations of total PCBs exceeded the ER-M value of 180 mg/kg at just two stations within San Diego Bay: one station within the marina stratum (Site 8121 in Americas Cup Harbor), and one within the industrial/port stratum south of the Coronado Bridge.

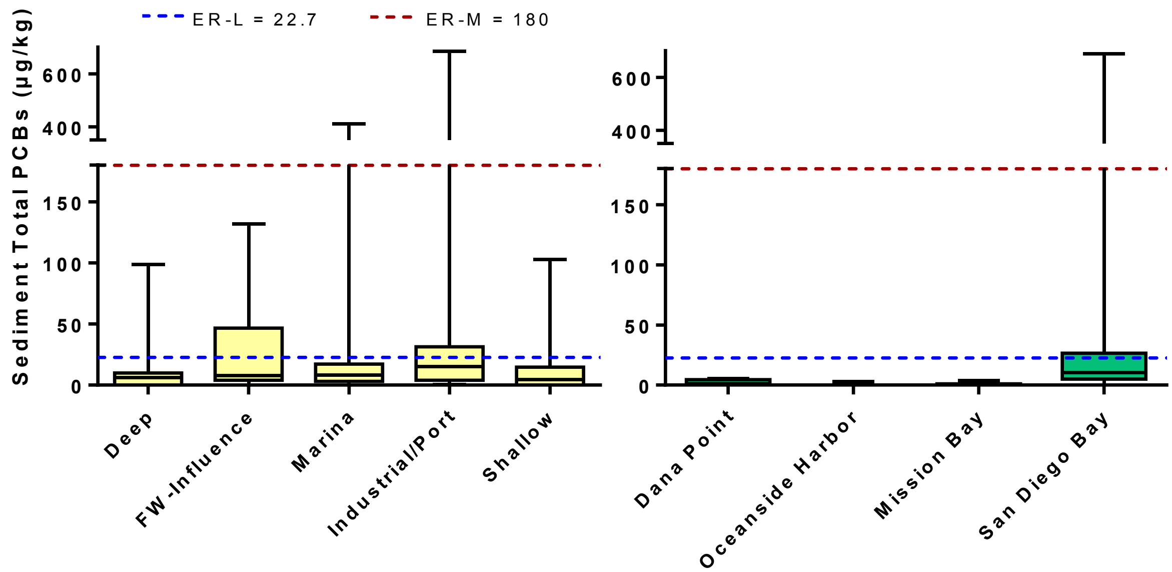


Figure 3-36. Comparisons of Sediment Total PCB Concentrations Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

Based on historical data, the target for the percentage of stations with PCB concentrations greater than the total PCB ER-L threshold value was 53%, indicating a substantial improvement over time for PCBs (Table 3-9).

For the CSI score, sediment PCB concentrations were tabulated specifically to meet SQO criteria. A selected list of congeners was summed and a correction factor was applied (Bay et al., 2014). Based on PCBs alone, most stations were considered to be in either the minimal exposure (37% of stations) or low exposure (39% of stations) categories. Two stations were considered to be in the high exposure category based on the CSI; these stations were located in the marina stratum (Station B13-8121 in America's Cup Harbor) and industrial/port (Station B13-8090, located just south of the Coronado Bridge). Stations within Dana Point Harbor, Oceanside Harbor, and Mission Bay were all within the minimal exposure category threshold, as displayed in Figure 3-37.

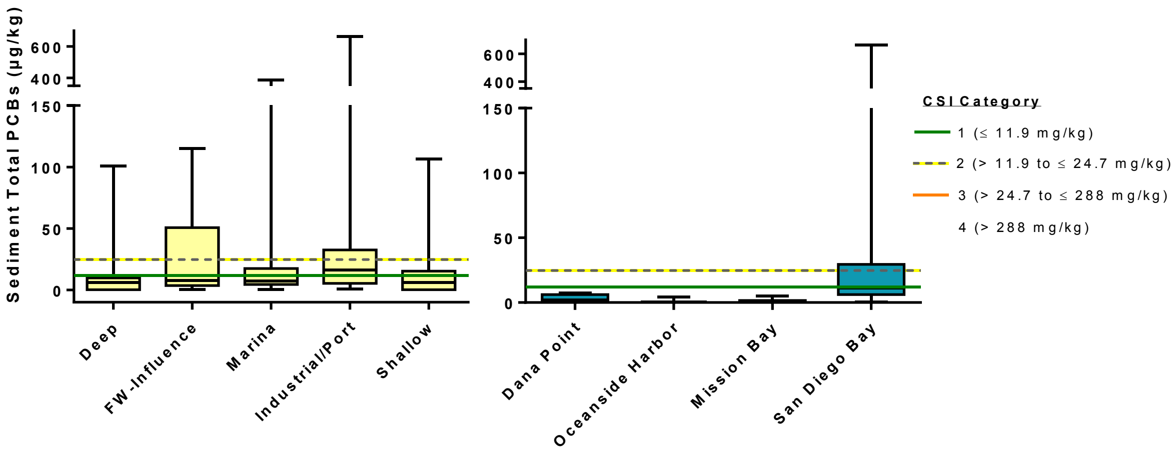


Figure 3-37. Comparisons of Sediment Total PCBs (SQO Congeners Only) Among Strata and Harbors Versus SQO CSI Thresholds

1 = Minimal Chemical Exposure; 2 = Low Exposure; 3 = Moderate Exposure; 4 =High Chemical Exposure
Box plots showing median, 25th percent quartiles, and range of values

The spatial distribution of total PCBs among harbors is detailed in Figures 3-38a through 3-38f.

Figure 3-38a. Spatial Distribution of Sediment Total PCB Concentrations in Dana Point Harbor

Figure 3-38b. Spatial Distribution of Sediment Total PCB Concentrations in Oceanside Harbor

Figure 3-38c. Spatial Distribution of Sediment Total PCB Concentrations in Mission Bay

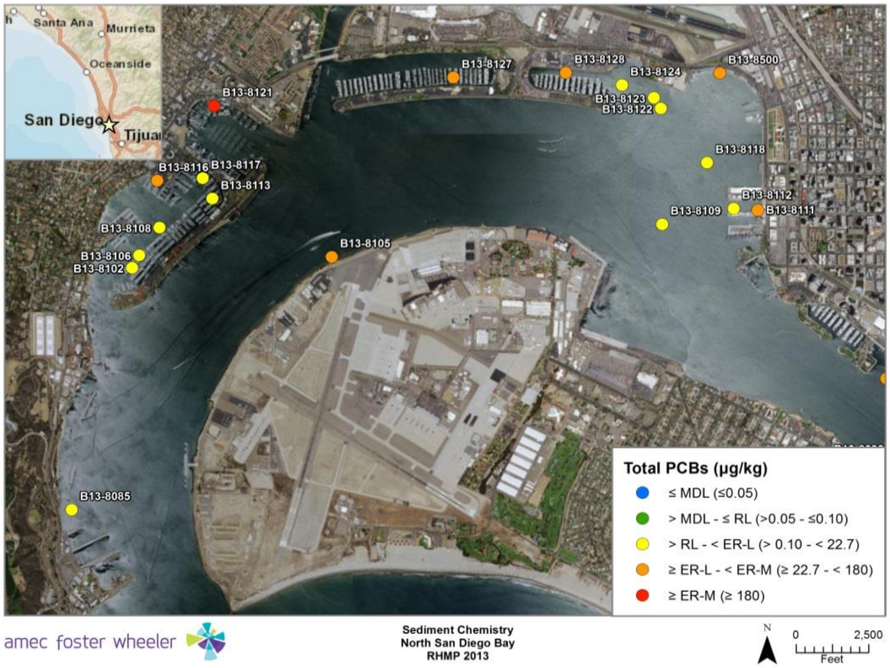


Figure 3-38d. Spatial Distribution of Sediment Total PCB Concentrations in Northern San Diego Bay

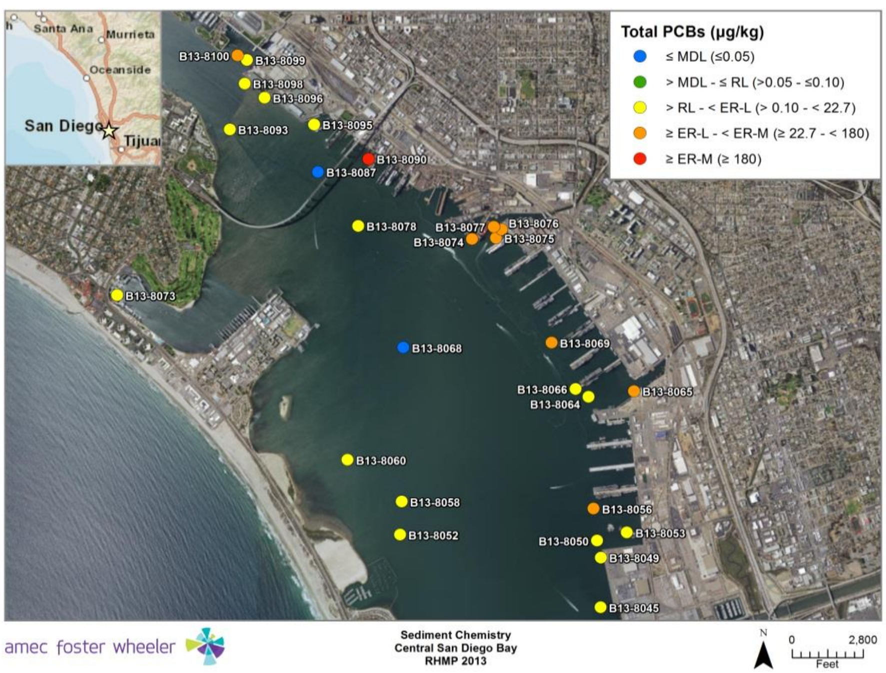


Figure 3-38e. Spatial Distribution of Sediment Total PCB Concentrations in Central San Diego Bay

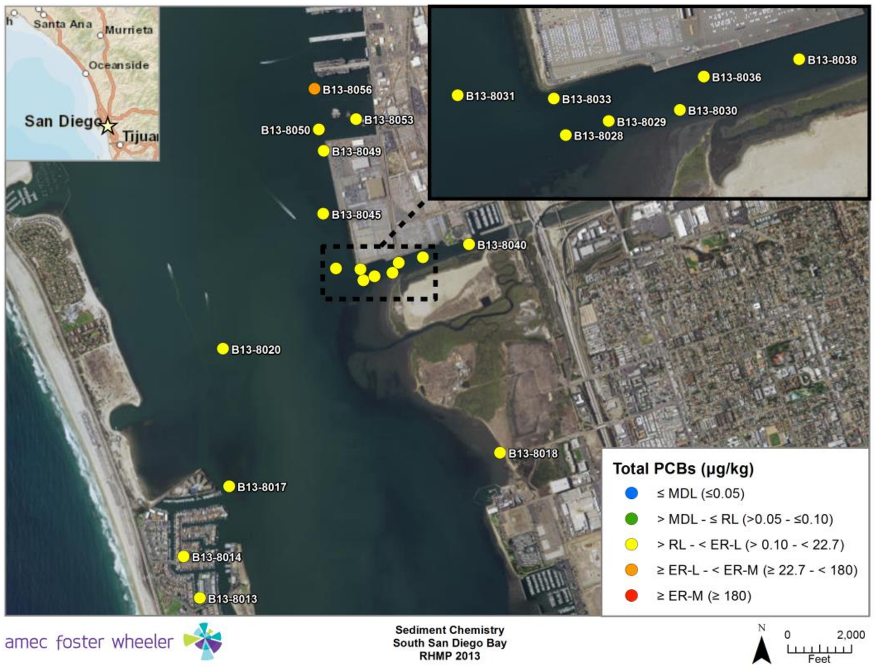


Figure 3-38f. Spatial Distribution of Sediment Total PCB Concentrations in Southern San Diego Bay

Other Sediment Contaminants of Concern

Total Pyrethroids

Over the past 20 years, pyrethroid insecticides have become the dominant pesticide in both agricultural and nonagricultural applications, replacing organophosphate pesticides, which have been phased out (Amweg et al., 2006). During the 2013 RHMP, 84% of stations had non-detectable concentrations of pyrethroids in the sediment (< 0.25 µg/kg), which is similar to what was observed during the 2008 RHMP. The 12 locations where pyrethroids were detected were near areas influenced by freshwater inputs and in several marinas with concentrations ranging from 0.37 to 2.31 µg/kg among 11 locations, and 19.1 µg/kg at a single location; Site 8500 located near a storm drain in the Laurel Hawthorne embayment of north San Diego Bay. Toxic concentration thresholds of pyrethroids for sediment-dwelling marine species are not available at this time, although concentrations as low as 2 µg/kg have been found to be toxic to freshwater amphipods (Amweg et al., 2005).

Total PBDEs

PBDEs, the chemicals used in flame retardants, have recently been labeled as a “chemical of emerging concern” (CEC) (Kimbrough et al., 2009). The first national assessment of PBDEs (completed by the National Oceanic and Atmospheric Administration [NOAA] Mussel Watch Program in 2009) suggests that these chemicals are ubiquitous in coastal environments, and that urban runoff is likely a major source for marine waters.

During the 2013 RHMP, concentrations of total PBDEs were detectable at 77% of stations, and ranged from non-detect (less than 0.05 µg/kg) to 58.5 µg/kg. 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 µg/kg within embayments (Dodder et al., 2012). Thirteen stations (all in San Diego Bay) had concentrations at or above this value; six of these were in the freshwater-influenced stratum, and three were in the industrial/port stratum. The toxicological effects of PBDEs in the marine environment are not well understood; thus, an effects-based threshold for comparison is not currently available. Like PCBs, PBDEs are known to be neurotoxins and endocrine disruptors (Siddigi et al., 2003). They are also known to be bioaccumulative. Hence, PBDEs have been included in the list of analytes evaluated for the food web study (Question 4).

Other Organochlorine Pesticides

A large suite of additional organochlorine pesticides and insecticides (including toxapehene and fipronil) were analyzed and reported for the RHMP. A vast majority of these compounds with few exceptions were non-detected. Two components of the chlordane mixture, *cis*-nonachlor and *trans*-nonachlor were detected in 17% of stations (primarily within the freshwater-influenced stratum). The fungicide hexachlorobenzene was detected in one station within the deep stratum (Station B13-8109). A complete summary of results for all analyzed constituents is provided in Appendix F for reference.

Simultaneously Extracted Metals – Acid Volatile Sulfide (SEM-AVS)

SEM-AVS calculations were performed to assess the potential for heavy metals (cadmium, zinc, lead, silver, and zinc) found in the sediment to cause toxic effects to benthic infauna. A summed SEM to AVS (∑SEM:AVS) ratio value of 40 or higher was considered to be a threshold above which trace metals are likely to become bioavailable at toxic concentrations to sediment dwelling organisms as determined by Weston following a review of published literature and historical data for the RHMP (Weston, 2005b).

Only 3% of the 2013 RHMP stations had ratios of ∑SEM:AVS that exceeded the threshold ratio of 40. This is a notable improvement from the 2008 RHMP, when 27% of the stations exceeded the threshold value (Table 3-10). The two 2013 RHMP stations that exceeded the threshold value of 40 were both in San Diego Bay in the marina stratum (Sites B13-8113 and B13-8117) located within the inner portion of Shelter Island Yacht Basin (SIYB) in San Diego Bay (Figure 3-39).

Table 3-10.
SEM-AVS Exceedances by Stratum

Indicator	Threshold Value[1]	RHMP Data Mean Percent		Percent (%) of 2013 RHMP Stations Below Threshold Value				
		2008	2013	Freshwater-Influenced (%)	Marina (%)	Industrial/Port (%)	Deep (%)	Shallow (%)
∑SEM:AVS Ratio	40	27	3	0	13	0	0	0

Notes:
1. The target value of 40 is a ratio of SEM to AVS.

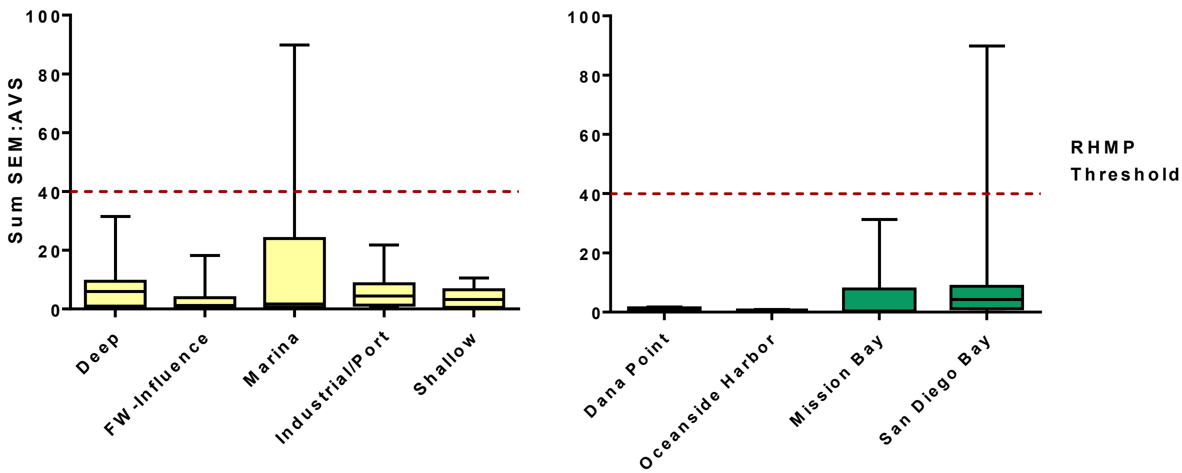


Figure 3-39. Comparisons of Sediment ∑SEM:AVS Ratios in Sediments Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

The bioavailability of metals, as indicated by ∑SEM:AVS, was not statistically correlated with toxicity as measured by the amphipod solid-phase survival tests, or benthic community based on BRI scores (Figure 3-40). Despite the lack of these relationships among all samples, the two stations in SIYB with SEM-AVS ratios >40 did show a moderate toxic effect to amphipod survival (see Section 3.2.2).

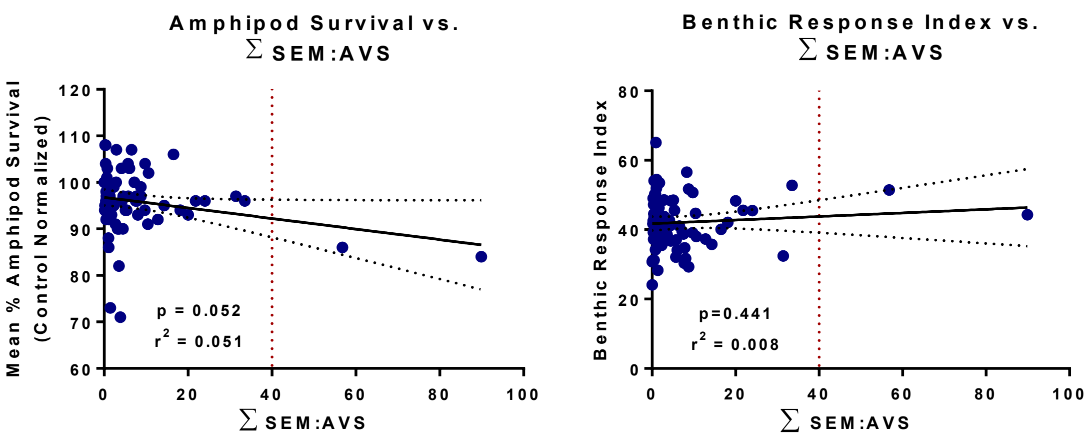


Figure 3-40. Relationship of ∑SEM:AVS to Amphipod Survival and the Benthic Response Index

Calculation of the ESB metric (USEPA, 2005) for the 2013 RHMP data found several stations with values between 130 and 3,000 µmol/g_{OC} considered to potentially result in toxic effects, but none with a value greater than 3,000 µmol/g_{OC} where toxicity is more certain, as shown in Figure 3-41 among all strata and harbors.

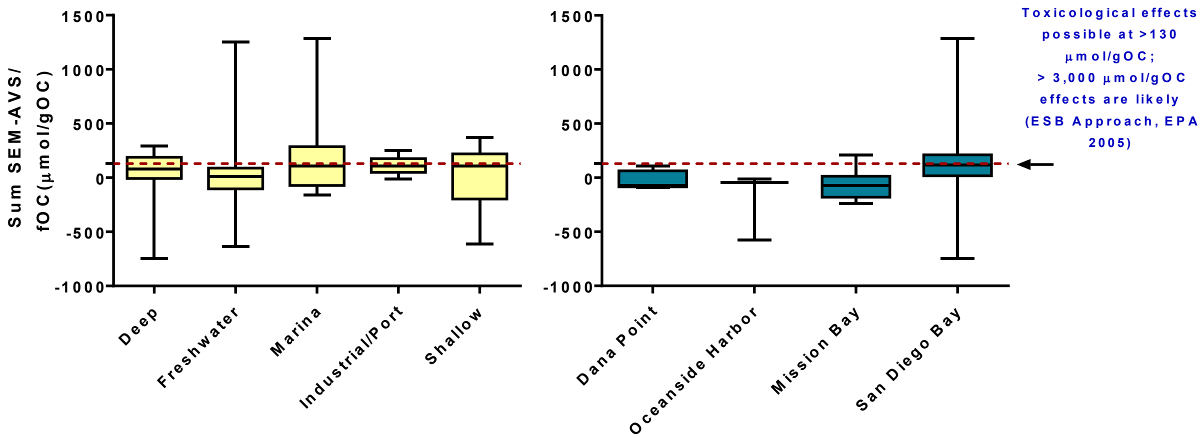


Figure 3-41. Concentrations of SEM-AVS Normalized to Organic Carbon among Strata and Harbors to Assess the Bioavailability of Trace Metals Using the USEPA Equilibrium Partitioning Sediment Benchmark Approach

Box plots showing median, 25th percent quartiles, and range of values

Grain Size and TOC

Sediment TOC and grain size data are summarized in Table 3-8 and provided in Appendix F. Grain size and TOC data are used to help interpret biological responses and to help understand the distribution of contaminants within sediments as elevated TOC and grain size particles tend to be associated with elevated chemistry where anthropogenic influences are likely.

Most of the sediment samples collected within all strata were dominated by fine sediments (i.e., silt and clay) for all five strata and all harbors (Figure 3-42).

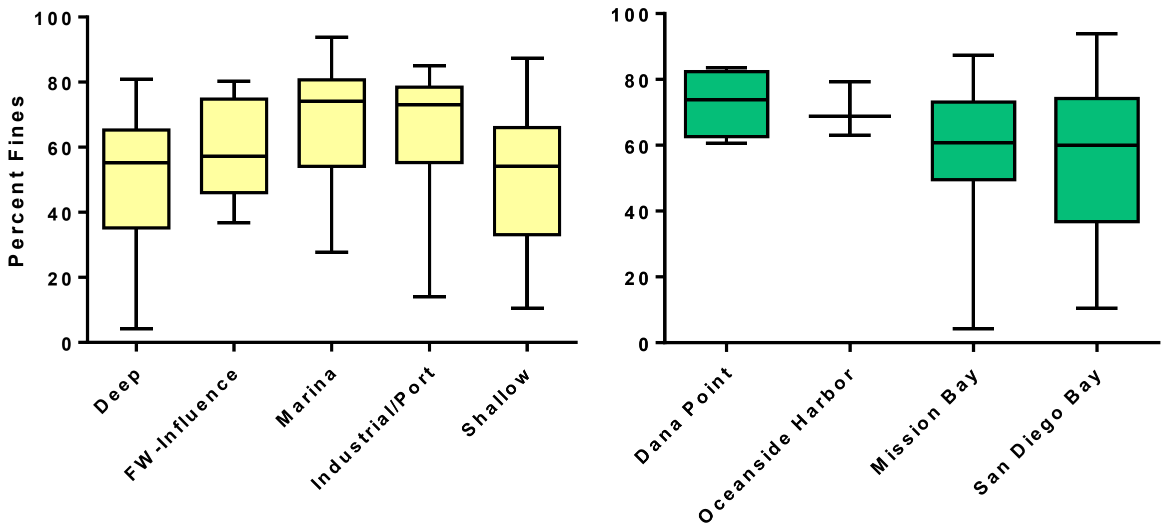


Figure 3-42. Comparisons of Percent Fine Grain Size Fractions Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

Stations with a greater percentage of fine sediments generally had higher fractions of TOC, resulting in a significant positive relationship (Figure 3-43). The integrated ER-M Quotient score was positively associated with percent fines, as generally expected given the greater surface area for chemical binding to occur (see Figure 3-44). The ER-M Quotient, however was not associated with TOC, likely due to the more consistent concentration of TOC across all regions.

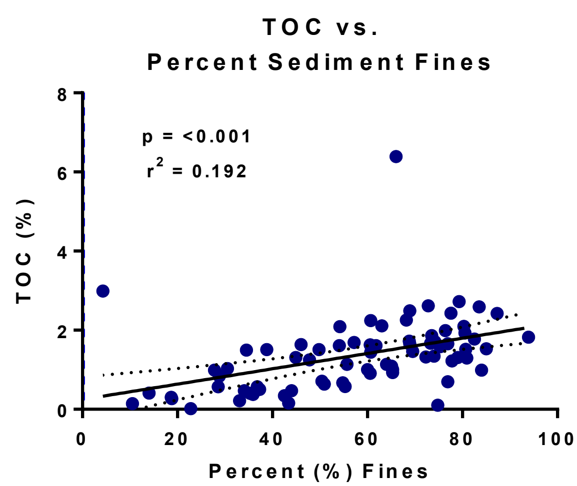


Figure 3-43. Relationship Between TOC and Fine Sediments

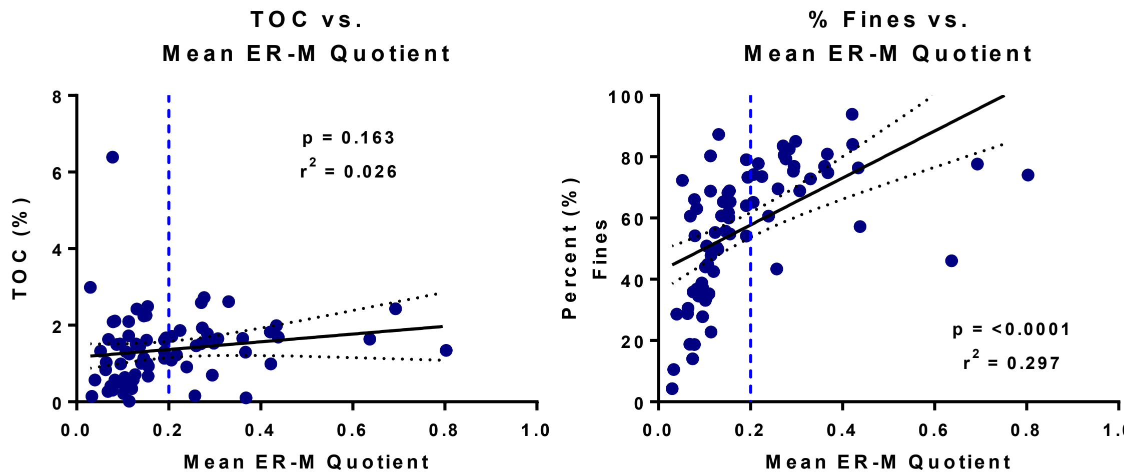


Figure 3-44. Relationship Between TOC and Percent Fine Sediment Relative to Elevated Chemistry Represented by the Mean ER-M Quotient

3.2.1.4 SQO Chemistry Lines of Evidence

Chemical SQO analysis included the integration of two sediment quality guidelines: the CA LRM and the CSI (discussed in the previous section). The integration of these two indices yields the final chemistry LOE, which provides a measure of the estimated magnitude of chemical exposure at each station, based on a scale of four exposure categories (minimal, low, moderate, and high).

54 percent of the 2013 RHMP stations were categorized as having Minimal or Low chemical exposure (Table 3-11). The majority of stations within the deep (88%) and shallow (87%) strata were categorized as having either minimal or low exposure potential. The majority of stations within marina (87%) and industrial/port (78%) strata were categorized as having either moderate or high exposure potential. Overall, the conditions are an improvement from those in 2008, when 44% of RHMP stations were categorized as having minimal or low exposure potential. Across all stations during 2013, the median level of chemical exposure potential was determined to be low.

Table 3-11.
Percentage of RHMP Stations in each Sediment Quality Objective Chemistry LOE Category

Stratum		Percent of Stations Per Category			
		Minimal Exposure (%)	Low Exposure (%)	Moderate Exposure (%)	High Exposure (%)
2008 RHMP – All Data		5	39	49	7
2013 RHMP – All Data		7	47	39	8
2013 Strata	Deep	13	75	13	0
	Freshwater-Influence	7	47	20	27
	Marina	0	13	80	7
	Industrial/Port	7	14	71	7
	Shallow	7	80	13	0

Analysis of each harbor found only San Diego Bay to have stations with high exposure potential following the SQO approach, with 10% (6 of 59) of the stations falling in this category (see Map Figures 3-45d through 3-45f). Three of the harbors were dominated by stations in the low exposure category, while in Dana Point Harbor they comprised 50% (2 of 4) of the stations. Within a given harbor, Mission Bay had the greatest proportion of stations in the minimal exposure potential category (6 of 9 stations; 67%).

These results indicate a general improvement over the 2008 results, when the percentage of stations with minimal or low exposure potential combined was 42% in San Diego Bay, 33% in Oceanside Harbor, and 25% in Dana Point Harbor; values increased to 51%, 67%, and 50% in 2013, respectively. Mission Bay was the only harbor to have an increase in stations with moderate or high exposure (i.e., an increase in chemical exposure risk), increasing from 25% in 2008 to 33% in 2013 based on the increased score for a single location.

A summary of integrated SQO scores showing results for both the CA LRM and CSI (half circles), and an integrated score derived from these two metrics (shown by the outer ring), are displayed on maps for all harbors in Figures 3-45a through 3-45f.

Figure 3-45a. Integrated Chemistry LOE Results using the SQO Approach for Dana Point Harbor

Figure 3-45b. Integrated Chemistry LOE Results using the SQO Approach for for Oceanside Harbor

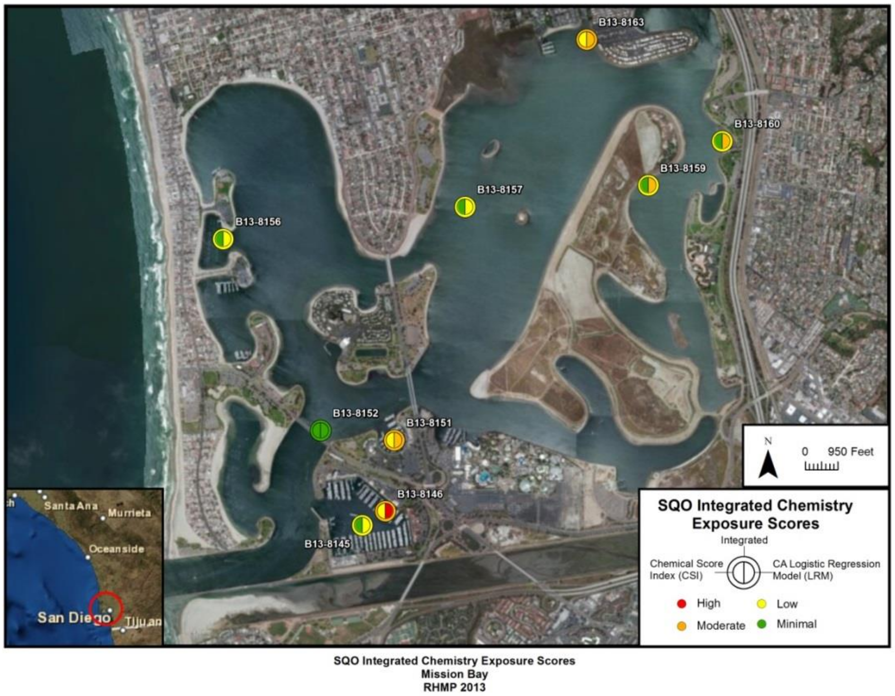


Figure 3-45c. Integrated Chemistry LOE Results using the SQO Approach for Mission Bay

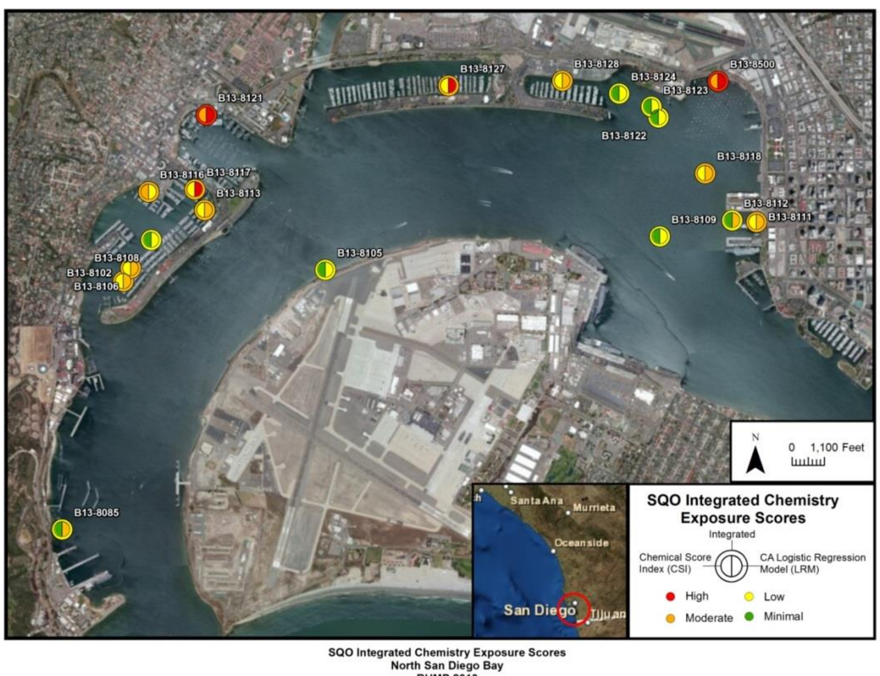
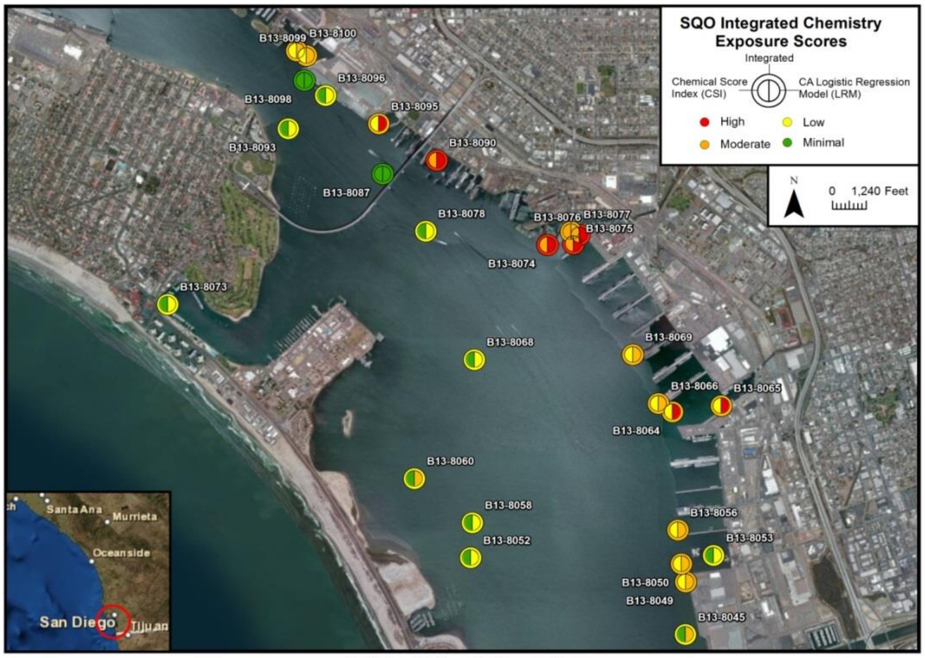
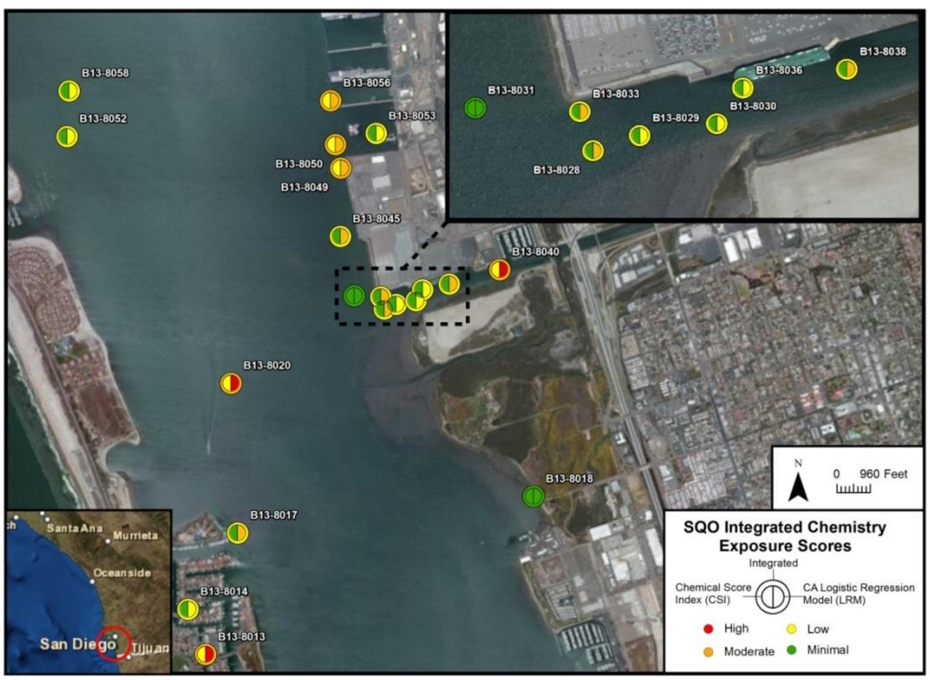


Figure 3-45d. Integrated Chemistry LOE Results using the SQO Approach for Northern San Diego Bay



SQO Integrated Chemistry Exposure Scores
Central San Diego Bay
RHMP 2013

Figure 3-45e. Integrated Chemistry LOE Results using the SQO Approach for for Central San Diego Bay



SQO Integrated Chemistry Exposure Scores
South San Diego Bay
RHMP 2013

Figure 3-45f. Integrated Chemistry LOE Results using the SQO Approach for Southern San Diego Bay

3.2.2 Sediment Toxicity

The 10-day acute solid-phase test using the marine amphipod *E. estuarius* was identified during development of the RHMP as a primary indicator of sediment toxicity, with the 48-hour chronic SWI test using the bivalve *M. galloprovincialis* as a secondary indicator of toxic effects. Both species are consistent with SQO guidance and were used for region-wide testing during Bight ’08 and Bight ’13. Detailed test conditions and acceptability criteria are summarized in the Toxicity Manual for Bight ’13 (SCCWRP, 2013d), and Appendices G-1 and G-2. Results of the sediment toxicity tests for all stations are provided in Appendix G (Table G-3 and G-4 for the amphipod and bivalve tests, respectively). Results of statistical comparisons are presented in Appendix K.

Toxicity was limited throughout all harbors and strata. All 75 stations were considered nontoxic or to have low toxicity according to the integrated SQO scores. Box plots comparing results in 2013 among strata and harbors are presented in Figures 3-46 and 3-48. A cumulative distribution graph showing historical comparisons for the amphipod test is provided in Figure 3-47. Bar graphs comparing results in 2008 to 2013 are provided in Figures 3-49 and 3-50. Individual and integrated SQO scores for toxicity are in Figures 3-51a through 3-51e. A description of results of the two toxicity tests using amphipods and bivalve embryos follows.

3.2.2.1 Primary Toxicity Indicator: Amphipod Survival

Toxicity to amphipods was minimal in every stratum and harbor, with mean control-normalized survival greater than 71% across all samples tested (Figure 3-46). Only two of the 75 stations sampled, both in San Diego Bay, had mortality responses that exceeded the 20% threshold; mean control-normalized survival was 71% in both (Table 3-12).

A pre-set target of 45% represents the fraction of historical samples with results exceeding a 20% effect relative to a control for amphipod survival (less than 80% survival rate). During the 2013 RHMP, toxicity exceeded the 20% effect threshold at just one station in the marina stratum (Station 8127, in East Harbor Island), and one freshwater-influenced station (Station 8031, off the southern corner of the National City Marine Terminal, near the Sweetwater Channel). These collective results are very similar to those observed in 2008 where only 4% of the stations exceeded the 20% effect threshold. Both monitoring periods show improvement over historical conditions across all strata (Table 3-12, Figure 3-47). A summary of historical toxicity results using *E. estuarius* since Bight ’98 in the four RHMP harbors is shown spatially on maps for reference in Appendix G. The stratified randomized design of these four regional monitoring programs provide a consistent basis for statistically robust historic comparisons over time. In addition, as part of the final Bight ’13 Toxicity Report, an interactive scalable map containing results of the amphipod test results conducted in support of the entire Bight regional monitoring program in 1998, Bight ’03, Bight ’08, and Bight ’13 was developed and is available via the following link in the final Bight ’13 Toxicity Report: http://sccwrp.maps.arcgis.com/apps/webappviewer/index.html?id=bb8abeffdce94ef9945d2a8c044c6858. Results for bivalve embryo development tests are also included along with the integrated SQO toxicity scores for Bight ’08 and Bight ’13.

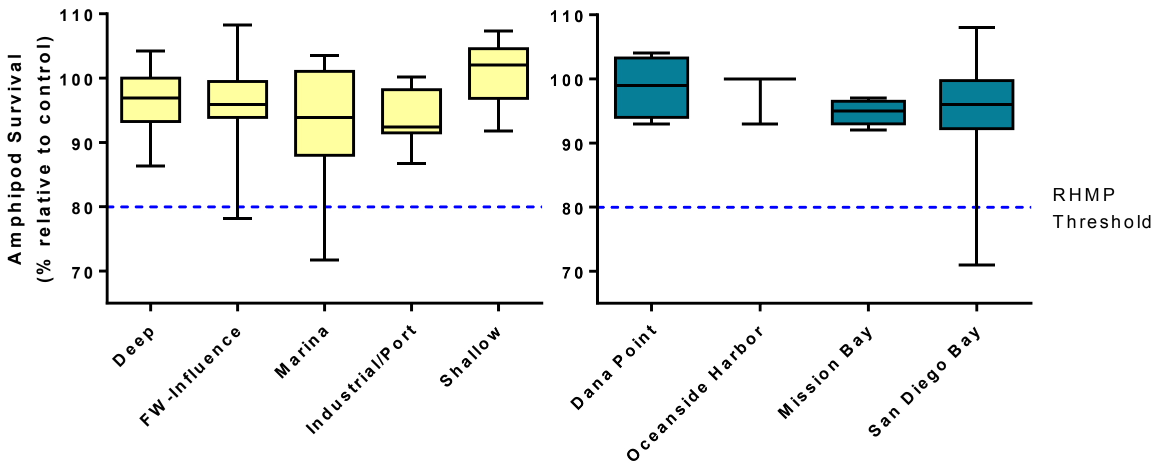


Figure 3-46. Comparisons of Amphipod Survival Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

Table 3-12.
Percent of Stations with Results Exceeding the Threshold for Acute Toxicity to Amphipod Survival

Indicator	Threshold Value	Pre-set Target (%)	RHMP		2013 Strata				
			2008	2013	Deep (%)	Freshwater-Influenced (%)	Marina (%)	Industrial/ Port (%)	Shallow (%)
Amphipod Survival	20% effect relative to control	45%	4%	3%	0%	7%	6%	0%	0%

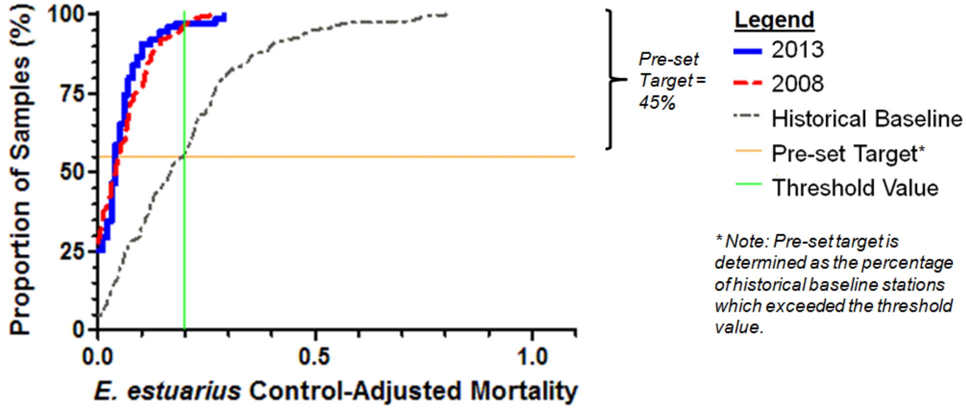


Figure 3-47. Cumulative Distribution Curves for Amphipod Mortality in 2008 and 2013 Compared to Historic Values and the RHMP Pre-set Threshold

3.2.2.2 Secondary Toxicity Indicator: Mediterranean Mussel *Mytilus galloprovincialis*

In 2013, 100% of the stations were considered nontoxic using the chronic bivalve embryo development SWI test following the SQO guidance criteria (Table 3-13; Bay et al., 2014). Mean normal-alive embryo development (normalized to the control), ranged from 81% to 110% across all RHMP sampling stations in 2013. Among all strata, mean percent normal-alive embryo development (normalized to controls) exceeded 90%, ranging from 94% in the industrial/port stratum to 98% in the shallow stratum (Figure 3-48). These values compare to a pre-set target of 60% normal-alive development that was derived during implementation of the 2008 RHMP. This value was based on a 10% effect relative to reported minimum test control performance criteria of 70% normal/alive[12]. An historical data set was not available for this test endpoint, although this test was used in 2008 where 15% of the samples were found to exceed the pre-set threshold (see Figure 3-50). An associated statistically significant improvement was found between the 2008 and 2013 data sets for the bivalve embryo development tests.

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[12] The source for the reported 70% criterion in the 2008 RHMP final report is not referenced. The most relevant current criterion is that reported in the final SQO guidance requiring 80% combined normal-alive embryo development using mussel embryos exposed to sediments using the SWI exposure method (Bay et al., 2014).

**Table 3-13.
Percentage of Stations with Results Below the Threshold for Chronic Toxicity Using the Bivalve Embryo Development SWI Test**

Indicator	Threshold Value	Pre-set Target	RHMP		2013 Strata				
			2008	2013	Deep	Freshwater-Influenced	Marina	Industrial/ Port	Shallow
Bivalve Embryo Development - Normal/alive	40% effect relative to control	40%	15%	0%	0%	0%	0%	0%	0%

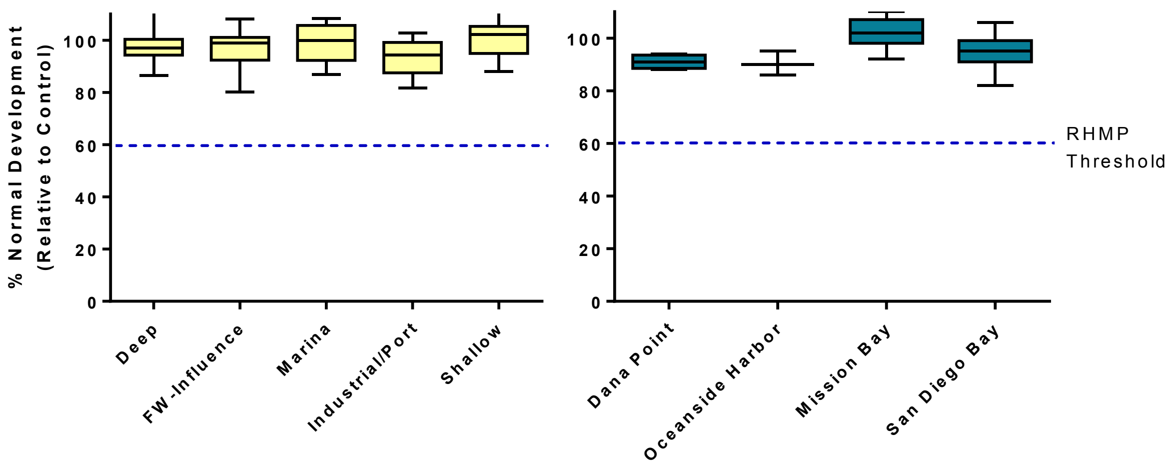


Figure 3-48. Comparisons of Mussel Embryo Development Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

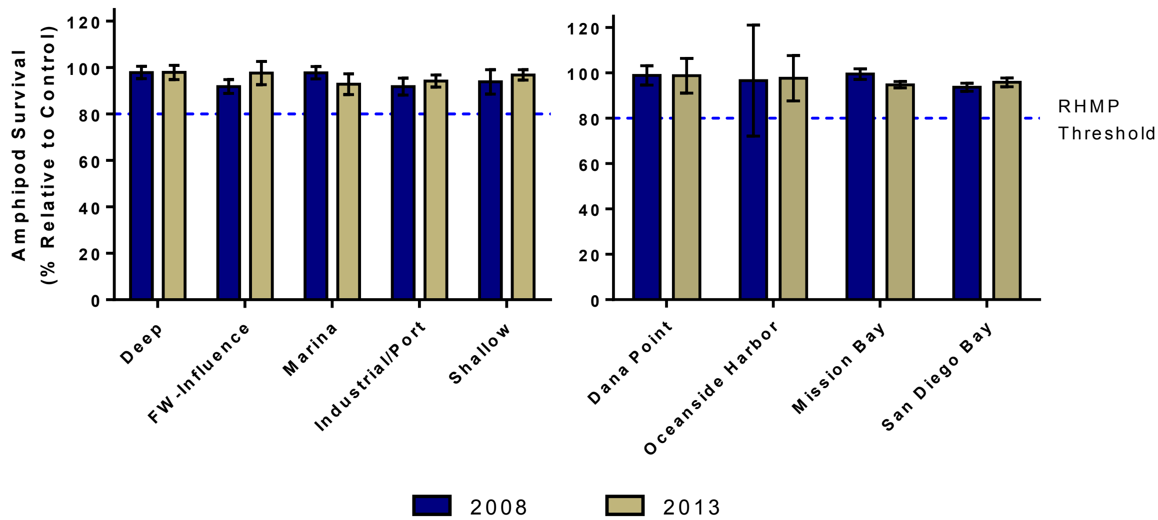


Figure 3-49. Comparisons of Amphipod Survival Among Strata and Harbors (*E. estuarius*) – 2008 and 2013
Mean ± 95% CI

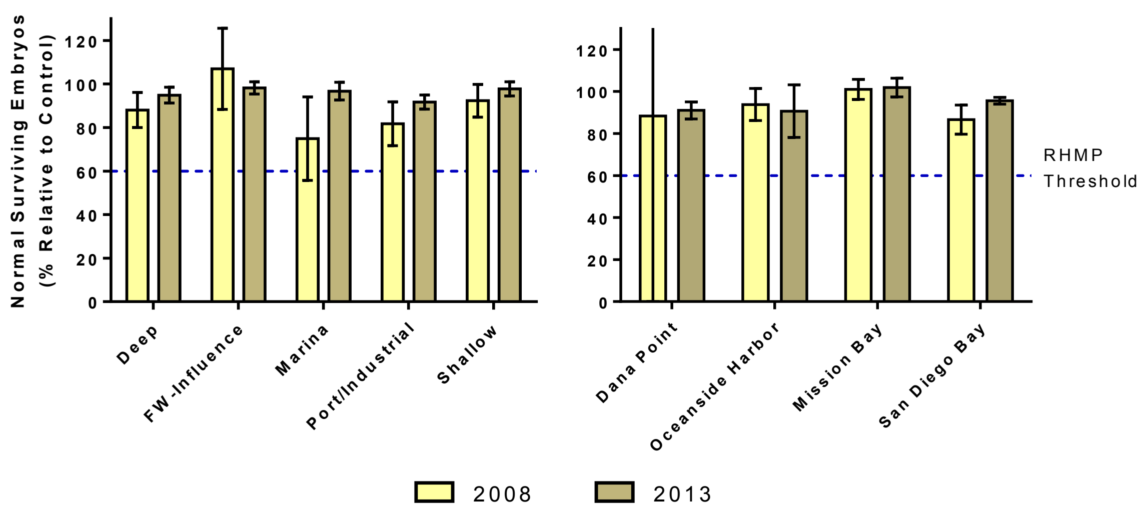


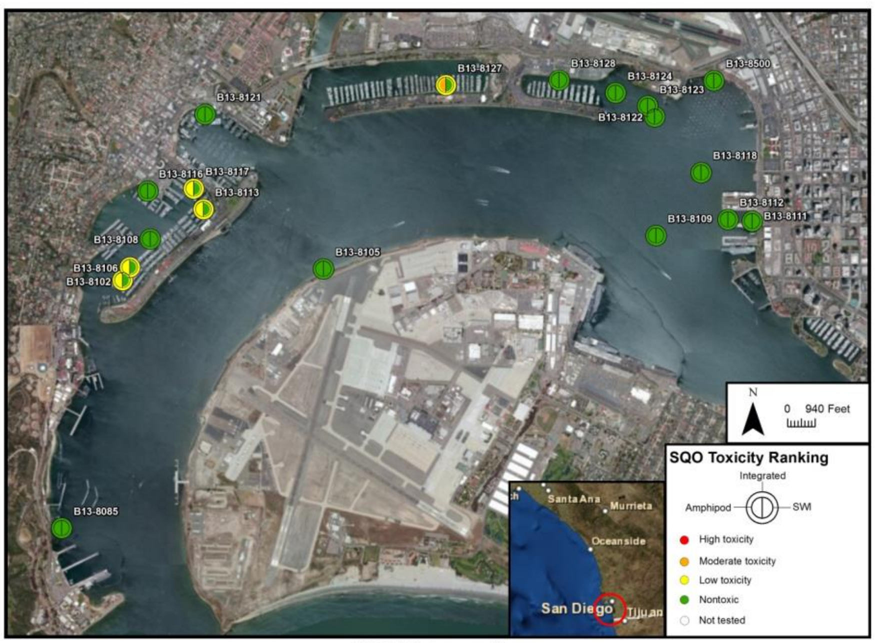
Figure 3-50. Comparisons of Bivalve Embryo Development Among Strata and Harbors (*M. galloprovincialis*) – 2008 and 2013
Mean ± 95% CI

Figure 3-51a. Integrated Toxicity LOE Results Using the SQO Approach for Dana Point Harbor

Figure 3-51b. Integrated Toxicity LOE Results Using the SQO Approach for Oceanside Harbor

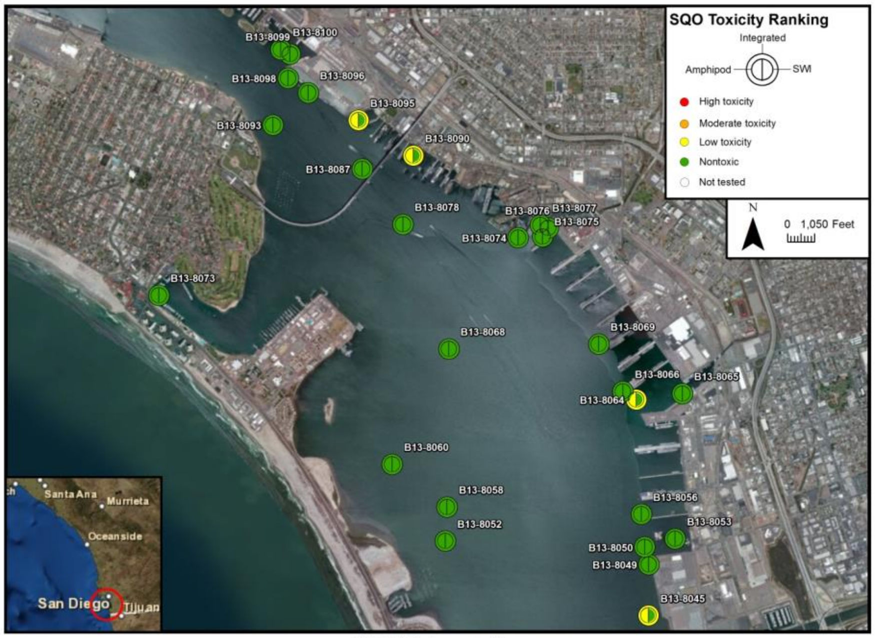
SQO Toxicity Assessment Scores
Mission Bay
RHMP 2013

Figure 3-51c. Integrated Toxicity LOE Results Using the SQO Approach for Mission Bay



SQO Toxicity Assessment Scores
North San Diego Bay
RHMP 2013

Figure 3-51d. Integrated Toxicity LOE Results Using the SQO Approach for Northern San Diego Bay



SQO Toxicity Assessment Scores
Central San Diego Bay
RHMP 2013

Figure 3-51e. Integrated Toxicity LOE Results Using the SQO Approach for Central San Diego Bay

SQO Toxicity Assessment Scores
South San Diego Bay
RHMP 2013

Figure 3-51f. Integrated Toxicity LOE Results Using the SQO Approach for Southern San Diego Bay

3.2.3 Benthic Infauna

Sediment samples were collected and sieved to determine the relative health of the benthic invertebrate community within. The primary indicator of benthic community condition for this analysis was the BRI, while secondary indicators included the SWI and taxa richness (i.e., the number of taxa present). Taxonomic identification and abundance for each taxon encountered in all five strata are provided in Appendix H (Table H-1). Primary and secondary indicator values for all stations are provided in Table H-2 and a summary of SQO benthic community indices is provided in Table H-3. Statistical relationships between benthic infauna community metrics and measures relative to sediment chemistry are shown graphically in Appendix K.

The BRI is an abundance-weighted pollution tolerance score of the organisms present in a benthic sample. For the BRI, lower values indicate a less disturbed benthic community, while for Shannon-Wiener diversity and taxa richness, lower values indicate a more disturbed benthic community. The BRI is also one of the four LOEs that contribute to the SQO analysis and these results are presented in Section 3.2.3.3. Comparisons with historical data used information provided in the previous RHMP report (Weston, 2010).

3.2.3.1 Primary Indicator: Benthic Response Index (BRI)

Results of the 2013 BRI analysis for all RHMP stations combined showed that 40% of the stations were equivalent to a defined reference condition (i.e., a BRI score <39.96), 41% were in the low disturbance category, 19% were in the moderate disturbance category, and none were in the high disturbance category (i.e., a BRI score of >73.27) (Table 3-14). A plot showing BRI scores relative to the SQO thresholds among strata and harbors is presented in Figure 3-52. Historical analyses of the benthic communities in the survey area have shown that stations equivalent to reference condition composed 55% of the stations for pre-2008 surveys and 77% of the stations in 2008. The 2013 survey indicated a decrease in BRI-based reference condition stations from 77% to 40% since 2008.

However, it is important to note that discrepancies in the 2008 analysis for RHMP infauna have been documented during the QA/QC process for this report that appear to have resulted in a bias toward lower (i.e., better) BRI scores in 2008 than that reported. Some of these discrepancies are related to updates in the SQO methodology for infauna classification (i.e., how some species were grouped prior to analyses). The results of this investigation are provided in greater detail for reference at the end of Appendix H. Based on these findings, a valid historical comparison for the BRI response is currently not possible without re-analyzing all prior data, but indications suggest that the results would look very similar to those in 2013.

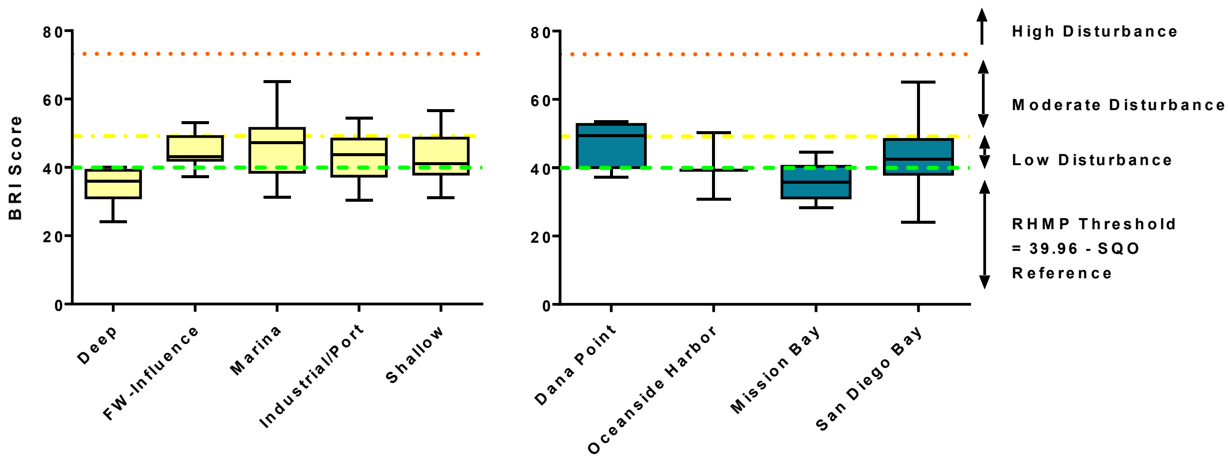


Figure 3-52. Comparisons of Average Benthic Response Index Values Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

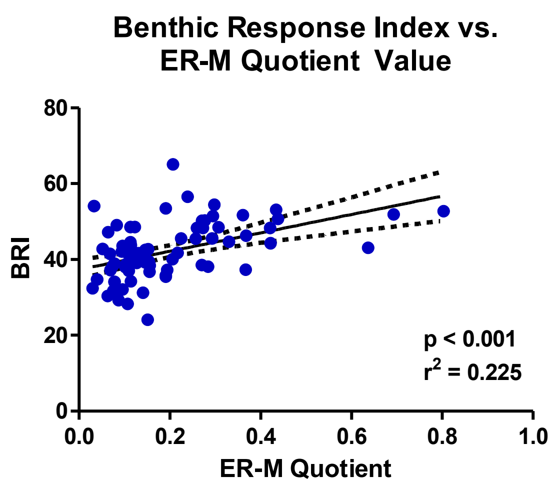
Assessment of stations by stratum indicated that the deep harbor sites have substantially better infaunal community condition than the other strata, with 94% and 6% in the reference and low disturbance categories, respectively, based on the BRI (Table 3-14). All other strata also had most of the stations in these two categories. Freshwater-influenced stations had the lowest percentage in the reference condition (7%). Only 20% were considered to have moderate disturbance and none were considered to have high disturbance. The marina stations had the greatest percentage in the moderate disturbance category (40%).

Table 3-14.
Percentage of RHMP Stations in Each Benthic Response Index Category

Stratum		Percentage of Stations			
		Reference (%)	Low Disturbance (%)	Moderate Disturbance (%)	High Disturbance (%)
2008 RHMP – All Data		77	12	11	0
2013 RHMP – All Data		40	41	19	0
2013 Strata	**Deep**	94	6	0	0
	Freshwater-Influenced	7	73	20	0
	Marina	27	33	40	0
	Industrial/ Port	36	50	14	0
	Shallow	33	47	20	0

Assessment of each harbor individually indicated that Mission Bay had the healthiest benthic community conditions, according to the BRI metric, which classified the bay-wide benthic community as reference with a mean BRI value of 35.9 (Figure 3-52). The average community conditions in Dana Point Harbor, Oceanside Harbor, and San Diego Bay, according to the BRI, were determined to have low disturbance, with mean BRI values of 47.4, 40.1, and 42.9, respectively. Oceanside Harbor, however, had a median BRI score that was within the reference range. In Dana Point Harbor, 25% of the stations were determined to be in reference condition, while 67% of the stations in Oceanside Harbor, 78% of the stations in Mission Bay, and 34% of the stations in San Diego Bay were in reference condition. None of the stations in the RHMP study area were determined to have high disturbance conditions using the BRI scoring metric.

The relationships between the BRI and enhanced sediment chemistry using the integrated chemical measures of the ER-M Quotient and the SQO CSI are shown in Figure 3-53a-b. The CSI score was developed by assessing the relationship between sediment chemistry and benthic community conditions in Southern California bays and estuaries (hence the interest in evaluating this relationship). Statistically significant relationships are shown for both comparisons; however, the degree of predictability represented by r^2 was very low in both cases due to substantial scatter among the data points. Note that the BRI is just one line of evidence used to assess benthic community conditions. This metric has been used as a primary indicator based on widely available historical data that were used to calculate this pre-set target for comparative purposes. The more robust SQO methodology now incorporates the BRI with three other measures of benthic community, as described in Section 3.2.3.3. The SQO method continues to be applied and will become a more relevant basis for analysis of historical benthic community conditions over time.



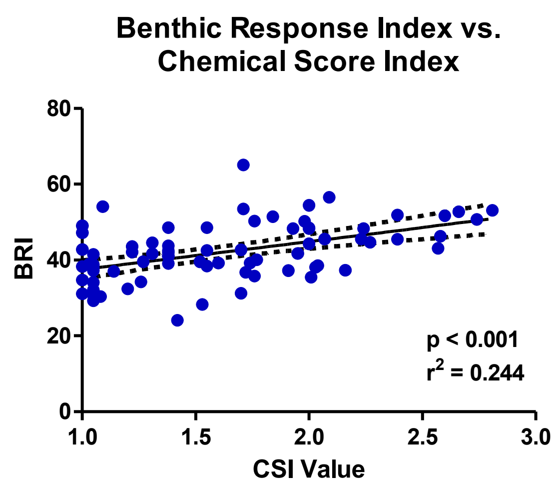


Figure 3-53. Relationship Between the BRI and (a) the Mean ER-M Quotient and (b) the CSI in 2013

The relationship between the BRI and TOC and % fines was also evaluated as these physical parameters alone may also impact biological community structure. With all of the data combined there was a significant relationship between the BRI scores and percent fines, indicating that fine sediments which are often associated with elevated chemistry may have a negative impact on benthic communities (Figure 3-54). There was no significant relationship however between the BRI and other measures of benthic community health and TOC, likely due to the relatively consistent concentration of TOC within and among the harbors and strata. A more in depth analysis of benthic community relationships to chemical constituents and physical parameters is provided in Section 4.5. A number of linear regression relationships between various benthic community measures and chemical and physical parameters also provided in Appendix K.

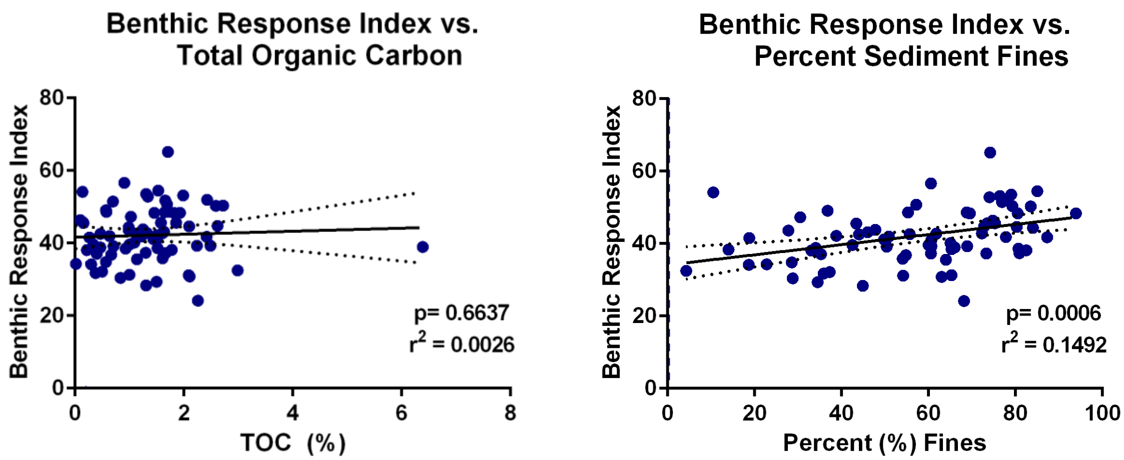


Figure 3-54. Relationship Between the BRI and (a) TOC and (b) Percent Fine Sediment in 2013

3.2.3.2 Secondary Indicators

The Shannon-Wiener diversity index (Shannon-Wiener index) and taxa richness were used as secondary indicators of benthic infaunal community condition for historical comparisons. Both indicators are a measure of taxonomic diversity, but Shannon-Wiener index weights for evenness of the abundance distribution of each taxon in a community, while taxa richness is a simple tally of the number of unique taxa encountered at a station. Higher values are indicative of healthier benthic infaunal communities and, for this analysis, stations with Shannon-Wiener index values greater than 2 and taxa richness values greater than 24 were considered to be equivalent to a reference condition.

Shannon-Wiener Diversity Index

Assessing all 2013 RHMP stations combined, 89% of the stations had Shannon-Wiener index values considered to represent a reference condition (Figure 3-55, Appendix H). By individual harbor, the percentage of stations with SWI values representative of a reference condition was 75% in Dana Point Harbor, 100% in Oceanside Harbor and Mission Bay, and 88% in San Diego Bay. Historically (i.e., the RHMP historical baseline study), 76% of all RHMP stations had SWI

values equivalent to a reference condition, indicating an improvement over past conditions (Figure 3-55). Shannon-Wiener index scores in 2013 were very similar to those determined in 2008, where 91% of the RHMP stations were considered to represent reference conditions based on this metric.

Taxa Richness

Raw taxa richness values indicated slightly poorer benthic community conditions than determined using the Shannon-Weiner index values; however, the results were similar to those identified using the BRI metric. In 2013, 83% of all RHMP stations combined had taxa richness values that were considered to represent a reference condition. These results are similar to historical conditions, when RHMP survey-wide mean taxa richness was 82% pre-2008 and 85% in 2008. By individual harbor, the percentage of stations with taxa richness representative of a reference condition was 50% in Dana Point Harbor, 67% in Oceanside Harbor, 100% in Mission Bay, and 83% in San Diego Bay (Figure 3-56).

Based on the secondary indicators, benthic community quality was generally within the range of historical conditions and appears to be somewhat better than that observed before 2008. Regardless of the primary or secondary indicators described, a significant observation is that a majority of the RHMP stations in all harbors and strata in 2013 were considered to have benthic communities indicative of reference or low disturbance conditions.

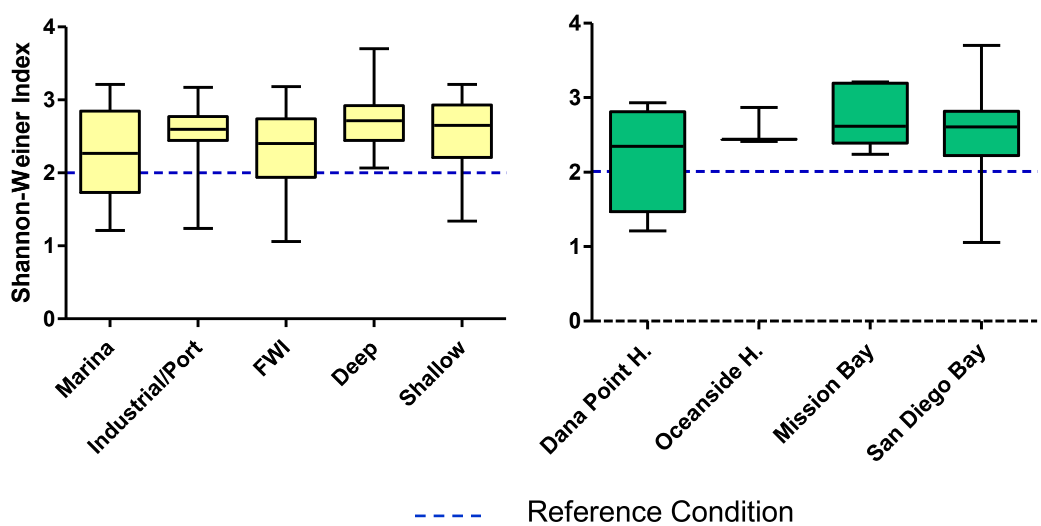


Figure 3-55. Shannon-Weiner Index for Benthic Infauna Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

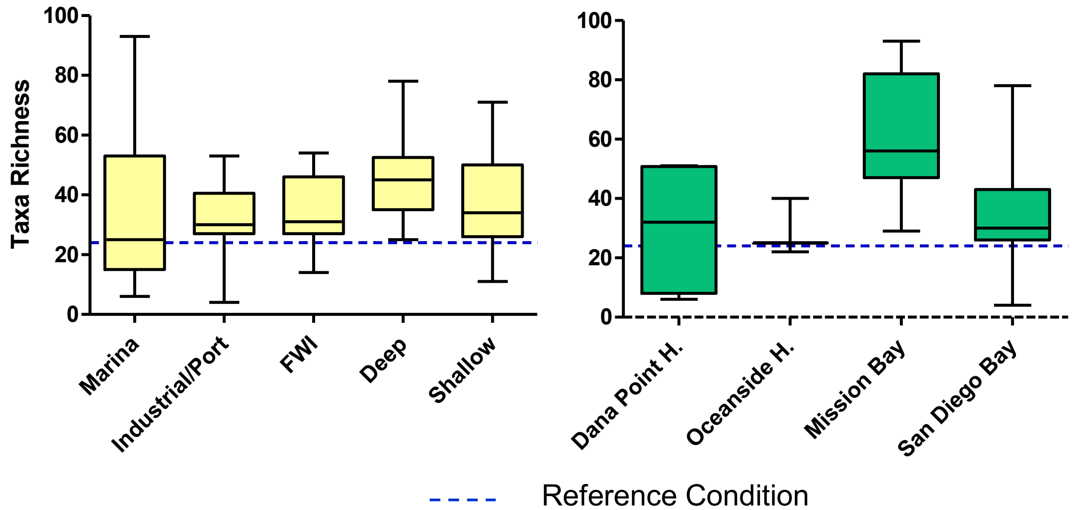


Figure 3-56. Banthic Infauna Taxa Richness Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

3.2.3.3 Benthic Community Condition SQO Lines of Evidence

Benthic community assessments using the SQO benthic LOEs incorporate four indices: the BRI (discussed above), IBI, RBI, and RIVPACS. Each index is calculated and categorized into four disturbance categories (reference, low, moderate, and high disturbance). The highest and lowest index scores are discarded and the final assessment of benthic community disturbance is determined by the two median index scores, as described in the SQO technical guidance document (Bay et al., 2014).

Using the integrated SQO methodology Benthic infaunal communities were categorized as having reference conditions at 21% of all RHMP stations combined and low disturbance conditions at 39% of the stations (Table 3-15). Communities representative of moderate and high disturbance conditions were observed at 35% and 5% of the stations, respectively. By index type, the RBI and RIVPACS rated many more stations in the moderate and high disturbance categories (31 and 45 stations, respectively) than did the BRI and IBI (13 and 5 stations respectively) (Appendix H). As a result, the integrated SQO benthic community score is generally lower than that using the BRI, Shannon-Wiener index, or taxa richness indicators, as described above.

Since 2008, the integrated benthic SQO score indicates a decrease in stations with reference and low disturbance conditions (from 72% in 2008 to 60% in 2013) and an increase in stations with moderate and high disturbance conditions (from 27% in 2008 to 40% in 2013). As mentioned, conclusions based on comparisons of the BRI between 2013 and older data warrant caution because of differences in calculation methods noted for the 2008 data that appear to have skewed those benthic community results higher than they should be.

Table 3-15.
Percentage of RHMP Stations in each Sediment Quality Objective Benthic Community LOE Category

<table>
<tr><th colspan="2" rowspan="2">Stratum</th><th colspan="4">Percentage of Stations</th></tr>
<tr><th>Reference (%)</th><th>Low Disturbance (%)</th><th>Moderate Disturbance (%)</th><th>High Disturbance (%)</th></tr>
<tr><td colspan="2">2008 RHMP – All Data</td><td>31</td><td>41</td><td>27</td><td>0</td></tr>
<tr><td colspan="2">2013 RHMP – All Data</td><td>21</td><td>39</td><td>35</td><td>5</td></tr>
<tr><td rowspan="5">2013 Strata</td><td>Deep</td><td>44</td><td>44</td><td>13</td><td>0</td></tr>
<tr><td>Freshwater-Influenced</td><td>0</td><td>53</td><td>47</td><td>0</td></tr>
<tr><td>Marina</td><td>20</td><td>13</td><td>53</td><td>13</td></tr>
<tr><td>Industrial/ Port</td><td>29</td><td>21</td><td>43</td><td>7</td></tr>
<tr><td>Shallow</td><td>13</td><td>60</td><td>20</td><td>7</td></tr>
</table>

By stratum, the deep harbor stations had the least impacted communities, with 44% in a reference condition and 44% in the low disturbance category. Most shallow water stations (73%) were in the reference and low disturbance categories combined. Freshwater-influenced stations were split between the low disturbance and moderate disturbance categories; however, no stations were categorized as high disturbance. The marina and industrial/port stations showed the greatest impact on benthic infauna, with 66% and 50%, respectively, in the combined moderate and high disturbance categories.

Among harbors, benthic communities in Mission Bay exhibited the best condition, with 88% of stations (8 of 9) in the reference and low disturbance categories combined, one station in the moderate disturbance category, and none in the high disturbance category. In San Diego Bay, 58% of the stations were classified as having communities representative of reference and low disturbance conditions, while 37% were in the moderate disturbance category. Three stations in San Diego Bay (5%) were considered to have high disturbance conditions for the benthic community. Dana Point Harbor had one station in each of the four disturbance categories and Oceanside Harbor had one site considered to have low disturbance and two sites with moderate disturbance conditions.

Integrated benthic community SQO scores are summarized by stratum and harbor in Figure 3-57. Integrated benthic community SQO scores showing results for all four benthic indices (quarter circles), and an integrated score derived from these four metrics (shown by the outer ring) are displayed on maps for all harbors in Figures 3-58a through 3-58f.

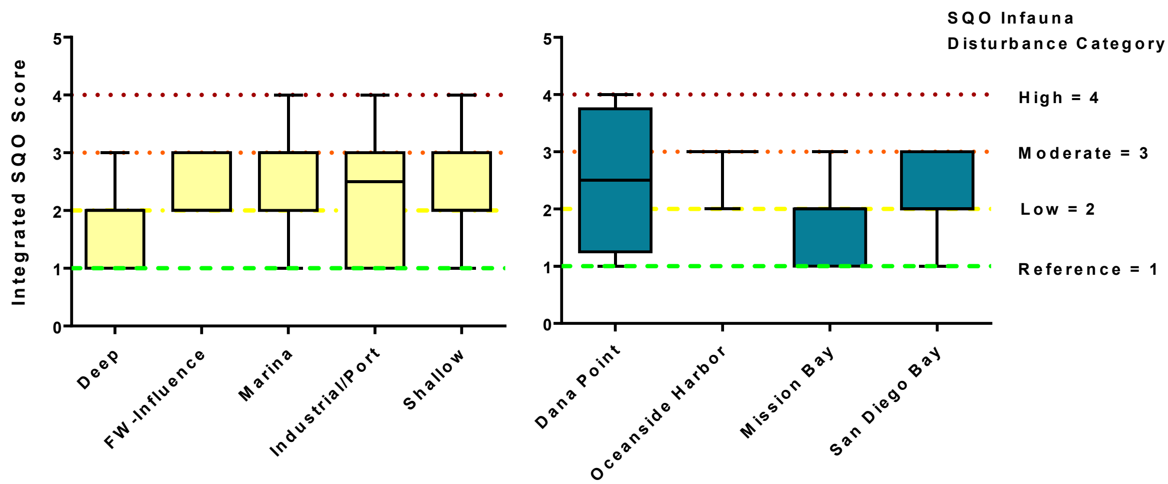


Figure 3-57. Comparisons of the Integrated SQO Benthic Infaunal Community Score Among Strata and Harbors

Box plots showing median, 25th percent quartiles, and range of values

Figure 3-58a. Integrated Benthic Community LOE Results Using the SQO Approach for Dana Point Harbor

Figure 3-58b. Integrated Benthic Community LOE Results Using the SQO Approach for Oceanside Harbor

Figure 3-58c. Integrated Benthic Community LOE Results Using the SQO Approach for Mission Bay

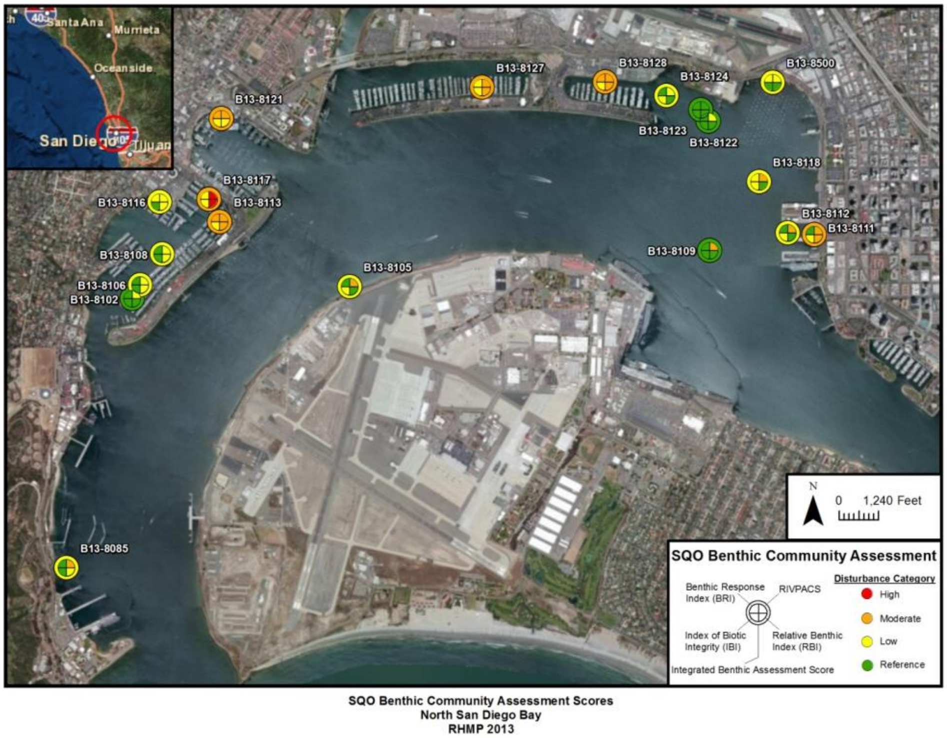


Figure 3-58d. Integrated Benthic Community LOE Results Using the SQO Approach for Northern San Diego Bay

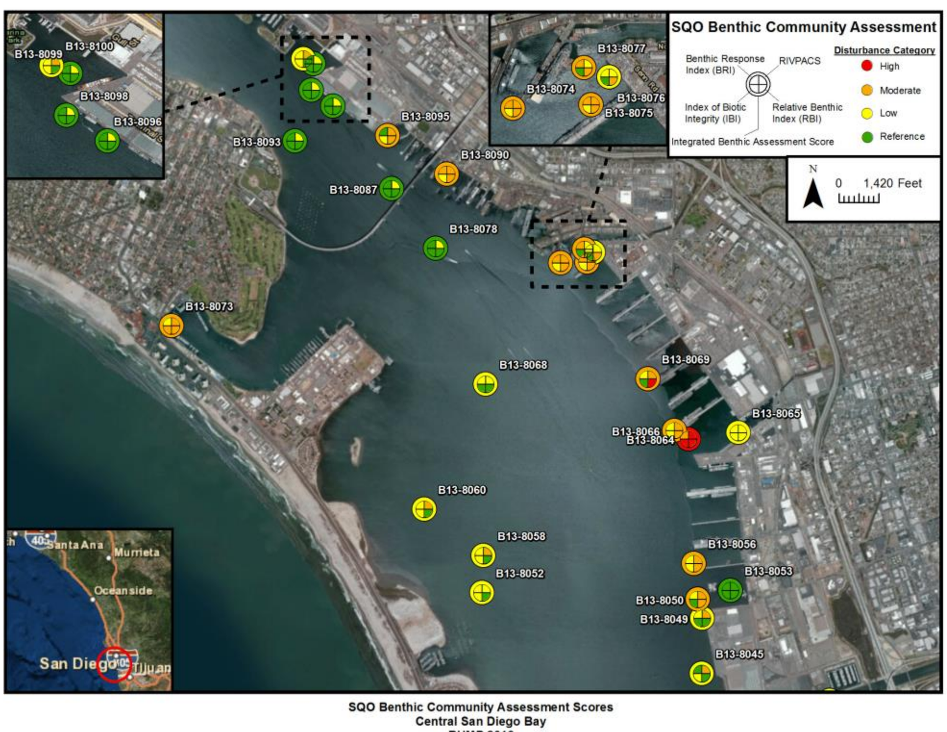


Figure 3-58e. Integrated Benthic Community LOE Results Using the SQO Approach for Central San Diego Bay

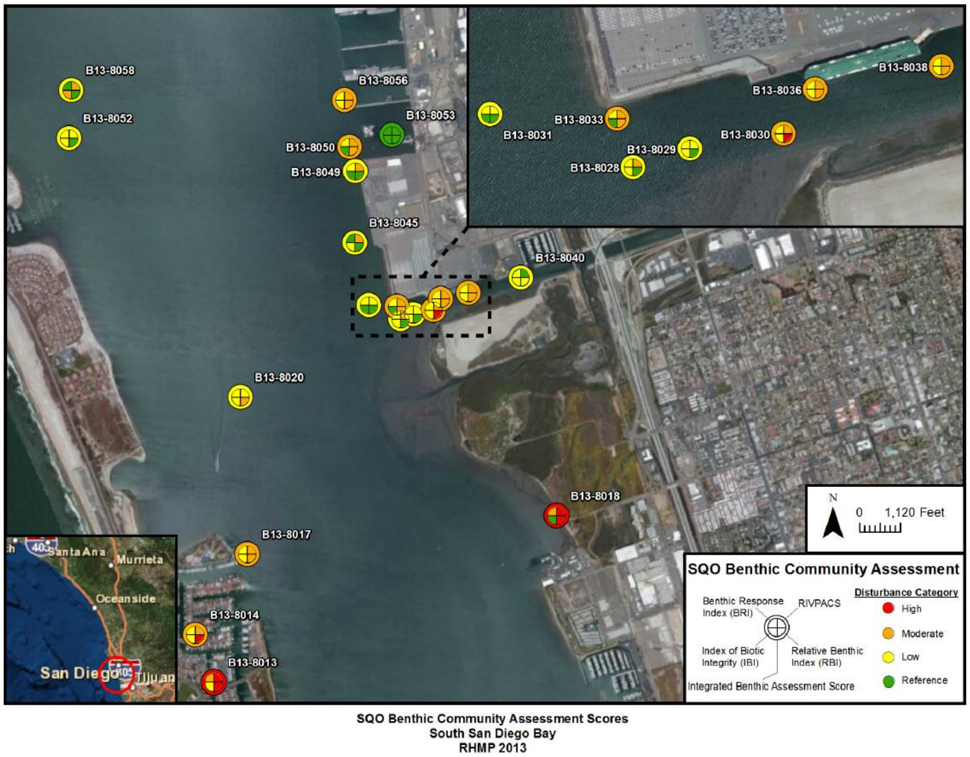


Figure 3-58f. Integrated Benthic Community LOE Results Using the SQO Approach for Southern San Diego Bay

3.2.3.4 Overall SQO Station Assessment

As described previously, an integrated measure of the quality of sediments for RHMP is assessed using the SQO guidelines based on the three LOEs highlighted in the previous sections, including sediment chemistry, laboratory-based toxicity, and benthic infaunal community condition. This MLOE approach evaluates both the severity of measured biological effects and the potential for chemically mediated effects, and integrates the three LOEs to provide an overall station-level assessment of sediment quality. The assessment places a station into one of five qualitative condition categories, ranging from unimpacted to clearly impacted. The specific methods associated with each LOE and the integration of the MLOEs are described in the *Water Quality Control Plan for Enclosed Bays and Estuaries—Part 1, Sediment Quality* (SWRCB and Cal/EPA, 2009). Overall SQO station assessments and individual LOE assessments for all stations are provided in Appendix J.

Combining all of the 2013 RHMP stations, the overall SQO assessment identified 48% of stations as unimpacted, 24% as likely unimpacted, 13% as possibly impacted, and 15% as likely impacted (Table 3-16, Figures 3-59a through 3-59f). There were no stations that were considered to be clearly impacted. This is an improvement over the 2008 RHMP results, as the combined percentage of stations that were unimpacted and likely unimpacted was 64%, compared with 72% of stations that were unimpacted or likely unimpacted in 2013.

By stratum, the overall SQO assessment identified the deep and shallow water stations as having the best sediment quality. These strata had 94% and 93%, respectively, of stations in the unimpacted and likely unimpacted condition categories combined. The freshwater-influenced stratum had 80% of stations within these two categories. The marina and industrial/port strata had 40% and 50% of the stations in the unimpacted and likely unimpacted condition categories, respectively. Compared with the 2008 results, all strata showed improvement in sediment quality except the industrial/port stratum, with 60% of the stations in 2008 identified as unimpacted or likely unimpacted, compared with 50% of stations in 2013 in these two categories.

Table 3-16.
Percentage of RHMP Stations in Each Overall Sediment Quality Objective Station Assessment Category

Stratum		Overall SQO Station Assessment (Percent)				
		Unimpacted (%)	Likely Unimpacted (%)	Possibly Impacted (%)	Likely Impacted (%)	Clearly Impacted (%)
2008 RHMP – All Data*		55	9	23	11	1
2013 RHMP – All Data		48	24	13	15	0
2013 Strata	Deep	81	13	6	0	0
2013 Strata	Freshwater-Influenced	33	47	7	13	0
2013 Strata	Marina	7	33	20	40	0
2013 Strata	Industrial/ Port	43	7	29	21	0
2013 Strata	Shallow	73	20	7	0	0

Notes:
* Percentages do not sum to 100% because of an inconclusive sample collected at one location in 2008.

Sediment quality differed among harbors. Overall, Mission Bay had sediment quality conditions that were scored as the least impacted, with six of the nine stations classified as unimpacted and the other three as likely unimpacted (Figure 3-59c). Dana Point Harbor, Oceanside Harbor, and San Diego Bay had variable results among the stations monitored. Two of the stations in Dana Point Harbor were classified as unimpacted, one as possibly impacted, and one as likely impacted (Figure 3-59a). In Oceanside Harbor, the three stations were all different, with classifications of unimpacted, likely unimpacted, and likely impacted (Figure 3-59b). In San Diego Bay, 70% of the stations were classified as unimpacted or likely unimpacted, combined (Figures 3-59d through 3-59f).

Figure 3-59a. Final Integrated Sediment Quality Objective Scores for Dana Point Harbor

Figure 3-59b. Final Integrated Sediment Quality Objective Scores for Oceanside Harbor

Figure 3-59c. Final Integrated Sediment Quality Objective Scores for Mission Bay

SQO Integrated Assessment Scores
North San Diego Bay
RHMP 2013

Figure 3-59d. Final Integrated Sediment Quality Objective Scores for Northern San Diego Bay

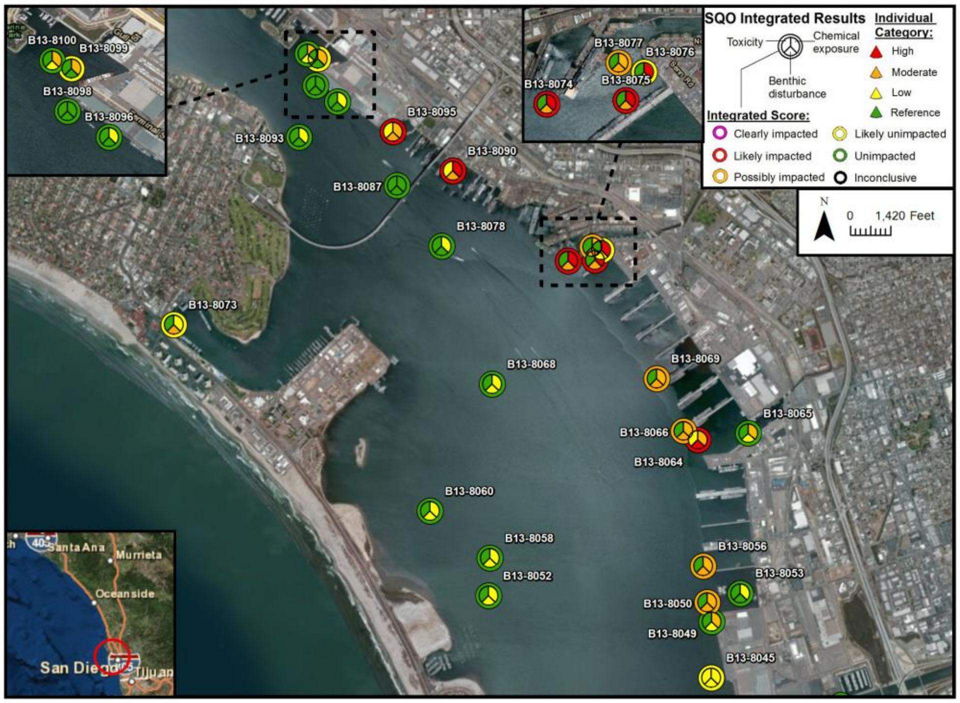


Figure 3-59e. Final Integrated Sediment Quality Objective Scores for Central San Diego Bay

Figure 3-59f. Final Integrated Sediment Quality Objective Scores for Southern San Diego Bay

3.3 Demersal Fish and Macroinvertebrate Community

Otter trawls were conducted for a period of approximately 5 minutes at 15 stations total to sample the demersal fish and epibenthic macroinvertebrate communities in the harbors. The complete results of the trawl surveys are presented in Appendix I, with fish data summaries and metrics provided in Tables I-1 through Table I-5 and macroinvertebrate data summaries and metrics in Table I-6 through Table I-11.

3.3.1 Fish Community

Fish abundance for all 15 stations in the four harbors totaled 2,134 individuals, representing 33 different species (Table I-1). For all taxa across harbors, the slough anchovy (*Anchoa delicatissima*), queenfish (*Seriphus politus*), deepbody anchovy (*Anchoa compressa*), California lizardfish (*Synodus lucioceps*), and round stingrays (*Urobatis halleri*) had the greatest number of individuals. Fish abundance per trawl was greatest at central San Diego Bay Station 8052, with 517 individuals, and was lowest at southern San Diego Bay Station 8029, with only 6 individuals captured. A summary of the top 10 fish species caught among all harbors is provided in Figure 3-30 normalized to the number of trawls performed in each region.

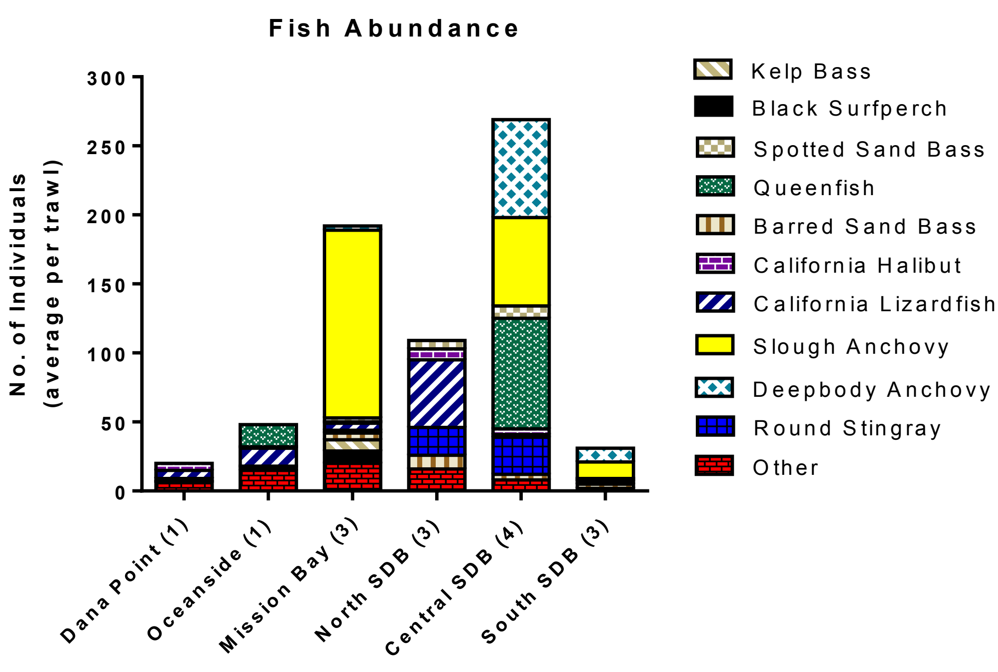


Figure 3-60. Abundance of the Top Fish Species Captured During Trawls among Harbors

The value in parentheses in the x-axis labels represents the # of trawls performed for each location. The total numbers on the y-axis represent an average for each trawl when more than one was performed for a given region.

The most frequently encountered fish species (i.e., the species collected at the most stations) was determined by calculating the percent frequency of trawl capture (i.e., the number of stations with species present divided by the total number of stations across harbors). The trawl capture frequencies were 93% for California halibut (*Paralichthys californicus*), which was caught at 14 of the 15 trawl stations; 87% for the barred sand bass (*Paralabrax nebulifer*), caught at 13 stations; and 80% for the round stingray (*Urobatis halleri*), caught at 12 stations.

Mean abundance per trawl of individuals by harbor was greatest in Mission Bay, with an average of 191 fish per haul (n=3) where the catch was dominated by the slough anchovy (Table H-1). Dana Point Harbor had 27 fish captured in a single trawl, dominated by lizardfish (*Synodus lucioceps*) and California halibut; Oceanside Harbor had 48 fish captured in a single trawl dominated by queenfish and lizardfish; San Diego Bay had a mean of 149 fish per trawl among all three regions (n=10), dominated by the slough anchovy, deepbody anchovy, and queenfish (*Seriphus politus*).

Fish biomass for all 15 stations totaled 177 kg (Appendix I, Table I-2). The total biomass of fish captured in each of the harbors is shown in Figure 3-61 normalized to the number of trawls performed in each region. Across harbors, species comprising the highest percentages of total catch biomass regionally were the round stingray (*Urobatis halleri*), comprising 46% of the total biomass; the bat ray (*Myliobatis californica*) at 13% of the biomass, and the spotted sandbass (*Paralabrax maculatofasciatus*) at 11% of the biomass. Fish biomass per trawl was greatest at central San Diego Bay Station 8052, with 35.7 kg of fish; the lowest total fish biomass was at southern San Diego Bay Station 8020, with 0.4 kg of fish.

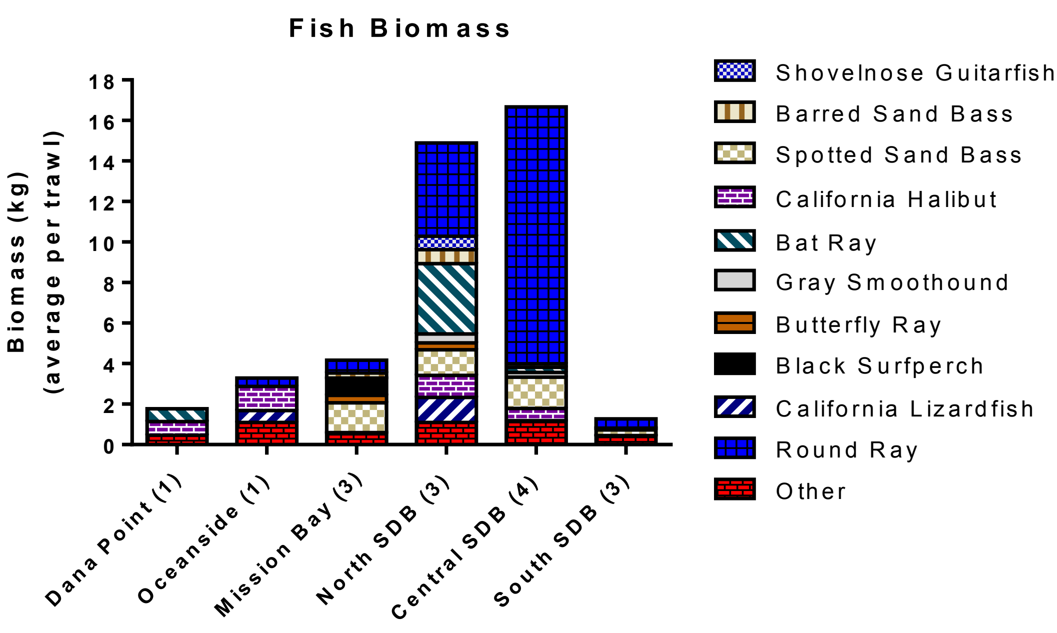


Figure 3-61. Biomass of Top Fish Species Captured During Trawls among Harbors

The value in parentheses in the x-axis labels represents the # of trawls performed for each location. The total numbers on the y-axis represent an average for each trawl when more than one was performed for a given region.

By harbor, mean biomass was highest in San Diego Bay, with an average of 11.1 kg of fish captured per station. Mission Bay had a mean of 4.7 kg of fish captured per station; Oceanside Harbor had a mean of 3.8 kg of fish captured per station; and Dana Point Harbor had a mean of 2.4 kg fish per station.

3.3.1.1 Fish Community Metrics

The Ecological Index (EI) is a metric based on the percentage of individual fish collected, the percentage of biomass, and the percentage of frequency of occurrence (VRG 2009). The EI values were calculated for each individual species (Appendix I). Table I-4 and Figure 3-62 present the ranked EI values of the top three fish species collected from the four harbors separately. The five species with the highest EI value across all harbors were the round stingray, slough anchovy, spotted sand bass, California halibut, and deepbody anchovy. In Dana Point Harbor, the three species with the highest EI value were California halibut, California lizardfish, and the bat ray. In Oceanside Harbor, the three species with the highest EI value were the California lizardfish, the queenfish, and the California halibut. In Mission Bay, the three species with the highest EI value were the slough anchovy, spotted sand bass, and round stingray. In San Diego Bay, the fish species with the highest EI values were the round stingray, the slough anchovy, and the deepbody anchovy.

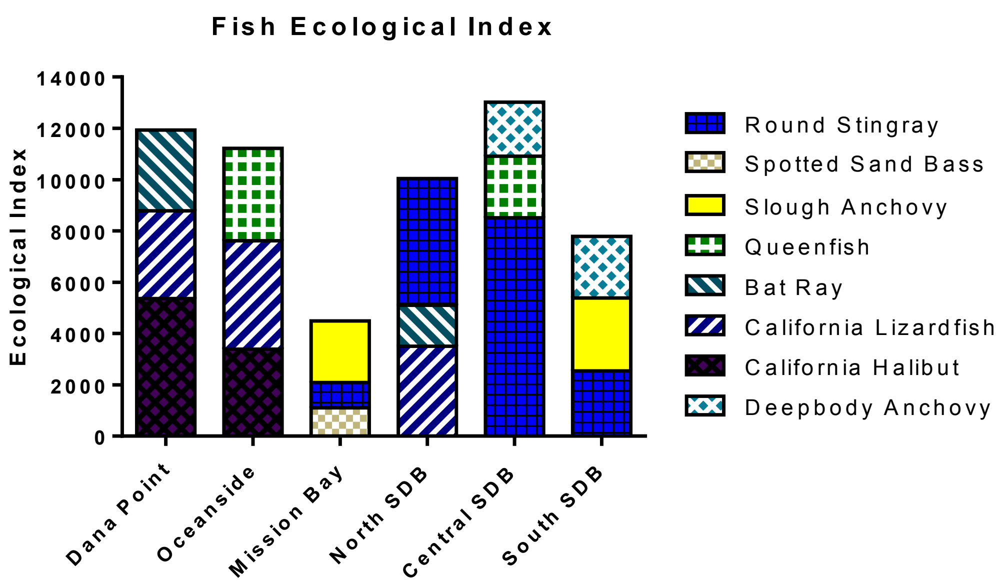


Figure 3-62. Ecological Index for the Top Three Scoring Fish Species Captured During Trawls in Each Harbor

Mean species richness for all stations was 9.1 species per station (Appendix I, Table I-3). The regional mean Shannon-Wiener diversity index was 1.49 (the same regional value from Bight '08); the regional mean Pielou's evenness value was 0.7 for all stations; and the regional mean dominance index was 2.9. The regional mean for dominance (i.e., percent composition of

the most abundant taxon) was 43.6%. Species richness was highest (15 species) at north-central San Diego Bay Station 8109, and was lowest (4 species each) at two southern San Diego Bay Stations 8029 and 8020. Shannon-Wiener diversity was both highest and lowest at stations in Mission Bay, where Station 8156 in western Mission Bay had a value of 2.25 and Station 8159 in eastern Mission Bay had a value of 0.24. Despite southern San Diego Bay Station 8029 having the lowest taxa richness, it exhibited the highest evenness index value (0.96), whereas Mission Bay Station 8159 (also with the lowest Shannon-Wiener Index value) exhibited an evenness index of 0.12. Percent dominance of the most abundant taxa was greatest at Mission Bay Station 8159, where the slough anchovy comprised 95.8% of the catch by number of individuals. There was also a low evenness index at this station, with the lowest evenness index at south-central San Diego Bay Station 8060, with a dominance value of only 14.4%. See Appendix I for a full summary of data. One notable observation for all harbors was the proportion of top predators observed (i.e. sharks, rays, halibut, and bass), ranging from 30 percent in Oceanside Harbor to 70 percent in Dana Point Harbor based on the average number of individuals per trawl (See Appendix I-3). The bay-wide average proportion of predators per trawl for both Mission Bay and San Diego Bay was 40 percent based on the number of individuals caught. Various studies suggest that top predators promote species richness and may be good indicators of overall ecological health (Sergio et al., 2008).

3.3.1.2 Cluster Analysis for Fish Populations

To assess regional fish assemblage structure, a Bray-Curtis dissimilarity matrix was created from all co-occurring fish species (Figure 3-63). Fish community assemblages were most similar between Dana Point and Oceanside Harbors, with four of the five stations clustering together, primarily due to the presence of white seaperch (*Phanerodon furcatus*) and spotfin croaker (*Roncador stearnsii*). Seven of the 10 San Diego Bay stations clustered due to the consistent presence of California halibut, barred sandbass, and spotted sandbass. These three species were collected from at least one station in every harbor and were the most ubiquitous species in the study. The three Mission Bay stations were classified in separate clusters, based on co-occurrence of one or two species.

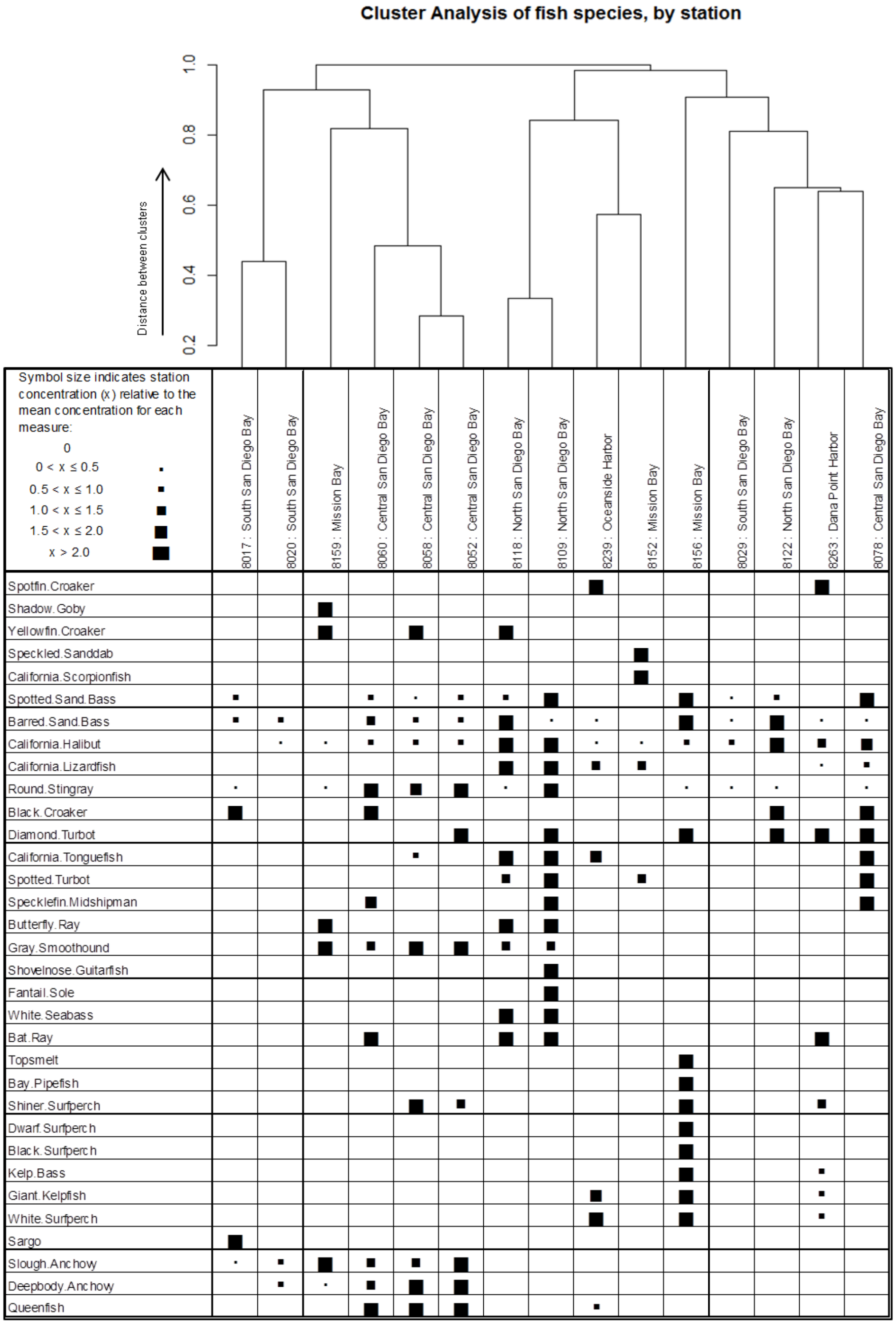


Figure 3-63. Cluster Analysis of Captured Fish Species and Station Locations

3.3.1.3 Fish Health

Overall, the fish captured appeared healthy, and most specimens had normal color and energy. External anomalies such as lesions, tumors, and fin erosion were very rare, observed for only two fish caught in San Diego Bay; one spotted turbot had both ambicoloration and a fin deformation, and a spotted sand bass had a skeletal deformity and fin erosion (Table 3-17). Three fish, all in Mission Bay (one at each sampling station), were noted to have external parasites, including an eye parasite on a slough anchovy, a gill parasite on a California lizardfish, and an external parasite on the caudal peduncle of a kelp bass. This represented a frequency of parasitism of 0.18% of the specimens caught study-wide; however, the incidence of the parasite *Nerocila sp.* was likely more common than observed, as free-swimming individuals were occasionally noted in the processing tubs but could not be associated with specific fish.

Table 3-17.
Fish Anomalies and Parasites Identified from Benthic Trawls

Station	Harbor	Sample Date	Species	Common Name	Size Class (cm)	Anomaly
B13-8159	Mission Bay	8/8/2013	*Anchoa delicatissima*	Slough anchovy	N/A	Copepod eye parasite
B13-8152	Mission Bay	9/11/2013	*Synodus lucioceps*	California lizardfish	12	Gill parasite
B13-8156	Mission Bay	9/11/2013	*Paralabrax clathratus*	Kelp bass	12-14	External caudal peduncle parasite
B13-8109	San Diego Bay	9/3/2013	*Plueronichthys ritteri*	Spotted turbot	11-16	Ambicoloration and fin deformation
B13-8029	San Diego Bay	9/5/2013	*Paralabrax maculatofasciatus*	Spotted sand bass	21	Skeletal deformity, fin erosion

3.3.1.4 Historical Comparison for Fish Catch

Historical comparisons with the RHMP study were made on the basis of abundance, diversity, and biomass data from prior Bight studies for the four harbors as a whole (Table 3-18). Additional historical information from fish studies in San Diego Bay was compiled from Allen (1999) and the Vantuna Research Group (VRG, 2006) as presented in Table 3-19. The Allen and VRG studies combined information from numerous gear types (versus the RHMP study, which was limited to otter trawls), so comparisons must be made with this in mind.

Average species richness and abundances by harbor for the 2008 RHMP and 2013 RHMP data are shown in Figure 3-64 for comparison. In 2013, increases in average species richness (diversity) per trawl were observed in Dana Point Harbor, Mission Bay, and northern and central San Diego Bay. Diversity was very similar in Oceanside Harbor and southern San Diego Bay between the 2008 and 2013 monitoring events. Average fish abundance increased in 2013 in Oceanside Harbor, Mission Bay, and northern and central San Diego Bay. Dana Point Harbor and southern San Diego Bay both exhibited slight decreases in average abundances in 2013.

A summary comparing fish species diversity, biomass, and abundance during RHMP in 2008 and 2013 relative to that during the Bight ’98 and Bight ’03 programs is provided in Table 3-18 (Allen et al., 2002; Allen et al., 2007; and Weston, 2010). The values for Bight ’98 and Bight ’03 were calculated from the same four harbors that were sampled for the RHMP, but with a different number of stations sampled in each survey. Note that many of the trawls performed in 1998, 2003, and 2008 were 5 minutes in duration, while all trawls performed in 2013 were 10-minutes in duration. Catch and diversity data were normalized to a 10-minute duration as described in the regional Bight monitoring reports (Allen et al. 2002 and 2007). The mean number of species per trawl was relatively similar for all four monitoring surveys, ranging from six species per trawl in the Bight ’03, to nine species per trawl in both the 2008 and the 2013 RHMP. A total of 33 unique fish species were caught in RHMP 2013, compared to a 43 species extrapolated estimate in 2008, 17 species in Bight ’03, and 26 species in Bight ’98. Mean abundance per trawl for the 2013 RHMP was much higher than for the three prior Bight/RHMP surveys, with a mean of 142 individuals per trawl in 2013 compared with an estimated mean of 48 individuals per trawl during the 2008 RHMP, 66 individuals per trawl in Bight ’03, and 60 individuals per trawl in Bight ’98. Mean biomass per trawl was also greatest in the 2013 RHMP with 9.1 kg of fish per trawl; compared to an extrapolated estimate of 5.6 kg per trawl in 2008, 6.1 kg per trawl during Bight ’03, and 7.2 kg per trawl during Bight ’08.

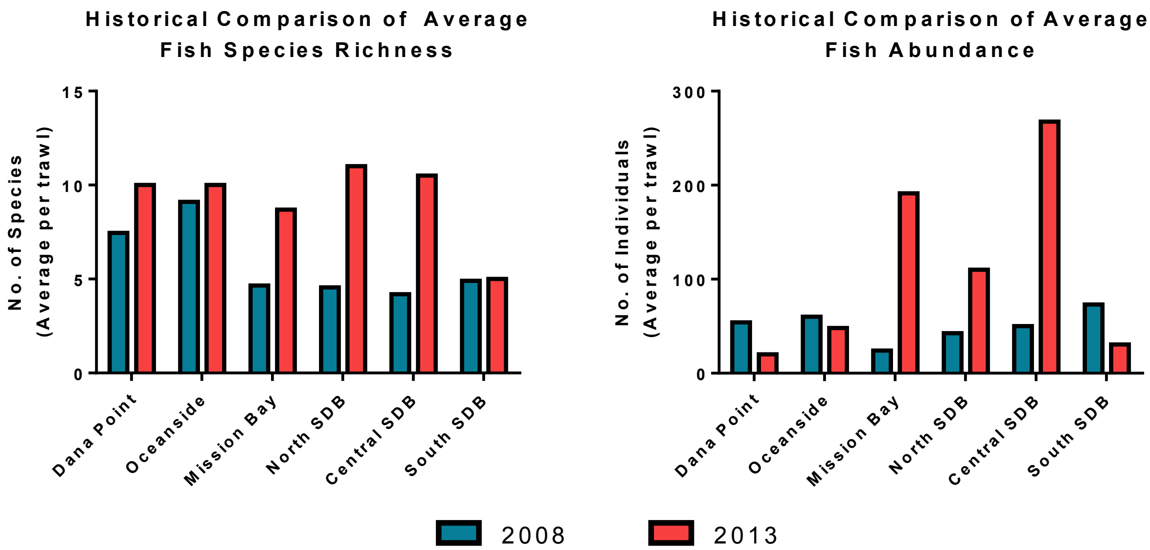


Figure 3-64. Comparison of Fish Taxa Richness and Abundance in the 2008 RHMP and 2013 RHMP

Data presented for 2008 trawls which were 5-minutes in duration were standardized to 10-minute trawl durations, consistent with that performed in 2013. Fish species richness data for 2008 was multiplied by 1.4, and fish abundance for 2008 was multiplied by 2.0, following regional Bight monitoring guidelines (Allen at al., 2002 and 2007).

Table 3-18.
Comparison of Fish Diversity, Abundance, and Biomass During the Last Four Regional Bight Surveys of the San Diego Regional Harbors Monitored Under RHMP (1998–2013)

RHMP Historical Fish Comparisons					
Species Diversity (Richness)					
Program	**Number of Stations**	**Total Number of Species**	**Range per Trawl**		**Mean Number per Trawl**
			Minimum	**Maximum**	
Bight '98	21	26	3	15	8
Bight '03	9	17	3	11	6
2008 RHMP	18	43	2	17	9
2013 RHMP	15	33	4	15	9
Abundance					
Program	**Number of Stations**	**Total Abundance**	**Range per Trawl**		**Mean Number per Trawl**
			Minimum	**Maximum**	
Bight '98	21	1340	6	464	60
Bight '03	9	593	10	215	66
2008 RHMP	18	866	2	130	48
2013 RHMP	15	2134	6	517	142

RHMP Historical Fish Comparisons					
Biomass					
Program	**Number of Stations**	**Total Biomass (kg)**	**Range per Trawl (kg)**		**Mean Biomass (kg) per Trawl**
			Min	**Max**	
Bight '98	21	174	0.4	27	7.2
Bight '03	9	55.3	1	17	6.1
2008 RHMP	18	101	0.1	16	5.6
2013 RHMP	15	141	0.4	36	9.1

Notes:
All historic data were standardized to 10-minute tow times, as described in the Bight '98 report and those thereafter. Standardization of data was not required for the 2013 data as all trawls were 10-minutes in duration for this survey period.

Given the number and variety of fish community surveys in San Diego Bay, a more robust assessment is possible for this harbor. The EI was chosen as a comparative method that might sufficiently account for the different methods employed. A summary of EI results for the last two RHMP efforts (2008 and 2013) and studies by Allen (1999) and VRG (2006) are shown in Table 3-19. Many of the highly ranked species were common to all four studies. The top four EI scoring fish species in RHMP 2013 (round stingray, slough anchovy, spotted sand bass, and California halibut) were also in the top 10 in the other three surveys. Most of the highly ranked species from the historical studies (Allen, 1999; and VRG, 2006) that were not highly ranked in the 2008 RHMP or Bight ’13 sampling events were pelagic or shallow water species that were caught by purse seine and/or beach seine nets, respectively (i.e., species not generally caught in high numbers in a benthic trawl net). These species included topsmelt (*Atherinops affinis*), northern anchovy (*Engraulis mordax*), shiner perch (*Cymatogaster aggregata*), and giant kelpfish (*Heterostichus rostratus)*. Three species that had the greatest EI value for the 2013 RHMP, but had not previously made the top 10 in 1999, 2006, or 2008, were the California lizardfish, the queenfish, and the grey smooth hound (*Mustelus californicus*). Although some similarities were noted among all surveys, overall results show that fish populations and biomass also demonstrated some variability over time.

Table 3-19.
Top 10 Fish Species in San Diego Bay
Based on the Ecological Index and Comparison with Historical Surveys

RHMP 2013		RHMP 2008	
Species	**Ecolo. Index**	**Species**	**Ecolo. Index**
Round Stingray	4636	***Spotted Sand Bass***	3193
Slough Anchovy	1315	***Barred Sand Bass***	2413
Spotted Sand Bass	1153	***Round Stingray***	2120
California Halibut	742	*Yellowfin Croaker*	1576
Deepbody Anchovy	631	*Black Croaker*	1008
Barred Sand Bass	533	***Slough Anchovy***	597
California Lizardfish	485	***California Halibut***	513
Queenfish	449	***Bat Ray***	193
Bat Ray	238	*Pacific Seahorse*	39
Grey Smoothhound	92	*Diamond Turbot*	33

VRG 2006 (2005)		Allen 1999 (1994-1998)	
Species	**Ecolo. Index**	**Species**	**Ecolo. Index**
Round Stingray	4055	*Pacific Topsmelt*	3133
Pacific Topsmelt	3454	*Northern Anchovy*	2715
Slough Anchovy	1912	***Round Stingray***	2271
Deepbody Anchovy	1456	***Slough Anchovy***	1857
Spotted Sand Bass	1178	***Spotted Sand Bass***	1496
Shiner Surfperch	580	***Barred Sand Bass***	565
Northern Anchovy	420	***California Halibut***	496
Bat Ray	314	*Shiner Surfperch*	401
California Halibut	277	*Giant Kelpfish*	219
Barred Sand Bass	266	*Pacific Sardine*	216

Notes:
Species are color coded to help visualize changes in patterns among surveys.

3.3.2 Epibenthic Macroinvertebrate Communities

Trawl collected macroinvertebrate abundance for all stations totaled 457 individuals, representing 40 different species (Appendix I, Table I-6, as well as Figure 3-65). The most abundant macroinvertebrates regionally were Asian mussels (*Musculista senhousia*), the brooding anemone (*Epiactis prolifera*), and the carinate dove snail (*Alia carinata)*. In general, macroinvertebrate distributions were relatively inconsistent. The sponge *Halichondria bowerbanki* was the most frequently encountered invertebrate, with a 53% trawl frequency (eight of the stations); the Asian mussel was next with a 47% trawl frequency (7 stations); and the California aglaja (*Navanax inermis*) followed, with a trawl frequency of 33% (5 stations). Macroinvertebrate abundance per trawl was greatest at Mission Bay Station 8156 (86 individuals) and was lowest at northern San Diego Bay Station 8109 (5 individuals). At Station 8156, 70 of the individual macroinvertebrates collected were proliferating anemones.

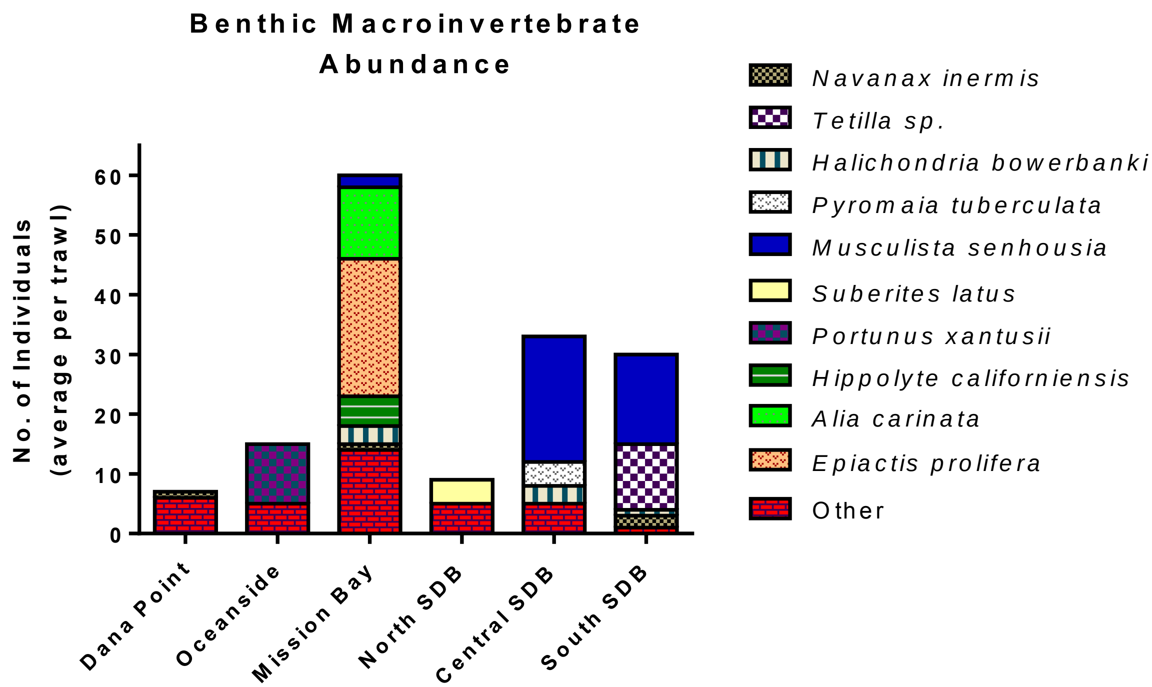


Figure 3-65. Abundance of the Top Benthic Macroinvertebrate Species Captured During Trawls among Harbors

By harbor, mean macroinvertebrate abundance per trawl was greatest in Mission Bay, with 61 individuals per haul (Table I-6). San Diego Bay had a mean of 25 individuals per haul; Oceanside Harbor had 15 individuals per haul; and Dana Point Harbor had 7 individuals per haul (the lowest). Regionally, macroinvertebrate species that composed the highest percentages of total biomass were “orange” bay sponge (*Suberites latus*) (9.2 kg, 36.4% of the total study-wide biomass), California spiny lobster (*Panulirus interruptus*) *(*3.8 kg, 15% of the total biomass), and another bay sponge, *Halichondria bowerbanki (*1.4 kg, 5.5% of the total biomass). Macroinvertebrate biomass per trawl was highest at Mission Bay Station 8156, with 4.9 kg per trawl, primarily due to nine California spiny lobsters in the catch. Macroinvertebrate biomass was lowest at southern San Diego Bay Station 8029, with approximately 0.3 kg per trawl.

By harbor, mean biomass per trawl was greatest in Mission Bay, with a mean of 2.2 kg of macroinvertebrates per trawl (Table I-7). Dana Point Harbor had 0.4 kg per trawl; Oceanside Harbor had 0.7 kg per trawl; and San Diego Bay had a mean of 1.8 kg of macroinvertebrates per trawl.

3.3.2.1 Macrobenthic Invertebrate Community Metrics

The EI value was calculated for each macroinvertebrate species in the same manner used for fish. Table I-8 presents the ranked EI values for all harbors combined, and Table I-9 presents the ranked EI value of invertebrate species collected from the four harbors separately.

Regionally, the top five species with the greatest EI value were Asian mussels, the orange bay sponge *Suberites latus*, the bay sponge *Tetilla sp.,* the bay sponge *Halichondria bowerbanki,* and the California spiny lobster (Table I-8). Distribution of these species was somewhat localized; they occurred only in Mission Bay and San Diego Bay, with a majority of stations where sponges were found located in San Diego Bay.

In Dana Point Harbor, the invertebrate species with the greatest EI value were the California bubble snail (*Bulla gouldiana*) and a marine snail (*Chlorostoma eiseni);* in Oceanside Harbor, the species with the greatest EI value were the swimming crab (*Portunus xantusii*) and the California rock crab (*Romaleon antennarium*); in Mission Bay, the species with the greatest EI value were the California spiny lobster (*Panulirus interruptus*) and the bay sponge (*Halichondria bowerbanki)*; and in San Diego Bay, the species with the greatest EI value were the Asian mussel and the orange bay sponge (*Suberites latus)*.

Mean species richness for all stations was 5.6 species per station (Table I-10). The regional mean Shannon-Wiener diversity index was 1.1 and the evenness value was 0.7 for all stations; the percentage of dominance of the top taxon was 61%. Species richness was greatest at Mission Bay Station 8156, with 15 species collected, and was lowest at three stations, all within San Diego Bay: Station 8109 (north), Station 8029 (south), and Station 8020 (south). Shannon-Wiener diversity and evenness indices were both greatest at north-central San Diego Bay Station 8078, whereas southern San Diego Bay Station 8020 exhibited the greatest dominance by a single taxon (92%). Phyla richness summarized by phyla across harbors is shown in Figure 3-66. Among phyla, the Molluscs and arthropods had the greatest diversity among all harbors.

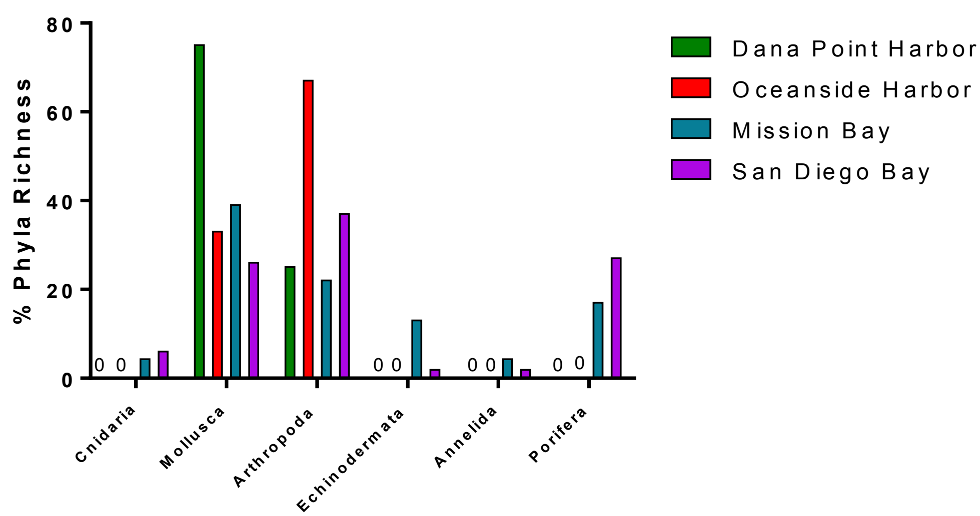


Figure 3-66. Epibenthic Invertebrate Phyla Richness Among Harbors

3.3.2.2 Macroinvertebrate Health

There were no recorded incidents of health anomalies on the macroinvertebrates collected in the RHMP study.

3.3.2.3 Historical Comparison for Macroinvertebrate Populations

A summary comparing macroinvertebrate species, diversity, biomass, and abundance during the 2008 RHMP and 2013 RHMP relative to that in the same four harbors during the Bight ’98 and Bight ’03 programs is provided in Table 3-20. The mean number of species per trawl (extrapolated estimate for a 10-minute trawl as described above) was greatest during the Bight ’98 sampling effort; however, the differences between the mean number of species per trawl were not substantially different, with seven estimated species per trawl in Bight ’98, six species per trawl in Bight ’03, five species per trawl in the 2008 RHMP, and an actual catch average of six species per trawl during the 2013 RHMP. The estimated mean abundance per trawl was substantially greater in both the Bight ’98 and Bight ’03 surveys (110 and 327 individuals per trawl, respectively) compared with an estimated mean of 55 individuals per trawl for the 2008 RHMP, and an actual count average of 31 per trawl during the 2013 RHMP. Mean estimated biomass per trawl was 11.5 kg in Bight ’98, 4.3 kg in Bight ’03, 8.2 kg in the 2008 RHMP, and an actual measure of 1.7 kg in the 2013 RHMP.

From 2008 to 2013, average species richness by harbor increased at every station except northern San Diego Bay (Figure 3-67). Average abundances decreased from 2008 to 2013 in northern San Diego Bay and Dana Point Harbor, and increased in southern and central San Diego Bay, Mission Bay, and Oceanside Harbor. Differences observed between years were likely a result of normal temporal and spatial variations that are expected when collecting trawl data.

Potential mechanisms driving some of the differences in both fish and macroinvertebrate populations is discussed further in Section 4.

Table 3-20.
Comparison of Macroinvertebrate Diversity, Abundance, and Biomass During the Last Four Regional Bight Surveys of the San Diego Regional Harbors Monitored Under RHMP (1998–2013)

RHMP Historical Invertebrate Comparisons					
Species Diversity (Richness)					
Program	**Number of Stations**	**Total Number of Species**	**Range per Trawl**		**Mean Number per Trawl**
			Minimum	**Maximum**	
Bight '98	21	49	1	18	7
Bight '03	9	29	0	14	6
2008 RHMP	18	44	0	8	5
2013 RHMP	15	40	3	15	6
Abundance					
Program	**No. of Stations**	**Total Abundance**	**Range per Trawl**		**Mean Number per Trawl**
			Minimum	**Maximum**	
Bight '98	21	2379	4	772	110
Bight '03	9	2948	0	1950	327
2008 RHMP	18	998	0	468	55
2013 RHMP	15	457	5	86	30.5
Biomass					
Program	**Number of Stations**	**Total Biomass (kg)**	**Range per Trawl (kg)**		**Mean Biomass (kg) per Trawl**
			Minimum	**Maximum**	
Bight '98	21	263	<0.1	125	11.5
Bight '03	9	39	0	20.6	4.3
2008 RHMP	18	148	0	93.6	8.2
2013 RHMP	15	25.3	<0.1	3.9	1.7

Notes:
All historic data were standardized to 10-minute tow times, as described in the Bight '98 report and those thereafter. Standardization of data was not required for the 2013 data as all trawls were 10-minutes in duration for this survey period.

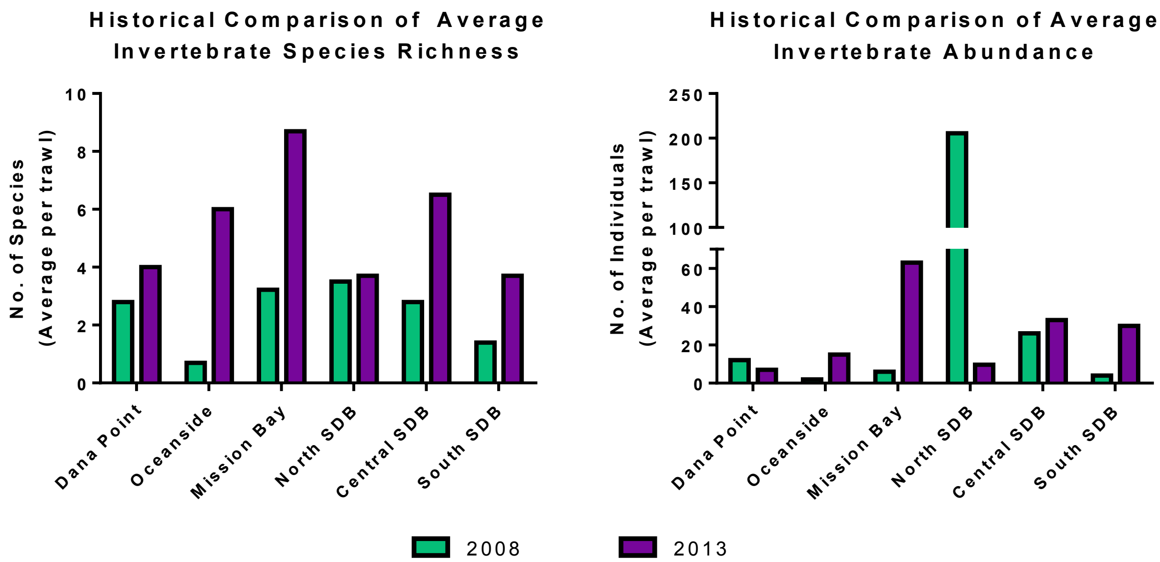


Figure 3-67. Comparison of Epibenthic Invertebrate Species Richness and Abundance During the 2008 and 2013 RHMP

Note: Data presented for 2008 trawls which were 5-minutes in duration were standardized to 10-minute trawl durations, consistent with that performed in 2013. Fish species richness data for 2008 was multiplied by 1.4, and fish abundance for 2008 was multiplied by 2.0, following regional Bight monitoring guidelines (Allen at al., 2002).

4.0 DISCUSSION

A substantial data set of water and sediment quality from which to draw robust conclusions exists for the four harbors under the RHMP. This discussion summarizes and highlights key spatial and temporal trends in the results. Efforts have also been made to better understand more complex relationships among the various parameters measured to assess the potential influence of primary anthropogenic indicators on water and sediment quality conditions in the harbors. The various relationships and observational information gathered as a part of this latest round of monitoring have provided substantial insight toward an enhanced understanding of existing conditions and areas where more or less effort may be warranted for future assessments. Although several inferences can be made and have been discussed herein, this RHMP core monitoring study was not designed to specifically address cause-and-effect relationships. A more concrete assessment of causal relationships where biological impacts are still apparent will require further focused studies before drawing solid conclusions.

The 2013 RHMP finds that the overall conditions of the four harbors have improved. In particular, the concentrations of several chemical indicators in sediments and the water column have decreased, and most stations were found to be nontoxic or to have low toxicity. While differences between 2013 and pre-2008 conditions show notable changes, more recent conditions over the previous 5 to 10 years appear relatively stable. It is important to note, however, that the RHMP and Bight sampling methodology reflects data collection that yields only a “snapshot” measurement of harbor conditions at a single point in time, and may not represent changing conditions on a shorter temporal scale than every five years. The probabilistic selection of sampling stations may also not account for varying small-scale harbor conditions. This limitation is discussed further in this chapter.

4.1 Water Quality

Areas immediately associated with anthropogenic disturbance and inputs of pollutants tended to be more influenced by contaminants. This was most notably the case for the marina stratum, but elevated chemical influence was also identified in other strata as well (primarily the industrial/port stratum) and select freshwater-influenced stations, particularly near the mouth of Chollas Creek in San Diego Bay.

4.1.1 Physical Water Quality Parameters and Depth Profiles

While the concentrations of DO in the water column within 1 meter of the surface at all of the RHMP monitoring stations were above the Basin Plan WQO of 5.0 mg/L, the DO concentration at depth (1 meter above the seafloor) was below 5.0 mg/L at five stations in the marina stratum, two stations in the industrial/port stratum, and 1 station in the deep stratum. The industrial/port stratum had the lowest average DO in surface waters, though still exceeding the 5.0 mg/L objective. DO concentrations below the 5.0-mg/L Basin Plan threshold have the potential to adversely affect less-mobile demersal species. Factors that may contribute to the decrease in DO with depth include local geography resulting in areas with limited flushing, particularly if combined with potential illicit discharges of organic waste (such as sewage) from vessels in low-flow areas (such as in marinas and industrial areas). The breakdown of organics consumes

oxygen and can deplete oxygen levels in both the sediments and overlying waters near the substrate (Milliken and Lee, 1990).

While average light transmittance at the surface was lowest in the shallow stratum, transmittance in the marina stratum declined at a higher rate with depth as compared with the other strata. Reductions in light have the potential to limit the abundance of primary producers, such as eelgrass and algae, and thus reduce the biodiversity and species abundances resulting from a less diverse habitat. Within marinas (and, likely, the industrial/port stratum), causes of increased turbidity may include the resuspension of sediments due to propeller-induced disturbances (Paulson and Da Costa, 1991), discharges from vessels, wind and tidal actions, and planktonic algal blooms.

4.1.2 Water Column Analytical Chemistry

Dissolved and total copper concentrations in surface waters frequently exceeded acute and chronic water quality criteria for the protection of aquatic life predominantly in the marina stratum; the surface water copper levels were generally lower in non-marina strata. Note, however, that these criteria do not take into account site-specific conditions (i.e., complexation capacity due to DOC) that have been well documented to reduce the bioavailability of copper in San Diego Bay and elsewhere (Rosen et al., 2005; Arnold 2004; Rivera-Duarte et al., 2005; Schiff et al., 2006a; Seligman and Zirino, 1998, Bosse et al., 2014). Results of the 2013 RHMP are consistent with findings of previous studies that have documented copper as a contaminant of concern in San Diego Bay marinas (McPherson and Peters, 1995; SDRWQCB, 2005; and 2008 RHMP Report) and in the larger San Diego region (Schiff et al., 2006a).

This observation, backed by multiple literature sources, including those referenced above, suggests that boating-related materials and activities have a more persistent effect on copper concentrations in the harbors than do other sources of pollutants such as stormwater runoff and industrial inputs. Compared with 2008 results, dissolved copper concentrations have increased slightly in Dana Point and Oceanside Harbors, and have decreased slightly in Mission Bay and San Diego Bay.

Mean values of dissolved copper by stratum across all harbors decreased from 2008 to 2013 (Figure 4-1 and Appendix K). All other dissolved and total metal concentrations were below their respective acute and chronic water quality criteria values among all harbor and strata.

Total PAHs were present region-wide, but were below concentrations expected to be of toxicological concern.

4.1.2.1 Potential Sources of Chemicals of Concern in the Water Column

Spatial distributions of pollutants varied among harbors, with Mission Bay generally having lower average concentrations of measured chemicals in the surface water. In the same pattern observed during the 2008 RHMP, copper and zinc surface water concentrations in Mission Bay were noticeably less than those of the two northern harbors, while those of San Diego Bay were intermediate. Although there are differences among the harbors (such as in their size, flushing

rates, and percentage of sampling stations in particular strata), metal inputs to surface waters were more closely associated with land uses and local pollutant inputs than any other spatial factor, with copper and zinc concentrations being consistently highest in the marina stratum in all four harbors.

In most instances, elevated concentrations of pollutants were more closely associated with a particular stratum than a specific harbor, as noted for copper and zinc. A general exception was the trend observed for PAHs; the greatest concentrations of these compounds (consistent with 2008 results) were generally observed in central San Diego Bay, where industrial activities are most intense. Potential sources of PAHs to RHMP waters include petroleum products and byproducts from both boating activities and urban stormwater discharges, groundwater flow from historical waste oil and drum disposal sites, shipping activities, spills at fuel docks during fueling, incomplete combustion of fossil fuels, and (to a lesser extent) leeching from creosote pilings (Fairey et al., 1998; and Katz, 1998).

4.1.2.2 Water Chemistry Historic Comparisons

Six surface water indicators were used to assess changes between the RHMP historical baseline dataset, as well as other relevant studies (Bight ’98, Bight ’03, and the 2008 RHMP). For the 2013 RHMP report, historical comparisons (i.e., changes over time) are based on the methodology of comparing the percentage of stations exceeding its respective threshold value between studies. Bar charts with region-wide average values and 95% confidence intervals are provided in Appendix K for the six surface water indicators, as well as in Figure 4-1 for total and dissolved copper and total and dissolved zinc.

Based on the percentage of stations exceeding the water quality thresholds during the 2013 RHMP, surface water quality conditions overall appear suitable to support healthy biota. While total and dissolved copper concentrations exceeded threshold values in portions of the harbors, the percentage of stations with dissolved copper concentrations below threshold values for the 2013 RHMP have increased not only from historical values, but also from the 2008 RHMP, indicating improving conditions over time. A historical summary of copper and zinc concentrations in surface waters is presented graphically in Figure 4-1 for comparison.

Of all the analytical and physical parameters assessed, copper and DO were the only two parameters observed that did not meet water quality thresholds, and such exceedances primarily occurred in the marina stratum. Concentrations of all other analytes fell below threshold values for adverse effects and, furthermore, were similar in concentration to historical conditions (i.e., did not exhibit increasing or decreasing concentrations). Further evidence of sustained improvement of water quality extends to concentrations of total PAHs, specifically within San Diego Bay. The replacement of creosote pilings along with changes in ballast water discharge practices at naval facilities in San Diego Bay have resulted in a sustained decrease in surface water total PAH concentrations from the 1990s. Averages declined from 623.9 ng/L (based on surveys conducted from 1990–1994) to 91.4 ng/L in 1997 (Katz, 1998), then to 32.4 ng/L in the 2008 RHMP, and finally to 18.7 ng/L in the 2013 RHMP.

For all RHMP stations as a whole, total and dissolved copper concentrations in the surface water have decreased substantially compared with historical conditions. When compared to the historical baseline values, the number of stations with concentrations of dissolved copper below the threshold in 2013 increased by 19%; while the number increased by 26% for total copper. However, dissolved copper concentrations at most of the stations in Oceanside Harbor and Dana Point Harbor, while below a daily maximum value of 12 µg/L published in the California Ocean Plan (SWRCB, 2012), still exceeded both the CTR chronic threshold of 3.1 µg/L and RHMP acute CTR threshold of 4.8 µg/L. Mission Bay had only one station (1/9) in Quivira Basin with concentrations of dissolved copper that exceeded both the acute threshold and chronic CTR value for dissolved copper. Likewise, a majority of the stations in San Diego Bay had concentrations of copper below both the dissolved and total RHMP thresholds (88% and 86% of stations, respectively) and chronic dissolved CTR (64% of stations). Those stations with results exceeding the criteria were primarily within the marinas, as discussed previously. While some studies of San Diego Bay prior to 2008 have recorded historically elevated concentrations of copper, others have found overall dissolved copper concentrations similar to those observed in 2013, including a prior study by the Navy that recorded a bay-wide average of 3.6 µg/L in 1997 (Katz, 1998), compared with 3.5 µg/L in the 2008 RHMP and 3.4 µg/L in the 2013 RHMP. To enhance certainty and confidence with regard to actual RHMP-wide historical trends for copper, a more careful review of the previous literature (sampling stations, conditions, etc.) will be required.

As discussed previously, the patterns observed for copper are primarily influenced by the marina stratum. Dissolved copper concentrations in marinas showed a slight improvement. The current average concentration was determined to be 6.2 µg/L, as compared with 6.9 µg/L during the 2008 RHMP; however, this value is still well above the threshold levels. The slight improvement in dissolved copper levels specifically within marinas may be a result of both regulatory implementation of the Copper TMDL in San Diego Bay and voluntary participation by recreational boaters in using copper-free hull paint, and a greater awareness on behalf of the hull cleaning industry to employ best management practices during hull cleaning activities. Despite these efforts, it is not unexpected that copper levels still exceed thresholds, especially within marinas, because copper-based antifouling paints are still widely used by recreational vessels and the transition to alternative coatings has been slow. In San Diego Bay, antifouling paints are estimated to contribute approximately 80% of the loading of copper to the water column (Valkirs et al.,1994). This issue is now being addressed in places such as Shelter Island in San Diego Bay. In 2015, the Port of San Diego released the results of a SWRCB Grant Project (10-437-559) with a goal of providing financial assistance to boaters to encourage the switch to non-biocide hull paint. This program successfully converted 41 vessels, resulting in a 38.51-kilogram-per-year reduction in copper loading. These conversions, along with continued boater education and outreach, are contributing to efforts to reduce loadings of copper in the bay. Other documented sources of copper to regional harbors include stormwater runoff, aerial deposition, historical contamination, and various industrial activities and associated discharges (e.g., steam condensate), and motor exhaust, among others (Schiff et al., 2006a).

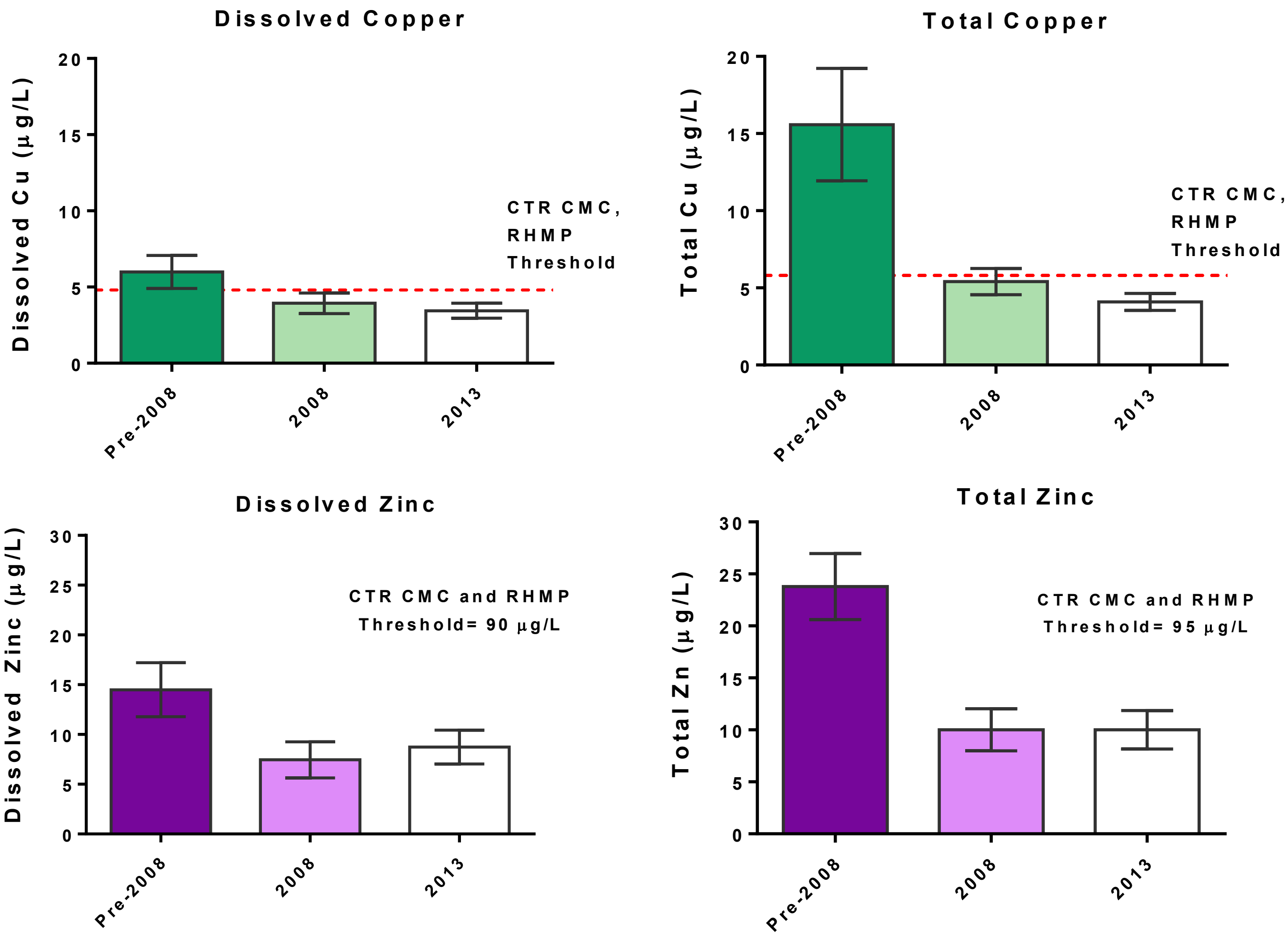


Figure 4-1. Historical Comparisons for Total and Dissolved Copper and Zinc (Mean ± 95% CI)

Notes: Studies for pre-2008 include all monitoring programs and studies used to develop the historical baselines used in 2013 RHMP reporting

4.2 Sediment Chemistry and Physical Characteristics

In addition to water quality, sediment conditions in general also appear to be more supportive of healthy biota within the deep and shallow strata, and most freshwater-influenced stations, based on overall reduced chemical concentrations and the presence of healthy benthic communities at a majority of stations. The greatest sediment chemical exposure potential generally occurred in strata with anthropogenic influences, most notably the industrial/port and marina strata. Based on the integrated SQO score for the sediment chemistry LOE, more than half (54%) of the RHMP stations were considered to have minimal or low exposure potential; 39% exhibit moderate exposure potential, and only 8% are considered to have high chemical exposure

potential as shown in Figure 4-2. A more detailed discussion related to conditions in the different strata follows.

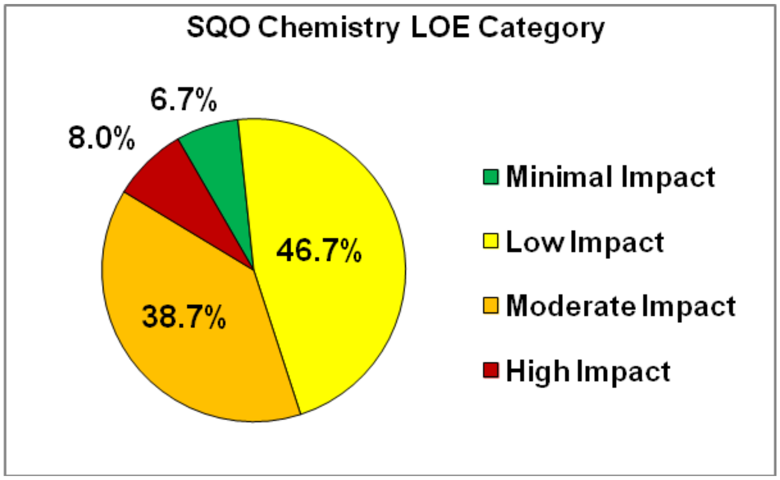


Figure 4-2. Pie Chart Summary of the Fraction of RHMP Stations in Each of the SQO Exposure Potential Categories for the Integrated Sediment Chemistry LOE

The industrial/port stratum had elevated sediment chemical concentrations relative to many of the other stations monitored. Stations within the industrial/port stratum make up 24% of all sampling stations in San Diego Bay; San Diego Bay is also the only harbor with an industrial/port stratum. These stations are associated with high levels of current and past industrial activities, such as container shipping, naval operations, and ship construction and repair. Additionally, the eastern shoreline of San Diego Bay (where the industrial/port stratum is primarily located) is adjacent to busy roadways and has inputs from a large watershed (including Chollas Creek and Paleta Creek). These may be contributing factors to the industrial/port stratum having the greatest number of ER-L exceedances (68), as well the greatest percentage of stations (64%) with results exceeding the mean ER-M quotient threshold of 0.2 among the five strata. Additionally, 78% of stations within the industrial/port stratum in San Diego Bay scored in the moderate to high exposure potential categories using the sediment chemistry SQO LOE. These scores were primarily driven by elevated concentrations of sediment copper, mercury, total PCBs, total DDTs, and chlordanes.

The marina stratum was classified as having impacted sediment chemistry conditions at many stations: 50% of stations were within the marina stratum in Dana Point Harbor, 33% of stations were within the marina stratum in Oceanside Harbor, 22% of stations were within the marina stratum in Mission Bay, and 17% of stations were within the marina stratum in San Diego Bay. Results at 60% of these stations exceeded the mean ER-M quotient, indicating that pronounced adverse impacts on biota and habitat may be expected in this stratum. Marinas are typically associated with high densities of recreational vessels, high levels of boating activity, and often reduced tidal flushing, and often are close to roadways. These may be on-going contributing factors to the marina stratum having the highest number of ER-M exceedances (14), as well as the greatest number of stations (87% of stations among the marina stratum) classified in the

moderate and high exposure potential categories using the SQO sediment chemistry LOE. These scores were primarily driven by elevated concentrations of sediment copper, mercury, and zinc, and secondarily driven by total PCB and total PAH levels.

The freshwater-influenced stratum overall had fewer exceedances than the industrial/port and marina strata; however, 47% of these stations were categorized as having moderate to high exposure potential using the sediment chemistry LOEs. These scores were primarily driven by zinc concentrations, as well as total DDT and total chlordane levels. The freshwater-influenced stations represented a great deal of variability with regard to physical characteristics. An elevated proportion of samples (8 of 15) were all located within the Sweetwater Channel in southern San Diego Bay. A number of samples in this channel were sandy with shell hash, likely reflective of dynamic environment with scouring due to tides, currents, and runoff. The two freshwater-influenced stations in Mission Bay were located in relatively quiescent protected areas of the bay characterized as having fine sand and silt with eelgrass beds in the vicinity. The four freshwater-influenced stations near the mouth of Chollas Creek in San Diego Bay were in deeper water than the others, and were predominantly composed of silt and clay. Unlike all other stations in this stratum, these stations are surrounded by industrial/port operations and are thus likely heavily influenced by associated previous and current activities within the bay. The remaining freshwater-influenced station was in front of a 42-inch storm drain in the Laurel Hawthorn embayment located in northern San Diego Bay. The wide variety of these stations must be considered carefully when making any conclusions as a whole, based on the combined freshwater-influenced stations comprising this stratum.

The deep and shallow strata generally had concentrations that were below established threshold levels for most of the chemical indicators, regardless of harbor or proximity to other strata. This provides an indication that chemical exposure is more closely associated with specific inputs of pollution rather than larger spatial differences in contaminant exposure within the Dana Point, Oceanside, and San Diego regions.

Primary Indicator: Mean ER-M Quotient

Despite some of the trends noted above, sediment chemistry concentrations appear to be generally protective of healthy biota in most regions; results from 80% of the stations did not exceed a single ER-M for any analyte; results from 64% of stations had mean ER-M quotient scores below a 0.2 conservative threshold for toxic effects; and 72% of stations were classified as either Unimpacted or Likely Unimpacted by the overall integrative SQO assessment

Spatial Trends and Potential Sources of Individual Chemicals of Concern

The following primary chemicals of concern are those constituents that exceeded the sediment quality guideline ER-M thresholds and/or were considered to have moderate to high exposure potential using the SQO CSI calculation.

Copper

Copper concentrations in the sediments had the highest incidence of ER-L exceedances; 89% of all RHMP station concentrations exceeded the ER-L value, especially in areas with high vessel densities and boat-related activities. Copper in the bay sediments may come from a variety of sources including urban runoff, industrial activities, atmospheric deposition, and its

common use as a biocide in antifouling paints due to its effectiveness in reducing the fouling of boat hulls. Copper is released from hull paints into the water column by passive leaching and hull cleaning, diffusing to the sediments where it can bind to sediment particles (Schiff et al., 2003; Valkirs et al., 2003).

However, natural ambient concentrations of copper in the region are also known to be elevated, often greater than the ER-L screening guideline values. Thus, using the ATL approach described in Section 2.3.1.2, only 16 stations (21%) had concentrations of copper that exceeded the ATL threshold value within three strata (marina, industrial/port, and freshwater-influenced stations near the mouth of Chollas Creek) in Dana Point Harbor, Oceanside Harbor, and San Diego Bay. Only 7% of stations had concentrations of copper that exceeded the ER-M screening guideline values.

Using the CSI following the SQO approach, 51% of total stations were classified as having moderate exposure potential due to copper, while the rest fell in the low to minimal exposure potential categories.

Within the marina stratum, stations with higher concentrations of copper were generally closer to the inner portions of marinas; this finding may be attributed to reduced tidal flushing. This is the case in Dana Point Harbor, Oceanside Harbor, and stations within marinas of San Diego Bay (specifically in America's Cup Harbor), the West Basin (northern San Diego Bay), and the Coronado Cays (southern San Diego Bay).

Additionally, the copper-based paints of the naval vessels and shipping vessels could also serve as a major source of copper along the eastern shoreline of San Diego Bay. Urban runoff from the larger watersheds and aerial deposition (SDRWQCB, 2005) also serve as a potential copper source due to high levels of copper in automobile brake pads and various construction materials.

Mercury

Mercury had the second highest incidence of ER-L threshold value exceedances at 67% of stations, most of which were within the marina and industrial/port strata. Concentrations of mercury at 11% of these stations also exceeded the ER-M. Using the CSI following the SQO approach, 68% of the stations were classified as having low or minimal exposure potential due to mercury. Previous studies have associated elevated sediment mercury concentrations with boating activities (including recreational boating, shipping, naval operations, and shipbuilding/repair facilities). A section of the San Diego Bay shoreline within the industrial/port stratum (between Sampson Street and 28th Street) is currently on the Clean Water Act Section 303(d) list for mercury. Although concentrations are elevated in the industrial/port and marina strata, the overall concentrations of sediment mercury are relatively high throughout all strata within San Diego Bay, possibly indicating a legacy contamination issue (Thompson et al., 2009), naturally occurring sources, and/or atmospheric deposition with this contaminant of concern.

Zinc

Stations with elevated zinc concentrations followed a similar distribution as those with elevated copper concentrations. Concentrations exceeded the ER-L threshold value across all harbors and all five strata; however, only two stations, which were within the marina stratum, had concentrations exceeding the ER-M value. Using the CSI following the SQO approach, 33% of the stations were classified as having moderate exposure potential due to zinc, while the rest fell in the low to minimal exposure potential categories. As with copper, the highest concentrations of zinc in the sediment were associated with areas that have greater boating activities. Zinc anodes are commonly used to prevent electrolytic corrosion of vessel motor and other metal parts. Zinc is a major additive in copper-based hull paints, and zinc-based hull paints are also available as an alternative biocide to copper-based hull paints (although they are used far less frequently). Such factors could indicate why overall zinc concentrations were highest in the marina stratum. Additionally, zinc deposition also been linked to automobile wear and building materials; hence, zinc concentrations have historically been higher near roadways due to runoff (Golding, 2006).

DDTs

DDT is an insecticide that was widely used in the 1940s and 1950s, and eventually banned in the United States in 1972 (USEPA, 1975). Stations within the freshwater-influenced and industrial/port strata had total DDT concentrations that exceeded the ER-L. DDT concentrations were elevated above the ER-L threshold value at four stations in central San Diego Bay; all were immediately outside of the mouth of Chollas Creek (Stations B13-8074 through B13-8077). A background study for TMDL evaluation in the outlet of Chollas Creek found a strong gradient of DDT in sediment toward the mouth of Chollas Creek, indicating that elevated DDT levels in the area may be a consequence of urban runoff and/or legacy contaminants (SCCWRP and SPAWAR, 2005). Only one RHMP station (B13-8500), a freshwater-influenced site in north San Diego Bay, had a concentration of total DDT that slightly exceeded the ER-M.

Total Chlordanes

Chlordane is an insecticide that was widely used until it was banned in 1983. Although no longer in use, chlordanes persist as a legacy contaminant (Howard, 1990). As with total DDTs, elevated chlordane levels were closely associated with freshwater-influenced stations. Only stations within the freshwater-influenced strata had total chlordane concentrations that exceeded the ER-M screening guideline value. Within the freshwater-influenced stratum, Station B13-8500 (near the Laurel Hawthorn Embayment storm drain in San Diego Bay) had the highest concentration of total chlordanes at 34.1 μg/kg, which is 5.7 times greater than the ER-M value. The four stations immediately outside the mouth of Chollas Creek (B13-8074 through B13-8077) also all had elevated concentrations of chlordanes. During a TMDL study in 2005, it was found that there was a strong gradient of chlordane in sediments toward Chollas Creek; indicating that elevated levels may be a consequence of urban runoff and/or legacy contaminants (SCCWRP and SPAWAR, 2005).

PCBs

Elevated levels of PCBs were evident within the marina and industrial/port strata within San Diego Bay. A single station in each of the marina and port/industrial strata had concentrations of total PCBs that exceeded the ER-M and were considered to exhibit moderate exposure

potential using the SQO CSI methodology. These findings are consistent with previous studies that have detected elevated PCBs both within the waters (Zeng et al., 2002) and sediments of central San Diego Bay (McCain et al., 1992). PCB contamination has largely been associated with industrial activities, specifically the production and refurbishing of electrical transformers and capacitors where PCBs have been used as cooling and insulating fluids. PCBs have also been incorporated into flexible polyvinyl chloride (PVC) coatings for electrical wiring and components and have been used in hydraulic fluids. Based on known uses as well as the observed spatial distribution of PCBs, it appears that past local industrial activities likely serve as a primary source to RHMP sediments.

Other Contaminants of Concern

Arsenic

Arsenic is a naturally occurring trace metal that has been identified as having natural concentrations that can often exceed risk-based corrective action guidelines (Harris et al., 2013) in the Bay Point Formation, which is the native geological formation in San Diego County. Arsenic also may be released from paints, pesticides, wood preservatives, and brass. Concentrations throughout all harbors and all five strata were slightly above the ER-L threshold level, but none exceeded the ER-M; hence, there was no evidence that a specific input of arsenic within a particular stratum or harbor was driving elevated concentrations. Sediment arsenic concentrations were not included in SQO chemistry LOE calculations.

PAHs

Only one station had total PAH concentrations marginally exceeding the ER-L threshold value (Station B13-8121 within the marina stratum). The SQO calculations utilized both HPAH and LPAH concentrations to analyze the potential effects of PAHs (see below). Primary sources of PAHs include runoff from shipping and industrial activities, fuel spills, industrial and municipal waste discharge, surface runoff, and aerial deposition (Zeng and Vista, 1996). A section of the San Diego Bay shoreline within the industrial/port stratum (between Sampson Street and 28th Street) is currently on the Clean Water Act Section 303(d) list for sediment PAHs. Although concentrations are elevated in the industrial/port and marina strata, the overall concentrations of sediment PAHs are elevated throughout all strata within San Diego Bay as compared to the other harbors. In a study completed in 1996, sediment sampled in San Diego Bay had proportions of <20% of two-, three-ring PAHs, indicating combustion sources appeared to prevail. Automobile exhausts, probably similar to boat engine exhausts, are known to contain both petroleum residues and incomplete combustion products (Zeng and Vista, 1996).

LPAHs

Three stations in two strata (deep and marina) had LPAH concentrations that were considered to have moderate exposure potential according to the CSI. All of these stations were within San Diego Bay. LPAHs are considered to be acutely toxic and non-carcinogenic to aquatic organisms (Neff, 1979; Moor and Ramamoorthy, 1984; Goyette and Boyd, 1989). Toxicity potential is enhanced by high water solubility (Duffus, 1980; Uthe, 1991).

HPAHs

Three stations in three strata (deep, marina, and industrial/port) were identified as having moderate exposure potential due to HPAHs, all within San Diego Bay. HPAHs are not generally acutely toxic; however, they are often carcinogenic (Neff, 1979; Moore and Ramamoorthy, 1984; Goyette and Boyd, 1989).

Total PBDEs

PBDEs comprise of a class of chemicals used in flame retardants, were identified as an emerging chemical of potential concern and have been recommended to be included in ongoing and future studies region-wide (Dodder et al., 2013). PBDEs are now considered ubiquitous in coastal environments and are particularly associated with areas influenced by urban runoff. Concentrations of PBDEs were greatest in the industrial/port and freshwater-influenced strata, which are both potentially influenced by urban runoff. Little is known about the risk of PBDEs; thus, there are no regulatory criteria for sediment PBDE concentrations at this time. However, because of the potential for bioaccumulation in higher order marine organisms, PBDEs should continue to be monitored to provide a historical context for interpretation once effects and risks are better understood (SCCWRP, 2013a).

Total Pyrethroids

Pyrethroid pesticides are relatively well-known urban and agricultural pesticides commonly found in stormwater runoff (Weston and Lydy, 2010), and were detected in over one-third of the Southern California Bight embayment areas in 2008 (Schiff et al., 2011). Overall, most RHMP stations in 2013 had non-detectable concentrations of pyrethroids (< 0.25 µg/kg), similar to the results observed during RHMP in 2008 for this particular region. Detections were limited to areas of freshwater influence and marinas.

Because of low standard recoveries during laboratory analysis, note that one batch of eight samples from the 2013 RHMP did not meet the chemistry QA/QC criteria specified in the project-specific QAPP as identified following a Level IV QA/QC review of 10% of the total data package. The data were initially rejected following a Level IV review, but have since been retained for reporting purposes with a flag because, consistent with results of previous Bight monitoring events, the specific pyrethroids in question (permethrin and resmethrin) are less common, composing a negligent fraction of the total pyrethroid concentration, which is dominated regionally by bifenthrin. Bifenthrin was also detected in 2013 RHMP samples from expected stations (near areas of freshwater influence), providing confidence in the analytical method. Details related QA/QC for pyrethroids are provided in Section 5.

SEM-AVS

SEM-AVS is an approach often used to assess the potential for trace metals in sediments to cause toxic effects in benthic organisms. Metal contaminants become bioavailable when dissolved in the pore water; sulfide binds metals ions to render them non-bioavailable (Berry et al., 1996). Hence, higher contents of sulfide (and thus lower SEM-AVS ratios) may reduce toxicity in sediments. During the 2013 RHMP, results from all but two stations located in a marina in San Diego Bay (SIYB) were below an RHMP-specific SEM-AVS threshold of 40, a ratio above which bioavailability of metals might be expected to cause toxicity, based on regional data sets reviewed by Weston (2005b). Correspondingly, the two stations with SEM-

AVS ratios greater than 40 were the only two stations among all RHMP stations to exhibit a moderate toxic effect to amphipods (Figure 3-40). Following more recent guidance where the SEM-AVS ratio is normalized to organic carbon following the ESB approach (USEPA, 2005), a similar assessment was made that indicated limited bioavailability of trace metals in sediments at concentrations that might be toxic among all RHMP samples (Figure 3-41). The two samples that showed greatest potential were likewise in San Diego Bay: one was in SIYB and the other was near the mouth of Chollas Creek; neither of which exhibited toxicity to either bivalve embryos or amphipods.

Physical Characteristics – Grain Size and TOC

Physical characteristics of the sediments in some cases varied substantially among different stations both within and between strata and harbors, and sometimes even within a single sampling station. The fraction of fine sediments ranged from 4% to 93% among all stations. TOC correlated well with fines and ranged from 0.1% to 6%. Percent fines also correlated with elevated chemistry represented by the ER-M quotient as well as several benthic community measures when considering data from all sampled locations (see plots provided in Appendix K). These results provide evidence indicating that the associated elevated chemistry may be influencing the biota region-wide.

However, when evaluating subsets of the data different trends are also apparent. For example, the relationship between % fines is positively correlated with benthic community measures among the freshwater-influenced sites. This observation indicates that the presence of sandy substrate, possibly from physical scouring, may have a detrimental impact on the ability to sustain long-term diverse infaunal communities.

Visual observations also noted substantial variability among samples, as depicted in the photographs of each grab sample provided in Appendix M. In some cases, variability in sediment composition was notable even at a single station, as shown in a photograph of adjacent sediment grab samples from Station 8014 in southern San Diego Bay, as presented in Section 4.8.

4.2.1 Sediment Chemistry Historical Comparisons

Thirteen sediment indicators were used to assess changes between the RHMP historical baselines dataset, as well as other relevant studies (Bight ’98, Bight ’03, and the 2008 RHMP). For this 2013 RHMP report, assessing changes over time is based on the methodology of comparing the percentage of stations exceeding respective threshold values between studies. Bar charts with study means and 95% confidence intervals are provided in Appendix K for each sediment quality indicator, as well as in Figure 4-3 for sediment copper, mercury, total PAHs, and total PCBs.

When comparing Bight ’98, Bight ’03, and 2008 RHMP datasets to the 2013 RHMP data set, few indicators showed negative trends. Of those that did (arsenic, PCB, and total chlordane; see Appendix K), background temporal variation is a likely contributor related to the changes that occurred, given that both chlordane and PCB are legacy contaminants with limited ongoing sources. For example, changes in loading and the binding of contaminants, dredging of bottom

sediments, and seasonal changes in physical-chemical properties in the water column that may influence the exchange of metals at the sediment-water interface have all been recognized to be factors affecting temporal and spatial variation in contaminant concentrations and bioavailability (Valdes et al., 2009). Currents, tides, and prop wash are also local factors known to alter the distribution of sediments and associated chemical concentrations (Katz and Blake, 2005). The documented spatial and temporal variability in bays and harbors can result in lower statistical power and enhanced uncertainty when evaluating trends in such habitats. Note also that arsenic is a naturally occurring trace metal that has not been identified at concentrations of toxicological concern in any of the harbors.

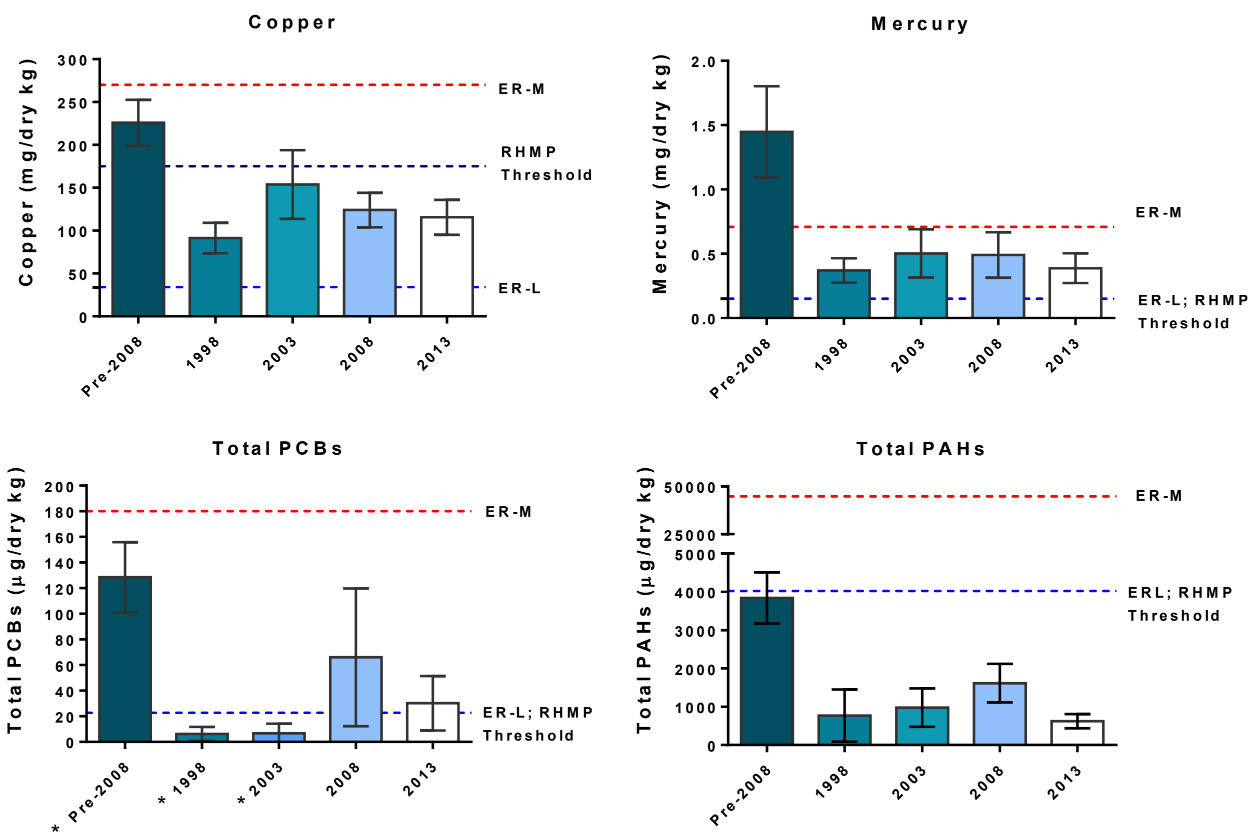


Figure 4-3. Historical Comparisons for Select Sediment Chemistry Indicators (Mean +95% CI)

Note:

Studies for pre-2008 include all monitoring programs and studies used to develop the historical baselines used in 2013 RHMP reporting

* PCB reporting limits for Bight 1998 and 2003 ranged from 0.03 to 3.0 mg/kg compared to 1.0 mg/kg in 2008 and 0.1 mg/kg in 2013. This discrepancy likely biased pre-2008 concentrations low.

4.3 Sediment Toxicity

Assessment of toxicity provides another indicator that the RHMP harbors are supportive of healthy biota; 84% of all RHMP stations were determined to be nontoxic according to the acute amphipod test, and 100% were categorized as nontoxic according to the chronic mussel embryo development test. Furthermore, 100% of the 2013 RHMP stations were classified as either nontoxic or as having low toxicity according to the combined SQO toxicity LOE as shown in Figure 4-4.

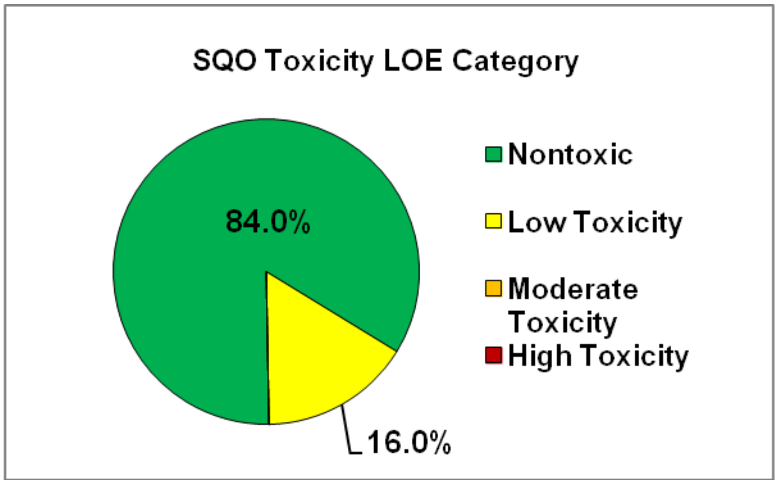


Figure 4-4. Pie Chart Summary of the Fraction of RHMP Stations in Each of the SQO Categories for the Integrated Toxicity LOE

4.3.1 Sediment Toxicity Trends

Overall, sediment toxicity has improved from the RHMP historical baseline conditions, Bight ’98, and Bight ’03. Amphipod survival in the 2013 RHMP was similar when compared to the 2008 RHMP, but 2013 still showed further improvement. Bar charts with means and 95% confidence intervals are provided in Figure 4-5 and Appendix K for amphipod survival. A total of 97% of RHMP stations in 2013 were considered to be nontoxic compared with 80% of the RHMP historical baseline stations and 96% of the stations during the 2008 RHMP.

The bivalve embryo development tests were also consistent with the finding of limited toxicity across all harbors, with 100% of stations considered to be nontoxic using the SQO guidance. The bivalve test showed a similar response in 2008, but the test was not used for prior efforts so longer time-frame comparisons are not possible. Following the interpretation of toxicity published in the final Toxicity Report for Bight ’13, 100% of the samples during RHMP for both amphipod and bivalve tests were considered nontoxic by lumping of the nontoxic and low toxicity categories (Bay et al., 2015).

With the exception of a slight decrease in average amphipod survival during Bight ’03 (which may be a result of spatial variability), toxicity has shown steady improvement over time. Since monitoring started, widespread efforts have been made to improve regional harbor health, with various regulatory actions and controls directed toward minimizing levels of contaminants that have the potential to cause toxicity.

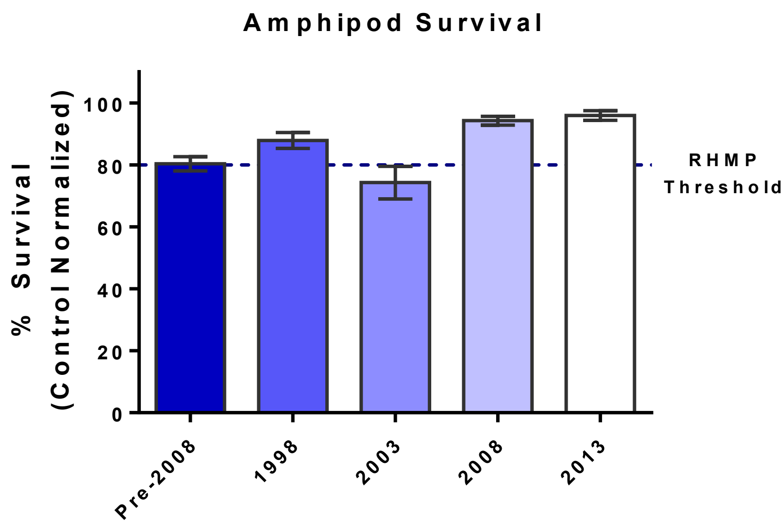


Figure 4-5. Historical Comparisons for Amphipod Survival (Mean +95% CI)

Notes:

Studies for pre-2008 include all monitoring programs and studies used to develop the historical baselines used in 2013 RHMP reporting

4.4 Benthic Community Condition

Sediments were found to support healthy benthic communities (reference or low disturbance conditions) at 60% of the RHMP stations region-wide as summarized in Figure 4-6, only 5% of the sites are considered to be representative of highly disturbed communities. Using the four LOE metrics for an integrated assessment following the SQO methodology, the deep and shallow strata were found to have the healthiest benthic communities (88% and 73% of the stations in the two categories above). The marina and industrial/port strata had a lower proportion of stations in the reference and low disturbance categories with 33% and 50% of stations, respectively, in these categories. In the freshwater-influenced stratum, 53% of stations were within the low disturbance category, but no stations in this stratum were categorized as having reference or highly disturbed communities.

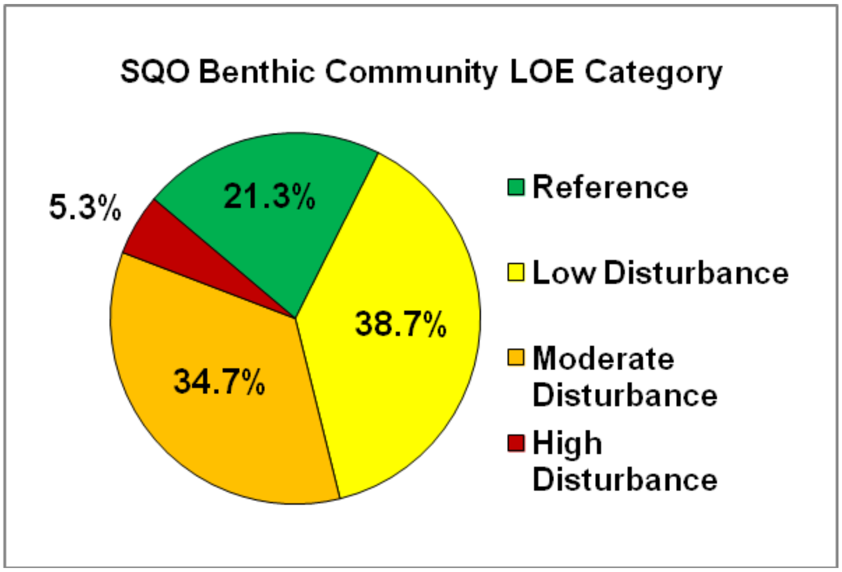


Figure 4-6. Pie Chart Summary of the Fraction of RHMP Stations in Each of the SQO Categories for the Integrated Benthic Community LOE

Benthic community measures are indicators of overall community health in response to both natural and anthropogenic disturbances, and so may or may not be closely associated with inputs of pollutants and toxicity (Smith et al., 2003). The impaired benthic community conditions observed within the marina and industrial/port strata are generally associated with elevated chemical exposure, but these stations also are influenced by a variety of physical factors (propeller wash, tides, and current), which may also have a substantial influence on the structure and stability of these communities (Katz and Blake, 2005).

Freshwater-influenced stations typically had moderately degraded benthic infaunal communities (47% were classified as moderately disturbed), which may be related to both disturbance and seasonal fluctuations in physical water quality parameters (i.e., low salinity during the wet season), as well as chemical inputs related to watershed runoff-borne contaminants such as pyrethroid pesticides. Based on AVS-SEM ratios and relatively low sediment concentrations, trace metals are not likely to be bioavailable at the freshwater-influenced stations monitored during the RHMP. Physical characteristics such as grain size can also have a large impact on the composition and stability of benthic infaunal communities. These are likely a significant factor in the 2013 RHMP, where most of the freshwater-influenced stations were located within the mouth of the Sweetwater River, and are generally higher in medium to coarse sand content because of physical scouring from runoff events and tidal currents.

Note that the four freshwater-influenced stations near the mouth of Chollas Creek in San Diego Bay are also influenced by industrial/port activities and physical disturbance related to propeller wash and scouring from tides, currents, and runoff events (Katz and Blake, 2005). Benthic communities in these more disturbed habitats will have a more difficult time establishing a stable community, resulting in potential impairment due to factors other than chemical exposure. Notably, the two freshwater-influenced stations in Mission Bay are in shallow, relatively

protected locations that are influenced by large urban watersheds, but both had benthic communities considered to be representative of healthy reference or low disturbance conditions, based on both the individual BRI scores and integrated multiple metric SQO methodology.

4.4.1 Historical Comparisons of Benthic Community Metrics

Historical benthic infauna data used for comparison purposes was summarized in the prior RHMP report (Weston, 2010). Results prior to 2008, however, were not subjected to the full SQO analysis because this methodology had yet to be developed and assessment of the benthic community condition was limited to only a single metric, the BRI.

Regarding the 2008 RHMP data, discrepancies in the benthic index calculations (particularly the BRI) were noted when comparing the 2008 and 2013 data sets. An investigation found that the BRI condition scores reported in the 2008 RHMP were biased low (indicating healthier conditions) than those reported by SCCWRP in its final assessment report using the same data set (Ranasinghe et al., 2012). A re-analysis of a subset of these data confirmed these discrepancies (see Section 5.0 for additional discussion on this topic). The comparisons that follow are based on 2008 data reported for RHMP, so these discrepancies must be considered when interpreting the described relationships over time.

Overall, the benthic community condition in 2013, as measured only by the BRI, appeared to have degraded somewhat from historical conditions, where 55% of pre-2008 stations and 77% of the 2008 RHMP stations had BRI scores indicative of reference conditions compared with 40% of stations in 2013. However, when considering stations that were in the reference and low disturbance BRI categories in combination, the difference becomes less pronounced, with 89% in these two categories combined in 2008 and 81% in 2013.

The final integrated SQO benthic LOE assessment indicated more of a decrease in community quality since 2008 than just the BRI score alone, as shown by the percentage of RHMP stations in the combined reference and low disturbance categories which decreased from 72% in 2008 to 60% in 2013. Given the discrepancies identified with the historic BRI scores that appear low, current integrated scores are likely more similar to past results than that suggested using the existing past calculations as is.

The Shannon-Wiener diversity index indicated somewhat better conditions in 2013 than did the BRI, with 89% of the stations in a reference condition. Historically, 76% of pre-2008 and 91% of 2008 mean SWI values were equivalent to a reference condition. Raw taxa richness values showed little difference from historical conditions, as the number of RHMP stations with taxa richness equivalent to a reference condition were 82%, 85%, and 83% for pre-2008, 2008, and 2013 monitoring periods, respectively.

Assessments of stations revisited from prior Bight surveys provided evidence that benthic communities are either slightly improving or are remaining at their former conditions on average. The only stratum that did not follow this larger RHMP-wide trend was the marina stratum, as only 33% of that stratum had communities characterized as having reference or low disturbance

conditions. By way of comparison, in 2008, 50% of the marina stratum was classified as having reference or low disturbance communities.

The benthic community indices were found to be a key driver of the final integrated SQO scores during RHMP. They also provide a direct measure of impacts and thus a more meaningful assessment endpoint regarding conditions that do or do not support healthy communities.

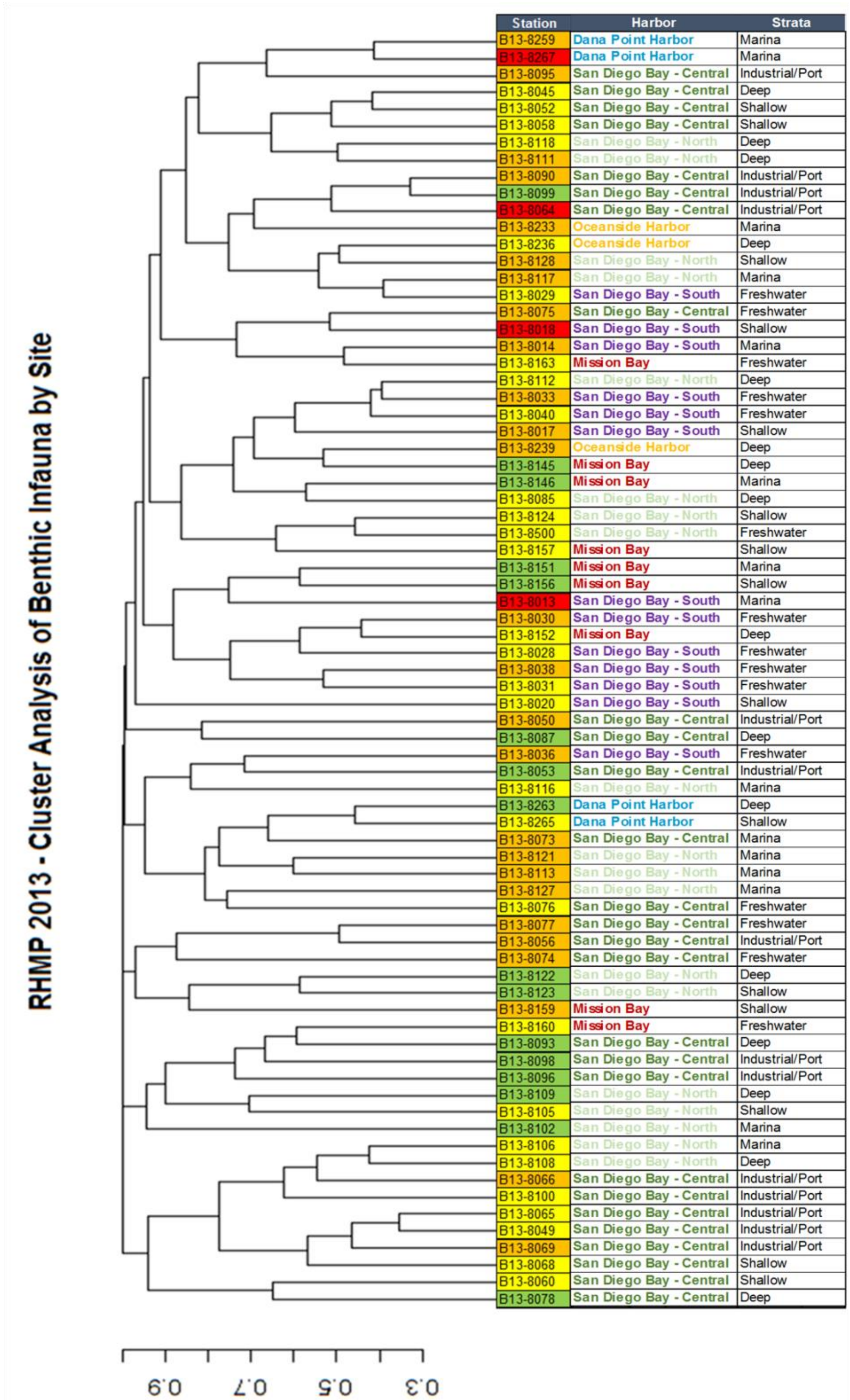
To help visualize the relationships among benthic community structure, strata, harbors, and the integrated SQO benthic infauna quality score, a multivariate cluster analysis was performed, as shown in Figure 4-7. This diagram clusters similar benthic infaunal communities on the basis of raw species counts. The output is then shown graphically with hierarchal groupings shown by connecting lines on the left axis. Lines that are shorter and closer together represent more similar communities. Corresponding stations are identified and color-coded on the basis of the integrated SQO score they received (green = reference, yellow = low impact, orange = moderate impact, and red = highly impacted communities). The associated harbor and strata are also shown for comparison. A few noteworthy observations are as follows:

- Stations in Dana Point Harbor have community composition similar to that of the marina stratum within San Diego Bay.
- Stations in Mission Bay are structured similarly to those in the shallow stratum in San Diego Bay.
- Some site clustering was driven by a single species, indicating that many of the stations supported relatively unique assemblages of benthic invertebrates.
- Several stations had impaired benthic communities, but the impairment did not relate to sediment chemistry (Station B13-8018 outside of Sweetwater Channel, Station B13-8159 in Mission Bay), as highlighted further below.
- Northern San Diego Bay and Central San Diego Bay stations were often clustered together.

To further assess the relationship specifically between elevated chemistry in the sediments and benthic community responses, a Spearman Rank correlation followed by plotting of a number of linear regression comparisons was performed. These analyses are presented in Appendix K for reference. Comparisons were made between various individual metrics and combined metrics to assess corresponding univariate relationships between benthic community and chemical and physical parameters. Overall, a large number of statistically significant relationships were observed, but predictive ability was low due to substantial variation. Because of the number of co-varying factors, teasing out direct causal effects from such relationships is not possible and is only speculative, but the analysis can provide guidance on what factors may be more or less important. In many cases, causal mechanisms are likely to be indirect or a combination of multiple factors. For these reasons, the integrated chemical and biological metrics are preferred to provide conclusions regarding overall trends. The relationships between the BRI and enhanced sediment chemistry using the integrated chemical measures of the ER-M Quotient and the SQO CSI were provided in the Results Section (Figure 3-53a-b), showing a statistically

significant relationship for both chemical exposure indices; however, the degree of predictability represented by r^2 was very low in both cases due to substantial scatter among the data points. The CSI was derived by comparing sediment chemistry with benthic community responses using data from Southern California bays and estuaries (Bay et al., 2014) rather than the LRM and ER-L/ER-M methods that are derived by comparing sediment chemistry and toxicity from a nationwide data set that is not specific to southern California. Therefore, the CSI provides a more applicable measure to compare current chemistry with infaunal condition in the San Diego region. The same figure between the BRI and CSI is shown below in Figure 4-8 with the SQO categories for the CSI superimposed on the figure for comparison. As shown, as the BRI increases (more impacted communities), the CSI score also increases. All samples considered moderately impacted (no samples were considered highly impacted) using the CSI also had elevated BRI scores above the threshold for reference conditions. This observation provides a good indication that those stations with the most elevated chemistry based on current conditions in the RHMP embayments will likely show impacts on the benthic community.

However, in the low and minimal exposure potential categories using the CSI, there is considerable scatter among the data points, suggesting that some factor other than elevated chemistry must be impacting the benthic communities, or possibly impacts from other chemicals not included in the CSI score. As an additional step to help further understand the relationships between benthic community structure and measured chemical and physical factors, multivariate analyses were performed using PCA and MDS to help tease out and display vectors and corresponding factors that appear to explain the greatest proportion of variance. Through various iterations and model inputs, these procedures have been able to explain only a limited degree of variance (<40%) with various combinations of metrics. These results indicate that multiple complex factors must be responsible for observed effects on the benthic infaunal communities; likely several measures that were not included in this assessment such as the degree of physical disturbance, frequency and magnitude of influence from freshwater, etc. The tremendous variability in physical/chemical and biological characteristics among the RHMP stations increases the challenge of identifying specific anthropogenic factors that may be responsible for observed effects on a region-wide or harbor/stratum-wide basis. A more robust assessment must therefore be conducted on a smaller scale specific to each station or similar groupings of stations. Using existing observations and readily available information, a more in-depth assessment of those stations showing the most disturbed benthic communities (based on the SQO assessment of benthic community) during the 2013 RHMP was conducted and is presented in the Section 4.5.



Station	Harbor	Strata
B13-8259	Dana Point Harbor	Marina
B13-8267	Dana Point Harbor	Marina
B13-8095	San Diego Bay - Central	Industrial/Port
B13-8045	San Diego Bay - Central	Deep
B13-8052	San Diego Bay - Central	Shallow
B13-8058	San Diego Bay - Central	Shallow
B13-8118	San Diego Bay - North	Deep
B13-8111	San Diego Bay - North	Deep
B13-8090	San Diego Bay - Central	Industrial/Port
B13-8099	San Diego Bay - Central	Industrial/Port
B13-8064	San Diego Bay - Central	Industrial/Port
B13-8233	Oceanside Harbor	Marina
B13-8236	Oceanside Harbor	Deep
B13-8128	San Diego Bay - North	Shallow
B13-8117	San Diego Bay - North	Marina
B13-8029	San Diego Bay - South	Freshwater
B13-8075	San Diego Bay - Central	Freshwater
B13-8018	San Diego Bay - South	Shallow
B13-8014	San Diego Bay - South	Marina
B13-8163	Mission Bay	Freshwater
B13-8112	San Diego Bay - North	Deep
B13-8033	San Diego Bay - South	Freshwater
B13-8040	San Diego Bay - South	Freshwater
B13-8017	San Diego Bay - South	Shallow
B13-8239	Oceanside Harbor	Deep
B13-8145	Mission Bay	Deep
B13-8146	Mission Bay	Marina
B13-8085	San Diego Bay - North	Deep
B13-8124	San Diego Bay - North	Shallow
B13-8500	San Diego Bay - North	Freshwater
B13-8157	Mission Bay	Shallow
B13-8151	Mission Bay	Marina
B13-8156	Mission Bay	Shallow
B13-8013	San Diego Bay - South	Marina
B13-8030	San Diego Bay - South	Freshwater
B13-8152	Mission Bay	Deep
B13-8028	San Diego Bay - South	Freshwater
B13-8038	San Diego Bay - South	Freshwater
B13-8031	San Diego Bay - South	Freshwater
B13-8020	San Diego Bay - South	Shallow
B13-8050	San Diego Bay - Central	Industrial/Port
B13-8087	San Diego Bay - Central	Deep
B13-8036	San Diego Bay - South	Freshwater
B13-8053	San Diego Bay - Central	Industrial/Port
B13-8116	San Diego Bay - North	Marina
B13-8263	Dana Point Harbor	Deep
B13-8265	Dana Point Harbor	Shallow
B13-8073	San Diego Bay - Central	Marina
B13-8121	San Diego Bay - North	Marina
B13-8113	San Diego Bay - North	Marina
B13-8127	San Diego Bay - North	Marina
B13-8076	San Diego Bay - Central	Freshwater
B13-8077	San Diego Bay - Central	Freshwater
B13-8056	San Diego Bay - Central	Industrial/Port
B13-8074	San Diego Bay - Central	Freshwater
B13-8122	San Diego Bay - North	Deep
B13-8123	San Diego Bay - North	Shallow
B13-8159	Mission Bay	Shallow
B13-8160	Mission Bay	Freshwater
B13-8093	San Diego Bay - Central	Deep
B13-8098	San Diego Bay - Central	Industrial/Port
B13-8096	San Diego Bay - Central	Industrial/Port
B13-8109	San Diego Bay - North	Deep
B13-8105	San Diego Bay - North	Shallow
B13-8102	San Diego Bay - North	Marina
B13-8106	San Diego Bay - North	Marina
B13-8108	San Diego Bay - North	Deep
B13-8066	San Diego Bay - Central	Industrial/Port
B13-8100	San Diego Bay - Central	Industrial/Port
B13-8065	San Diego Bay - Central	Industrial/Port
B13-8049	San Diego Bay - Central	Industrial/Port
B13-8069	San Diego Bay - Central	Industrial/Port
B13-8068	San Diego Bay - Central	Shallow
B13-8060	San Diego Bay - Central	Shallow
B13-8078	San Diego Bay - Central	Deep

Figure 4-7. Cluster Analysis Diagram for Analysis of Similarity Among Benthic Infauna Communities and Stations

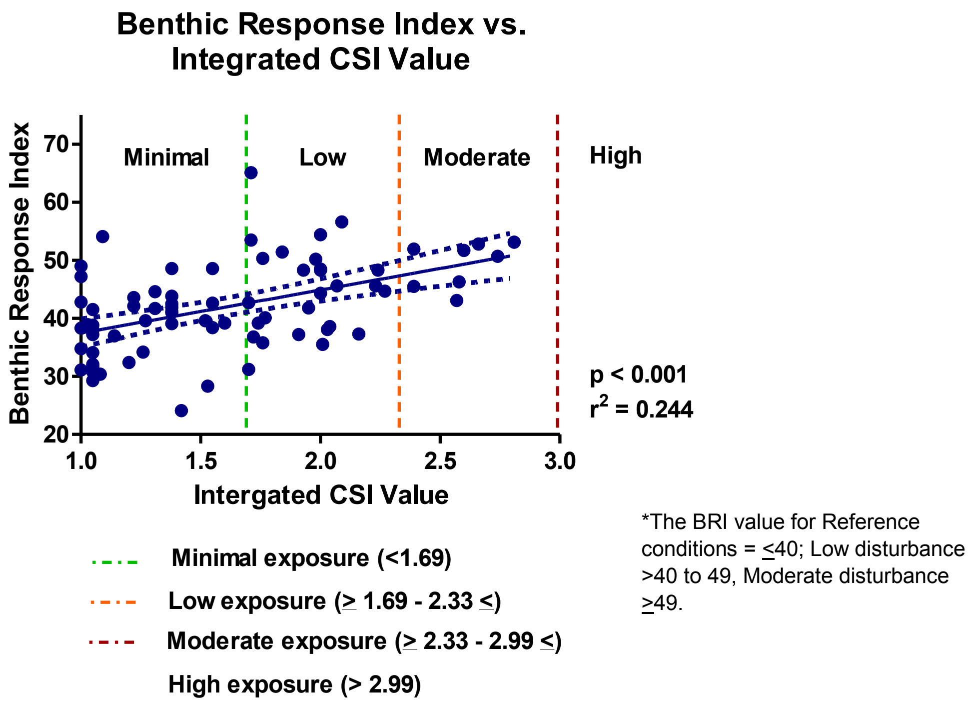


Figure 4-8. Relationship Between Integrated Chemistry Metrics and the Benthic Response Index

4.5 Assessment of Stations with Disturbed Benthic Communities

The SQO assessment of benthic community condition rated only four stations in the entire 2013 RHMP study area as having high disturbance as shown in Figure 4-9. One of these was in Dana Point Harbor (Station 8267) and three were in central and southern San Diego Bay (Stations 8013, 8018, and 8064). The four SQO benthic indices can lack flexibility when a station has a unique community composition or habitat conditions. This is sometimes evidenced by situations where the four indices are in disagreement with one another, indicating that the benthic community may have been missing key components of one index but not the others. (Note that this is why the final integrated benthic score discards the high and low scoring indices, and uses only the median scoring indices). Another confounding factor for benthic community quality may be spatially and temporally driven, where samples are collected in habitat conditions that do not represent typical conditions of the sampling station as a result of the probabilistic nature of the sampling design combined with how the stratum boundaries were drawn. Therefore, the following is an analysis of stations with benthic communities categorized as having high disturbance to determine whether the SQO category seemed appropriate, and what factors may have been driving the conclusion. The scope for this exercise was limited to only highly disturbed communities given that the resolution to tease out likely causes of impairment is greater with a more defined response. The same general approach presented herein, however, may also be applied to sites with moderately disturbed communities as a start for future assessments.

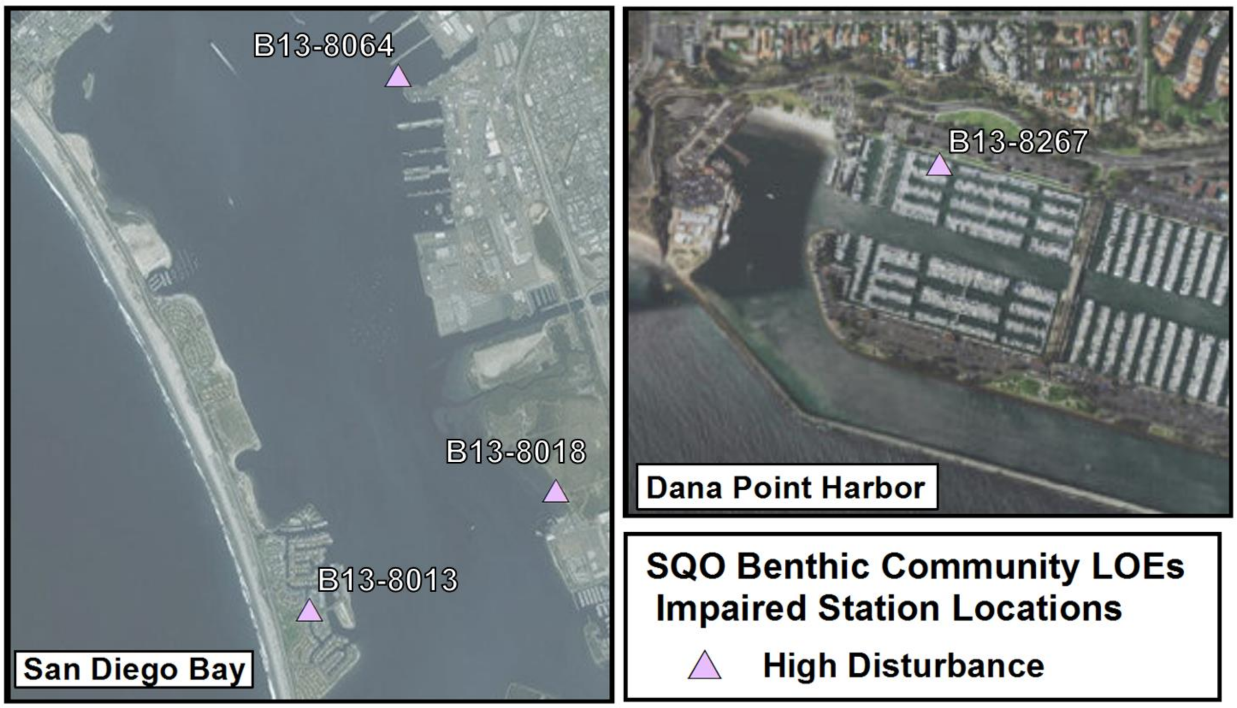


Figure 4-9. Locations of the Four RHMP Sample Locations Considered to have Highly Disturbed Communities

Station 8267

Station 8267 was located in the marina stratum in Dana Point Harbor, deep within the boat slip area. The benthic infaunal community at this station was determined to have moderate disturbance by the BRI, and high disturbance by the IBI, RBI, and RIVPACS. Taxa richness was low (six taxa), and one taxon was considered sensitive (although this sensitive taxon was represented by only one individual). Abundance was also low, with only 51 individuals. There was one other marina stratum in Dana Point Harbor (Station 8259), and the benthic community metrics there (14 taxa, none of which were sensitive, and an abundance of 46 individuals) were only slightly better than those at Station 8267 though this station was categorized as having moderate disturbance. A shallow water station that was very close to Station 8259, in the main channel of the marina and outside the boat slip area, had much better benthic metric scores and a low disturbance rating (43 taxa, 7 of which were sensitive, and 443 individuals). Additionally, the LRM for both of these marina stations indicated high exposure and copper was the CSI compound driver. The integrated SQO chemical exposure metric classified this station as having moderate exposure potential, primarily based on concentrations of copper in the sediments that exceeded the ER-M. In conclusion, it appears that the high disturbance benthic rating for Station 8267 is accurate and the condition is likely due to negative impacts from its proximity to the marina slips.

Station 8013

Station 8013 was located in the marina stratum in Coronado Cays, in southern San Diego Bay. Substantial disagreement existed in scoring among the four SQO benthic metrics. The benthic infaunal community for this station was determined to have low disturbance by the IBI, moderate

disturbance by the BRI, and high disturbance by the RBI and RIVPACS. The IBI rating for low disturbance was a result of the metric for the percent sensitive taxa, the absence of *Notomastus* sp., and the number of mollusk taxa being similar to a reference condition. However, overall taxa richness was low (11 taxa) relative to a reference condition and, with two taxa considered sensitive, the percentage of sensitive taxa was high, although the actual number of total taxa in the sample was small. Given this, it appears that the overall SQO assessment of high disturbance is accurate and that the IBI rating of low disturbance was not representative of the benthic community quality. The integrated SQO chemical exposure metric classified this station has having moderate exposure potential.

Station 8018

Station 8018 was located in the shallow water stratum adjacent to Sweetwater Marsh. The station was also the only RHMP station that was in the lower intertidal zone. Sampling occurred with a tide of +5 ft and the sample depth was recorded as 1 meter. An aerial image clearly shows the location of the site within the dry intertidal mudflat during a low tide condition (Figure 4-10). A photograph of the Van Veen grab from this site also shows the presence of intertidal vegetation and crab burrows (Figure 4-11). For this site as well there was substantial disagreement in scoring among the four SQO composite benthic metrics. The benthic infaunal community for this station was categorized as reference by the IBI, moderate disturbance by the BRI, and high disturbance by the RBI and RIVPACS. Taxa richness was moderate (22 taxa; 30% sensitive taxa) and abundance was relatively high (406 individuals). The RBI categorization was high disturbance because none of the three positive taxa indicators were observed, while both negative taxa indicators (*Capitella capitata* and *Oligochaeta*) were observed at this station. The RIVPACS rating of high disturbance was due to the station having an expected taxa richness of 21 specific species and, although the observed richness was 17, only one of the observed taxa was expected to occur at the station by the model (i.e., had a ≥50% probability of capture). This points out one issue with the SQO benthic indices, particularly RIVPACS: an index can devalue a station if it has a diversity of rare (unexpected) taxa that were not used to develop the index. Further, the SQO indices were also not developed for intertidal substrates, where the benthic community is inherently affected by changing tides and thus it is likely that the final SQO assessment rated the benthic community quality of this station as worse than it actually is. This conclusion is further supported by the finding that this station was considered to have low chemical exposure potential based on the integrated SQO methodology.

Figure 4-10. Aerial Image of Station 8018 Showing Intertidal Conditions at Low Tide

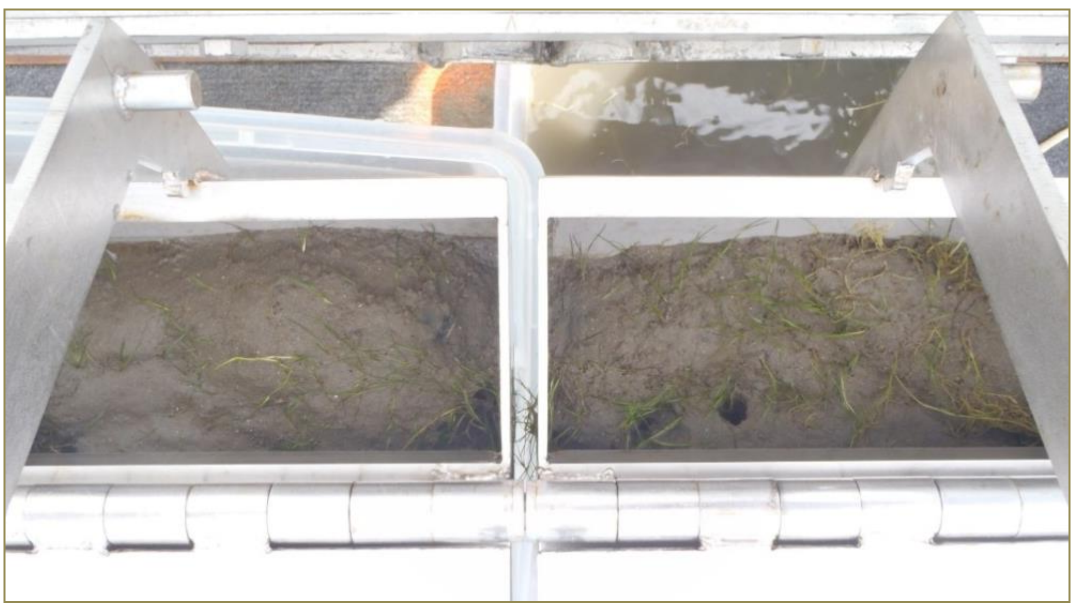


Figure 4-11. Station 8018 Van Veen Grab Sample Showing Intertidal Vegetation and Crab Burrows

Station 8064

Station 8064 was located within the industrial/port stratum of San Diego Bay, alongside one of the naval piers between the outflows of Paleta Creek and the Seventh Street Channel. The benthic infaunal community for this station was determined to have high disturbance by three of the four benthic LOEs and moderate disturbance by the BRI. The overall taxa richness was very low (four taxa), abundance was also low (six individuals), and none of the taxa were considered sensitive. Therefore, the integrated benthic assessment for this station was an accurate assessment of (poor) benthic community quality. However, two nearby stations, also in the industrial/port stratum, were rated with low disturbance (Station 8065) and moderate disturbance (Station 8066). Additionally, none of the four individual benthic LOEs within these two stations were considered to be rated as having high disturbance. Stations 8065 and 8066 had taxa richness values within the range expected for reference sites (45 and 27, respectively) and relatively high abundances (475 and 132, respectively). This could imply that the benthic community composition of Station 8064 was not representative of that area of the bay, and that the disturbance of the community at this station may have been due to some spatially limited stressor, such as scouring by naval ship docking. For reference, the integrated SQO chemical exposure metric classified this station has having moderate exposure potential.

4.6 Overall Integrated SQO Assessment

Overall integrated SQO assessments using the three LOE: chemistry, toxicity, and benthic community measures, classified 72% of all RHMP stations as having unimpacted or likely unimpacted sediment conditions as shown graphically in Figure 4-12. Relative assessments of RHMP-wide conditions improved in comparison to the historical baseline conditions; however, areas associated with localized anthropogenic inputs of pollutants, most notably the marina and industrial strata and, to a limited extent, freshwater-influenced stratum, had conditions that were less suitable for supporting healthy biota.

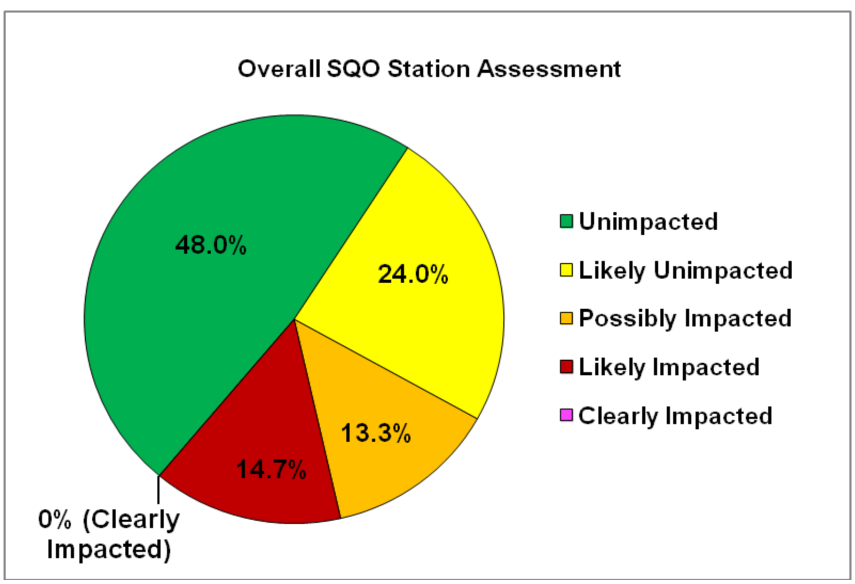


Figure 4-12. Pie Chart Summary of the Fraction of RHMP Stations in Each of the Final Integrated SQO Categories

Among strata the final integrated SQO scores classified 94% of the deep stations, 93% of the shallow stations, and 80% of the freshwater-influenced stations as unimpacted or likely unimpacted. The only freshwater-influenced stations that were considered to be possibly impacted or likely impacted were located near the mouth of the Chollas Creek. In contrast, a lower proportion of 40% of marina stations and 50% of industrial/port stations were classified as unimpacted or likely unimpacted.

While differences among harbors may be attributed to factors such as size, tidal exchange, depth, human uses, and flow rates, and while individual harbors may have some differences in each individual LOE, the overall integrated SQO results did not differ substantially among harbors and appeared to be determined more by stratum type. In Dana Point Harbor, 50% of sites were unimpacted (deep and shallow strata), while two additional stations were considered possibly impacted and likely impacted (both in the marina stratum). In Oceanside Harbor, 1 of 3 (33%) of stations were considered unimpacted; 33% were likely unimpacted (deep stratum); and 33% were likely impacted (marina stratum). Mission Bay had 67% of stations classified as unimpacted, and the remaining 33% were likely unimpacted. San Diego Bay had 46% of stations classified as unimpacted; 24% as likely unimpacted; 15% as possibly impacted (primarily composed of industrial/port or marina strata); and another 15% as likely impacted (made up primarily of industrial/port and marina strata and two freshwater-influenced stations near the mouth of Chollas Creek in San Diego Bay).

The harbors appear to have reached a relatively steady state with small improvements overall relative to 2008, compared with the much larger improvements noted based on a variety of data collected prior to 2008. Previous and developing regulations, a variety of significant source controls, and dredging and other cleanup activities have made tremendous improvements over the past few decades in the harbors. The areas of particular concern remain primarily within marinas and around industrial/port regions. These areas will warrant continued attention. There are some impairments noted near areas with freshwater influence in San Diego Bay, primarily related to the benthic communities, but overall conditions remain likely unimpaired on average, except for two stations near the mouth of Chollas Creek considered possibly impacted or likely impacted after integration of all three SQO LOEs. More focused assessments should be able to discern whether the impacts to benthic communities in these areas are related to watershed inputs, or some other chemical or physical factor.

With regard to long-term trend assessment, it should be reiterated that a number of studies used to establish historic thresholds for comparison were targeted non-randomized assessments making direct comparisons with current randomized approach for RHMP challenging, thus warranting some caution when interpreting these results as a whole. When comparing only those monitoring programs that have used a randomized sampling effort over the past 15 years comprising the past four regional Bight monitoring programs since 1998 (including RHMP in 2008 and 2013), fewer noticeable trends are apparent as mentioned with the notable exception of reduced toxicity over the years. Because a majority of RHMP stations are in good condition, the resolution to tease out trends at the fewer number of impaired locations is diminished when using data from all sampling locations. A closer look at results for

individual or closely grouped sites considered to historically be impaired that have been revisited over time will provide a more accurate assessment of trends on a more refined basis.

Differences in the way the key benthic infauna metrics have been calculated over time have also diminished the ability to look at these trends without a complete re-analysis of historic datasets which is highly recommended at some point, but beyond the scope of this current program.

4.7 Demersal Fish and Macroinvertebrate Community

The demersal community health appears to have remained relatively constant over the past 15 years, based on comparisons with prior Bight ’98 and Bight ’03 survey data, as well as with the 2008 RHMP data. The fish communities sampled in the 2013 RHMP were similar to those of prior Bight surveys in terms of the mean number of taxa caught per trawl, whereas the mean abundance and biomass were substantially greater in 2013. This change is most likely driven by large numbers of slough anchovies captured at Stations 8159, 8052, and 8058 in eastern Mission Bay and central San Diego Bay, as well as large numbers of deepbody anchovies and queenfish captured at Stations 8058 and 8052. Trawling offers a snapshot in time of what species are present in the trawl track and how abundant they are, but the same sampling station may have quite varied results due to the mobility of demersal organisms.

While abundance and biomass were greater at the aforementioned stations, means among other sampling stations were similar to those of previous years. Further, based on prior San Diego Bay studies (Allen, 1999; VRG, 2006; the 2008 RHMP and 2013 RHMP), lists of the top ten species with the greatest EI values (Table 3-19). Five species in common with those captured in 2013 appeared on each of these lists. Such overlap suggests that, overall, species composition does not appear to be drastically changing. Differences in catch from prior years may also be a function of methodology, as the Allen and VRG studies used several different sampling methods that may have been more or less successful at capturing certain benthic fish species. The goals of these two programs also differed, with the VRG survey providing a more complete assessment of overall fish populations, versus a snapshot condition of benthic fish species during the RHMP/ Bight ’13 efforts. The different methodologies likely explain the presence of benthic species more often in the 2008 RHMP and 2013 RHMP data sets (such as lizardfish in 2013 and the diamond turbot in 2008), whereas more pelagic species appeared in the Allen and VRG data sets. Further, the particular benthic species could also reflect the substrate type where sampling occurred, as demersal organisms tend to have particular habitat preferences.

Overall, the diversity, abundance, and biomass recorded in both the 2013 RHMP and historical data sets, along with minimal abnormalities, support the premise that regional harbors are capable of supporting healthy fish assemblages. However, regarding the demersal fish community, there is further evidence of long-term sustained and possibly improved health of local fish species. The current study is well aligned with the long-term trend of decreasing incidences of fish diseases and anomalies in the Bight since the 1970s, when Mearns and Sherwood (1977) reported an anomaly incidence of 5% (Allen et al., 2007) as compared with an incidence of anomalies of 0.6% in the 2008 RHMP and 0.3% in the 2013 RHMP. As with fish,

the demersal macroinvertebrates collected appeared healthy, based on the absence of abnormalities or obvious disease; however, average diversity, abundance, and biomass of invertebrates have varied greatly throughout the historical data collection. Average species diversity has been relatively similar among all surveys between 1998 and 2013. Based on this evidence alone, it is unclear whether there is a trend of decreasing invertebrate abundance and/or biomass, or whether any such differences are due to natural inter-annual variability or directly related to the substrate of the sampling station. The possibility exists that changes in climatic conditions, particularly the current drought, which has resulted in less input of organic matter, may have a significant impact on communities as well.

4.8 Assessment of Spatial and Temporal Variability Regarding Data Interpretation

Small scale spatial variability was observed both visually in the field during sampling efforts, and in the resulting data from the RHMP efforts where in some cases stations very close to one another had very different physical/chemical/ and/or biological characteristics. Visually different substrates, in addition to the variable presence of epibenthic macroalgae, eelgrass, and burrows were noted at many stations.

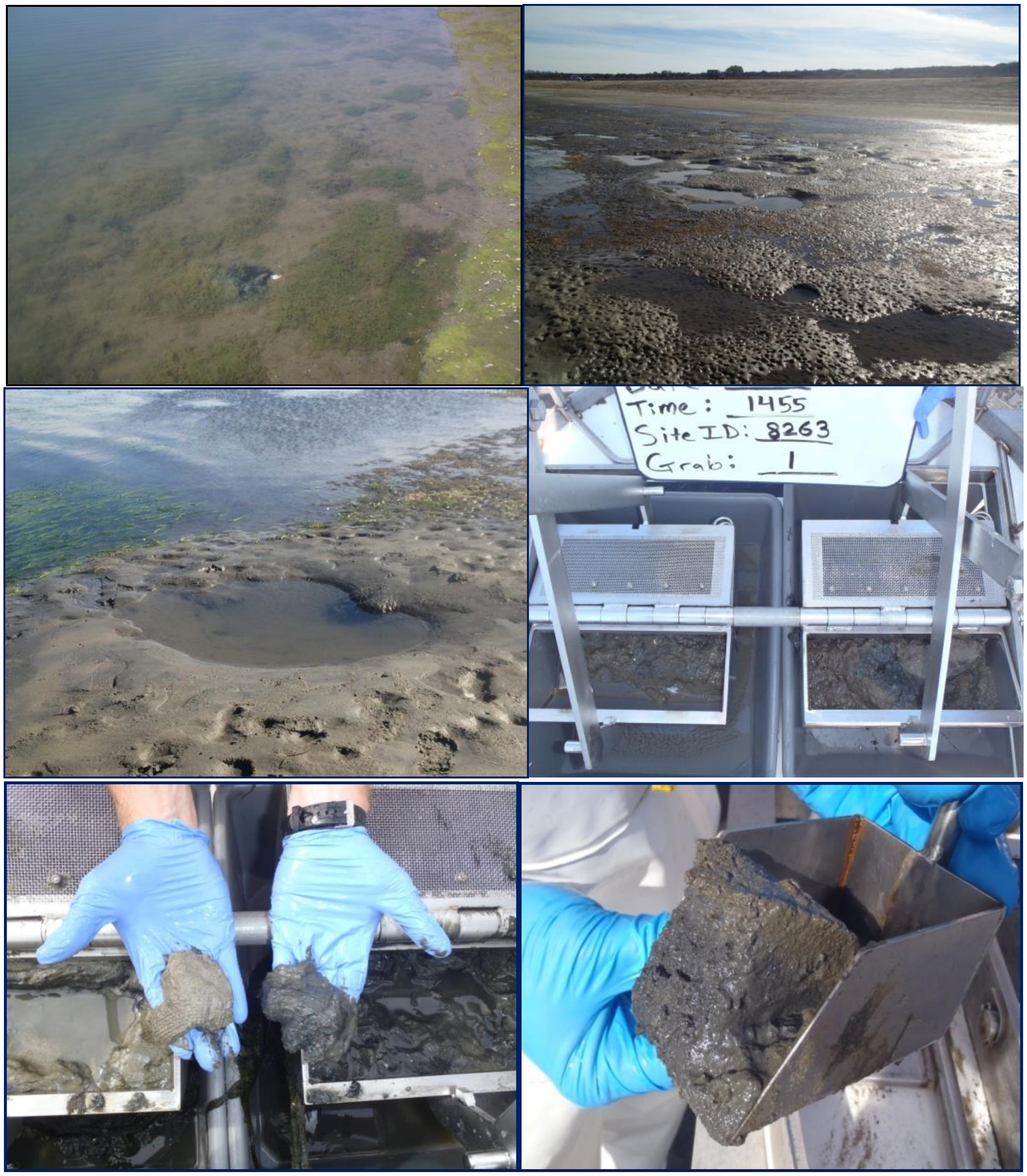
Temporal variability is harder to discern without more focused intense studies, but changes in climatic conditions such as temperature and storm water inputs, and physical disturbance related impacts such as dredging or propeller wash, are all short term impacts that cannot be accurately assessed with an every 5-year sampling program. Drawing conclusions and ignoring such variability may result in misunderstanding processes occurring within a certain sampling area and must be taken into account when determining management options for areas deemed impaired.

Many areas within the regional harbors may contain contaminants from past anthropogenic activity, and physical factors such as sediment particle size composition and flushing rates will have an impact on contaminant distribution. For example, wetlands have been found to store total mercury from historical anthropogenic influences due to their fine-grained and organic-rich sediments (Ullrich et al. 2001; Spencer et al. 2006). Several physical factors may be occurring in the harbors that also account for spatial variability observed within the data set. Tidal inundation as well as cycles of wetting and drying in the shallow stratum, physical sediment reworking by currents, bioturbation, and anoxia in areas of low flow or tidal exchange are all factors that may contribute to variability observed across harbors and strata (Marvin-DiPasquale and Cox 2007; Laverock et al. 2011). Propeller induced turbulence from boating activity has also been linked to disturbances such as sediment erosion and the exposing and remobilizing of contaminated sediments from the substrate (Lepland et al. 2010). Bioturbation can be carried out by an array of organisms including polychaete worms, crustaceans, benthic mollusks and echinoderms, fish, rays and both infaunal and meiofaunal communities (Meysman et al. 2006). Further, bioturbated sediment has been found to increase fluxes of oxygen, total carbon dioxide and dissolved inorganic nitrogen 2.5-3.5 times across the sediment/water interface when compared to non-bioturbated sediment (Laverock et al. 2011). Each harbor in the monitoring program experiences some, if not all, of the aforementioned disturbances on a daily basis. Many cases of spatial variability at the sediment surface were also observed during RHMP 2013 as

shown in a few photographs below. Within a single sampling area, variability in algal or eelgrass cover versus bare substrate, exposed versus inundated substrate, bioturbation via bat ray pits and infaunal activity, as well as vertical spatial variation within a single grab were all observed during the RHMP 2013 sampling efforts. These inconsistent attributes can have a substantial influence on sediment chemical and physical properties and associated benthic communities.

Disturbance related to bat rays or round rays is a very likely cause for the moderately impacted benthic community condition noted at Site 8159 in eastern Mission Bay. All other sites monitored in Mission Bay were considered to have benthic communities categorized as being in reference condition or having low disturbance. Furthermore, chemical concentrations in the sediment were low and the sediment was nontoxic. The photographs showing the bat ray pits below were taken at low tide in the same vicinity. Impacts to the benthic community due to bat ray pits has been documented in a paper by VanBlaricom (1982) that found substantial changes in benthic community following such disturbance.

The likelihood and potential ramifications of spatial and temporal variability must be considered carefully when assessing conditions at any single location.



Photographs showing large-scale and micro-scale spatial variability of sediments in the San Diego Regional Harbors: Clockwise from top left: algal patches intermixed with bare substrate in the shallow stratum (Mission Bay); bat ray pits in Mission Bay near Site 8159; second view of a bat ray pit also showing surface macroalgae and the upper edge of an eelgrass bed; noticeable spatial variability in appearance on the surface of a grab sample collected from Site 8263 in Dana Point Harbor; comparison of noticeably different sediment types from a single side-by-side grab sample (Site 8014 in south San Diego Bay, Coronado Cays); vertical microspatial variation in a single 5-cm grab showing the oxic brown layer over the darker anoxic sediment.

4.9 Special Considerations Related to Data Comparison between Harbors

In addition to physical differences that may result in variation among harbor conditions, it is also important to recognize that smaller sample sizes from smaller harbors, as well as the composition of strata sampled in each harbor, may also skew overall results. Further, in terms of the demersal community, ecosystem health is often measured in terms of biodiversity metrics. While a more diverse demersal community may indicate a healthy harbor, it does not take into consideration the effect of habitat type on such metrics. For example, while Mission Bay had both the least-impacted sediment condition of the harbors as well as the highest mean abundance of both fish and invertebrates, the higher biodiversity observed there is likely attributed to two trawl stations (Stations 8156 and 8159) containing eelgrass, a known nursery habitat that supports higher diversity than do nearby sandy bottoms. Therefore, while it might appear that greater diversity of demersal organisms may be a direct result of overall sediment quality, it is actually more likely a direct result of habitat diversity. The benthic infaunal community quality within the harbors will be closely associated with localized disturbances, harbor use (and therefore strata type), and inputs of pollutants, while demersal community abundance and diversity appear to be driven by a wider array of factors (e.g., human collection, habitat heterogeneity, and harbor size) that extend beyond localized inputs of pollutants within harbors.

Note that there are several limitations with the data that require special consideration. These limitations have been highlighted throughout the discussion and elsewhere in this report, but are summarized again briefly in Section 4.10 for reference.

4.10 Data Limitations

- The RHMP sampling methodology offers a “snapshot” in time of conditions of the harbors; it does not reflect seasonal, diel, or short time-scale variability that may occur.
- The great diversity of geography and physical habitats along with physical disturbance can result in an extremely heterogeneous benthic habitat in semi-enclosed bays and harbors, particularly in the shallower regions or areas with significant human activity. This was clearly observed and noted during sampling efforts of the harbors for the RHMP. High spatial variability in sediment characteristics can make comparative assessments challenging spatially and temporally. In several cases, samples that were collected relatively close to each other during the RHMP field efforts resulted in substantially different outcomes. The opposite was true as well in many cases, indicating similar or more homogeneous conditions in many areas as well. Interpreting trends over time also needs to consider the effects of spatial variation as well. There will be greater confidence for those areas that have a more uniform habitat than those areas with frequent disturbance or varied substrate.
- Having noted the challenges that spatial variability may impart, overall consistency in results over the previous two RHMP monitoring efforts indicates that the number of samples assessed by stratum and harbor were sufficient to provide good confidence in the overall assessment of existing conditions, general trends, and resulting conclusions.

- The integrated SQO approach utilizes three LOEs to provide a robust assessment of surface sediment conditions, however two limitations of this approach as described by Bay et al (2014) include the following: (1) This approach assesses only direct impacts to sediment biota and does not address the impacts to human health or wildlife through bioaccumulation and/or biomagnification of contaminants in fish and shellfish; and (2) the analysis does not identify specific chemicals causing impacts. Impacts to human health and wildlife are currently being addressed separately through the coordinated efforts described in Section 1.2 that will be reported under separate cover. Site specific studies will be required to tease out specific chemicals or other stressors of concern affecting biological communities, though a preliminary assessment is possible with the current SQO data as shown in Section 4.5 of this report for a few RHMP sites.
- Where impaired benthic communities are observed, careful consideration must be given regarding anthropogenic impacts in addition to physical characteristics and/or disturbance that may affect the stability of the communities. Communities are also only evaluated during the summer months, so changes that occur throughout the year are not accounted for by this program.
- Sediments collected during ambient summer conditions do reflect cumulative impacts over time; however, any small-scale changes that might occur throughout the year that may affect chemical contaminant distributions and potential toxicity (i.e., during wet weather conditions or resuspension events) are not explicitly addressed through the current assessment methodology. This tendency is even more pronounced for water quality, which can vary substantially at any given location depending on localized conditions and activities.
- Measures of benthic fish and invertebrate populations represent only a brief snapshot in space and time considering the often dramatic variation that is known to occur for these populations. This was noted several times during RHMP sampling efforts where multiple trawls in the same general area often captured substantially different populations. The single trawl stations in Dana Point and Oceanside Harbors also provide a limited spatial assessment and statistical power for these two harbors. Finally, this method of capture will target a limited habitat type where trawls are possible without interference, and will typically exclude larger fish that are quicker to move out of the way. Thus, comparisons with other survey methods or inferences on total fish and invertebrate populations must be made with caution. When taken as a whole, region-wide, these data provide a valuable assessment, but conclusions on observations, particularly on a smaller scale, must be clarified with these caveats noted.
- Watershed runoff inputs and subsequent related effects were not measured as part of the RHMP. It is likely that such events can have a substantial impact over brief periods given the high intensity runoff that often occurs in Southern California due to intense storms and a high degree of impervious surfaces, with the potential for longer term impacts. However, these dynamics were not assessed in this study and very few studies to date have specifically investigated potential impacts to benthic communities from runoff related events in southern California bays and estuaries.

- Discrepancies in the benthic index calculations for the 2008 RHMP data, (particularly the BRI) were noted when comparing the 2008 and 2013 data sets. An investigation found that the BRI condition scores reported in the 2008 RHMP were biased low (indicating healthier conditions) than those reported by SCCWRP in its final assessment report using the same data set. A re-analysis of a subset of these data confirmed these discrepancies. These discrepancies indicate that the historical comparison made in this report must be interpreted with caution, and it is recommended that a re-analysis of the entire 2008 data set (as well as data from earlier surveys) be completed for more accurate trend analyses.
- Method detection limits have varied for some chemicals over time with lower limits currently than that in prior surveys; particularly those for several organic constituents such as chlordanes, PCBs, and DDTs. This difference can have a substantial influence on final reported totals, so must carefully be considered when making trend comparisons over time for these constituents.
- It should also be noted that despite generally consistent methods and sampling equipment, some of the sampling designs and goals of the various studies used to develop historic pre-set values varied from the randomized approach used for RHMP and Regional Bight Program. In particular, some of these studies included targeted designs focused on identifying conditions at potential hot spots or site-specific characterization programs. These differences, along with the discrepancies noted related to the calculation of benthic indices and changes in detection limits for certain chemicals, must be considered carefully when drawing conclusions based on historic trend analyses with existing pre-set targets.

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5.0 QA/QC SUMMARY

QA/QC extended throughout each stage of the all RHMP-related efforts. The overall QA/QC process employed by the RHMP is summarized in the Materials and Methods Sections 2.4 through 2.6, with a more detailed summary of the complete data QA/QC process (encompassing a review of raw data, data processing and analysis, and reporting activities) provided in the accompanying QAPP for the RHMP (Amec Foster Wheeler, 2013b).

All data reported herein has undergone the QA/QC process described in the project-specific QAPP for the RHMP and has been considered acceptable for reporting and analysis. In addition, all methodologies and reported data have passed Bight ’13-specific requirements that have been undergoing an independent QA/QC review process through this coordinated program. One extra step required by the RHMP was a Level II internal review of 100% of the analytical chemistry data, as well as a third party Level IV validation of 10% of the analytical chemistry data associated with the RHMP. Both a Level II validation report by Amec Foster Wheeler’s Portland office, and a complete third party data validation report by LDC are provided in Appendix L for reference. Additional pertinent QA/QC information for all data collection activities is summarized below

5.1 Field Activities

All field-related activities met QA/QC requirements as set for forth in the project-specific QA/QC Plan for RHMP (Amec Foster Wheeler, 2013b) and the regional Bight monitoring methods outlined in the Bight ’13 QA Manual (SCCWRP, 2013c). This included the calibration and collection of data from the CTD and 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. Additional details related to QA/QC efforts for the trawling activities are highlighted further below given the extensive steps and protocols for this effort.

5.1.1 Trawl QA/QC

The quality of fish and invertebrate identification, enumeration, biomass, and length was ensured through pre-survey training, intercalibration, and in-survey and post-survey audits. Lead Invertebrate and Fish Scientists from Amec Foster Wheeler reviewed standard sampling procedures prior to field collection. During each survey, the Cruise Leader checked scale calibrations at the start of each day, confirmed appropriate identification aids and processing equipment were onboard, and ensured processing followed the protocol described in the Bight ’13 Field Operations Manual. In addition, the Cruise Leader re-weighed and re-measured four species (two fish and two invertebrates, each with at least 10 individuals) each day of trawling (if 10 individuals were not captured, 2 of each were selected). These internal QA/QC checks were detailed in the Bight ’13 Field Manual. External Field QA/QC Auditors also conducted one in-survey visit during trawl sampling using the same methods that the Cruise Leader used daily. Completeness objectives for fish and invertebrate counts and weights, and fish lengths were 90% and precision objectives for counts, weights, and lengths were 10%; all of which were met for the RHMP (100% complete).

The taxonomic identification of demersal fish and invertebrate species was ensured by a pre-survey training and intercalibration, in-survey audits, and post-survey voucher checks. Pre-survey QA activities included a taxonomic information transfer meeting, an in-field training/intercalibration exercise, and an intercalibration exercise assessing fish and invertebrate identification abilities. To be recognized as Bight ’13 taxonomists, Amec Foster Wheeler biologists identified specimens of representative fish and invertebrate species in buckets that were given as a test by SCCWRP, where a passing score was required to conduct surveys in the field. A project-assigned taxonomist audited taxonomic identifications in the field during one sampling day of the program. At least one voucher specimen of each species identified in the field was kept and used for taxonomic validation by SCAMIT and Southern California Association of Ichthyological Taxonomists and Ecologists (SCAITE) taxonomists.

The SCAMIT cooperated with Bight ’13 agencies to provide an important element of quality assurance for taxonomic identification. The taxonomic nomenclature used in Bight ’13 followed *A Taxonomic Listing of Soft Bottom Macro- and Megainvertebrates from Infaunal and Epibenthic Monitoring Programs in the Southern California Bight, Edition 8* (SCAMIT, 2013). In addition, SCAMIT protocols for the use of open nomenclature (SCAMIT, 1986) were followed. Amec Foster Wheeler taxonomists participated in special SCAMIT/Bight ’13 workshops prior to and after the sampling period that focused on the taxonomy of certain groups to promote uniform identification. The workshops provided training, pooling of regional resources, and local experts to be called upon for assistance during sample analysis. SCAMIT/Bight ’13 continued monthly post-sampling to address taxonomic problems arising during analysis of the Bight ’13 samples. A synoptic data review (SDR) of the data set was compiled from all participating Bight ’13 agencies and was conducted to ensure maximum QA/QC efforts for the entire data set.

5.2 Analytical Chemistry

5.2.1 Introduction and Background – Data Review and Validation Summary

As part of the RHMP effort, 75 sediment and surface water samples were collected in addition to 3 water samples, consisting of 1 field blank and 2 equipment blanks. Samples were collected between August 6 and September 10, 2013. Amec Foster Wheeler submitted the samples to the primary laboratory, Physis, located in Anaheim, CA.

Samples were collected in accordance with the approved Work Plan (Amec Foster Wheeler, August 2013) as submitted to the lead agency, the Unified Port of San Diego. Physis divided and assigned these samples into 18 sample delivery groups (SDGs). 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 Plan (dated August 30, 2015). Project DQOs were developed on the basis of SWAMP criteria consistent with the previous 2008 RHMP study (Weston, 2005 and 2010), and related regional monitoring efforts, including the Bight ’13 regional monitoring program managed by SCCWRP. Access to the results from multiple studies will be leveraged by upload into a common California Environmental Data Exchange Network (CEDEN) database.

5.2.2 Test Methods

Physis analyzed the sediment samples for AVS by the Plumb 1981 method and SEM by EPA Method 200.8; ammonia by SM 4500-NH3 D; metals and total phosphorus by EPA Method 6020; and chlorinated pesticides, fipronil and degradates, PBDEs, PCB aroclors (aroclors), PCB congeners, PAHs, and pyrethroid pesticides by EPA Method 8270C. Physis analyzed the surface water samples for ammonia by SM 4500-NH3 D, barium by EPA Method 200.8, metals by EPA Method 1640, mercury by EPA Method 245.7, MBAS by SM 5540-C, nitrate by SM 4500-NO3 E, oil and grease by EPA Method 1664A, total orthophosphate by SM 4500-P E, and PAHs by EPA Method 625.

Physis subcontracted subsamples of sediment to the IIRMES for analysis of TOC and total nitrogen by EPA Method 9060. Physis subcontracted surface water subsamples to Sunstar Laboratories, Inc. (Sunstar) for analysis of TOC and DOC by EPA Method 415.3.

5.2.3 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 water 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 4 data deliverables for two SDGs (1307002-005 and1307002-010, respectively) which were subjected to full Level 4 validation. 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.

5.2.4 Data Quality Objectives

DQOs are defined in the RHMP project-specific QAPP and summarized in Table 7-3 of the Amec Foster Wheeler DV report for seawater samples and Table 7-4 for sediments within this document. 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 as seawater. 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.

5.2.5 Data Usability

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 r-qualified and initially rejected 93 (0.5%) individual data points total including the following specific compounds: the pyrethroid pesticides permethrin, resmethrin, and deltamethrin/tralomethrin, and the organochlorine pesticide endrin aldehyde. The root cause of the rejections identified in corresponding sections of the DV report included a variation of unacceptable calibration curves (Section 5.2.5), extremely low initial calibration verification (ICV), (7.1.4), continuous calibration verification (CCV) (Section 5.2.5), Laboratory Control Sample (LCS) (Section 5.2.5), and/or matrix spike (MS) recoveries (Section 7.1.10), or missing QC (Section 5.2.5).

The data were initially rejected following a Level IV review, but have since been retained in the project database with a flag because, consistent with results of previous Bight monitoring events, the specific pyrethroids in question (permethrin, resmethrin, and deltamethrin/tralomethrin are less common, comprising a negligent fraction of the total pyrethroid concentration, which is dominated regionally by bifenthrin. Bifenthrin was also detected in 2013 RHMP samples from expected stations (near areas of freshwater influence), providing confidence in the analytical method. Likewise, the compound endrin aldehyde is uncommonly detected in current regional sediment samples suggesting the lack of its presence in the 2013 RHMP is not anomalous. These Level IV rejected compounds were not included in any of the results or analyses highlighted in the RHMP report for 2013, or the prior 2008 RHMP survey.

The remaining results are considered fully usable with the addition of the qualifiers specified in this report. In a few cases, rejection of data was a result of analyst error (e.g., unacceptable calibration curves by removal of a midpoint standard, and a continuing calibration standard that was run at a concentration above the highest calibration standard). These errors affected the

results of 14 sediment samples for pyrethroid pesticides. These samples were not reanalyzed with an acceptable calibration or verification; however, these discrepancies were noted in the corresponding case narrative and the laboratory initiated corrective action going forward. Therefore, these errors were considered as exceptions, but are highlighted because they are laboratory protocol deviations rather than a technical advisory (e.g., a validation qualifier resulting from a DQO exceedance or low-level blank contamination).

The Level IV report by LDC also identified three seawater samples that were flagged as rejected for nitrate due to a 48-hour holding time exceedance. However, because the samples were within the 28-day technical holding time for nitrate for samples that are preserved with H_2SO_4, they are considered usable.

It is recommended that r-flagged data be excluded from modeling inputs and that data users consider potential bias associated with use of these results on a constituent-specific basis for each of the root causes identified above. The data are appropriately flagged to indicate potential bias and a complete description of validation qualifiers and their application is provided in the full validation report.

Based on data usability, the calculated completeness is 99.5%, well above the 90% project goal.

Estimated Data

Both the Tier II and Level IV validation identified a variety of method protocol exceptions that warranted an estimated ("J-flagged") validation qualifier. Specifically, by using the available CLP functional guidelines for validation and assuming the prescriptive application of the EPA SW846 method requirements, the CLP validation guidelines do not readily accommodate more recent USEPA guidance using nonprescriptive performance-based measurement systems (PBMSs). As a result, affected data were globally assigned a J or UJ validation code and conservatively flagged as estimated. Based on the validation comments, additional efforts were made to (1) understand the technical rationale behind the assigned validation qualifiers, and (2) evaluate the laboratories' methodologies to ensure project DQOs were met to confirm data usability. The following section describes the PBMS and the validation rationale for assigning data as estimated.

Performance-based testing is used quantify actual method performance and any method modifications to "standard" EPA SW 846 methods to achieve lower detection limits, minimize sample interferences, and enhance accuracy and precision by measuring statistically derived control limits applicable to a given matrix. This performance-based approach is USEPA recommended in newer methods, is particularly appropriate for difficult matrices and low detection limits, and is compatible with SWAMP guidelines that provide the basis for this QA/QC program.

To arrive at the PBMS used in this project, the primary laboratory has made several method modifications for low-level testing of sediments, seawater, and tissues. In addition, the laboratory uses instrument-specific software for tuning of gas chromatograph (GC)/mass spectrophotometer (MS) match to a National Institute for Standards and Technology (NIST)

target compound library prior to calibration and sample analysis, and calibrations are performed on a mass basis, not using the concentration-based guidelines provided in EPA SW 846. A summary listing of USEPA method modifications employed by Physis is provided in Section 7.5 of the Amec Foster Wheeler DV report provided in Appendix L.

Due to these method modifications and the calibration procedures used by Physis, when the data analysts applied the data validation function guidelines, they were unable to resolve the mass-based instrument calibration compared to the volume basis sample digestion or extraction and internal standard quantification. With no guideline to evaluate mass-based calibration, these data were J or UJ flagged (estimated or non-detected estimated) for all sediment metals and organics test results. Complete descriptions of data qualifiers and reason codes are provided in the full validation reports.

5.2.6 Analytical Laboratory Method Modifications

The following summarizes method modifications provided by Physis and included in applicable SDG case narratives:

- Because of the longer and narrower GC columns used for GC/MS analyses (to maximize compound separation), the analytical run times are significantly extended. The method prescribes a calibration verification "tuning" solution frequency of every 12 hours. However, the laboratory uses a 20-sample batch limit, and analyzed the tuning solution at the beginning, middle and end of each batch.
- Some target analytes for the GC/MS method were analyzed in negative chemical ionization (NCI) mode. These produce nonstandard mass spectra and cannot be verified to the electron ionization spectra in the NIST library. These include pyrethroids and fiporonils, so PCB_{112} and PCB_{198} are used as surrogates for these compounds.
- Physis uses a congener-based calibration standard for PCB analyses and determines the Aroclor concentration by relative response factor of a predetermined congener profile of a known Aroclor standard. This method is considered more accurate than Aroclor-based calibration, because the quantification is based on individual peaks, rather than summed peaks.

Review of the above modifications did not identify any appreciable effect on data usability for this validation.

5.2.7 Analytical Laboratory Performance Evaluation

The laboratory's ability to deliver data that are sufficiently accurate, precise, and representative is paramount to fulfilling project DQOs and ultimately affects the intended usability. Because of the significant number of validation qualifiers applied to these data, a comprehensive follow-up was performed by Amec Foster Wheeler QA/QC specialists to ensure that the laboratory was producing sound, defensible data that are both usable and comparable. This was done by requesting full laboratory data backup and explanation throughout the comprehensive Level IV review process; scrutiny of laboratory case narratives to ensure full disclosure of method

modifications and performance-based chemistry protocols; review of any significant laboratory errors and corrective action; and a follow-up laboratory audit. A thorough analysis of spatial and temporal trends was also performed to assess whether the data were consistent with those generally expected. The results of this laboratory performance evaluation and data exploration exercises were also shared with project agencies and technical experts to verify data usability.

Amec Foster Wheeler staff conducted an onsite follow-up systems audit of the Physis facility on June 9, 2015. The audit revealed a few recordkeeping discrepancies between analyst standards preparation recorded in logbooks and direct traceability to instrument calibration. In addition, some training records were not immediately available during the audit, but appeared to be the result of recent staff reorganization. The laboratory was also evaluated for corrective action follow-up associated with rejected data, as detailed in Section 7.6 of the Amec Foster Wheeler DV report (Appendix L). The laboratory management was responsive to appropriate and timely corrective action for all laboratory errors that yielded rejected data, as documented in a July 27, 2015, audit response letter provided by Physis.

Overall, the laboratory embraces PBMS protocols and matrix-specific method modifications to address complex matrices and to achieve high compound resolution and low detection limits. The protocols as reviewed during the data validation, laboratory audit, and peer review process had generated usable data in agreement with SWAMP guidelines that are less prescriptive than CLP guidelines and are deemed relevant and applicable to meet the RHMP program DQO goals. Based on this comprehensive review, with the exception of rejected data identified in Section 7.4.1 of the Amec Foster Wheeler DV report, all data are considered valid for reporting and analysis as qualified. It is also worth pointing out that all analyzed data associated with the RHMP also has undergone a thorough QA/QC review process through the Bight ’13 Regional Monitoring Chemistry Workgroup subcommittee. All (100%) of the data collected by RHMP was considered acceptable for reporting and analysis efforts under the Bight Program.

5.3 Toxicity

All toxicity test QA efforts have been successfully completed and a final database has been submitted to the SCCWRP web portal and incorporated into a final report prepared by the Bight Toxicology Committee (Bay et al., 2015). All standard protocol QA/QC requirements were met for all data reported for RHMP. A subset of seven samples in San Diego Bay (Stations B13-8052, 8060, 8078, 8109, 8118, 8122, and 8033) did have an exceedance related to a Bight ’13-specific control replicate variability requirement, but the control met mean survival test acceptability of 90% and results for associated samples all had survival rates that were above or very close to 90%. Regardless of control performance, all of these samples would result in a nontoxic score following the SQO methodology. These data were flagged (noting this small deviation), but results were included as valid data for all analyses and comparisons. Details related to all toxicity QA/QC efforts are included in the project-specific Work Plan for RHMP (Amec Foster Wheeler, 2013b) and Bight ’13 Laboratory Manual for Toxicity Testing (SCCWRP, 2013d).

5.4 Infauna

All infauna identification and sorting QA has been successfully completed and a final database has been submitted to the SCCWRP web portal. There were no outstanding issues remaining at the time of this report. Details related to all benthic infauna QA/QC efforts are included in the project-specific Work Plan for RHMP (Amec Foster Wheeler, 2013b) and Bight ’13 Laboratory Manual for Benthic Infauna Analysis (SCCWRP, 2013e). A report of the results for the entire Bight ’13 Program is in progress and will include the data collected through the RHMP. A draft report by SCCWRP is anticipated to be ready by summer or fall of 2016.

6.0 CONCLUSION

The 2013 RHMP core monitoring program used a MLOE approach that integrated water and sediment quality assessments with biological community monitoring to effectively answer four core questions (the first three addressed herein) outlined in the §13225 letter by the SDRWQCB regarding inputs, distribution, and magnitude of pollutants of primary concern, the suitability of the harbor environments to support healthy biota, and long-term trends in environmental conditions of the harbors. The results demonstrate that most of the area within the harbors had sediment and water quality conditions that were supportive of healthy biological resources. The conclusions of the 2013 RHMP in relation to the three core questions are discussed below:

What are the contributions and spatial distributions of inputs of pollutants?
Areas of the harbors most closely associated with anthropogenic influences (i.e., the marina, industrial/port, and freshwater-influenced strata) tended to have elevated chemical concentrations and greater exceedances of chemical thresholds in surface waters and sediments, as compared with areas that were not closely associated with anthropogenic influences (the deep and shallow strata). This was most apparent in the surface waters and sediments of the marina stratum, which had consistently elevated levels of copper, as well as other metals (such as mercury and zinc) and a variety of organic compounds in the sediments. The industrial/port stratum, which was located solely along the eastern shore of San Diego Bay, also had elevated concentrations of metals and organics in its sediments, while the primary elevated contaminants in the freshwater-influenced stratum were pesticides (chlordanes and pyrethroids) and zinc, with the exception of a few samples near the mouth of Chollas Creek that also had a variety of elevated organics, consistent with many of the industrial/port influenced stations.

Do the waters and sediments in the harbors support healthy biota?
The results demonstrate that most of the areas within the harbors had sediment and water quality conditions that were supportive of healthy biological resources. SQO assessments determined that 72% of RHMP stations had unimpacted or likely unimpacted sediment conditions, and there were no exceedances of acute water quality thresholds at 81% of stations, although exceedances of chronic criteria for copper were more widespread in the water column.

Areas associated with localized anthropogenic inputs of pollutants, most notably the marina stratum and also the industrial/port stations and a limited set of freshwater-influenced stations, had conditions that were less suitable for supporting healthy biota. Elevated chemical concentrations in these regions of the harbors generally correlated well with impaired infaunal benthic communities. The marina stratum had consistently elevated levels of copper both in the surface waters and sediments, as well as mercury, zinc, and organics in the sediments. The industrial stratum, which was located solely along the eastern shore of San Diego Bay, also had elevated concentrations of metals and organics in sediments, while the primary elevated contaminants in the freshwater-influenced stratum were pesticides (i.e., chlordanes and pyrethroids) and zinc. PBDEs, an emerging chemical of concern, were widespread at low concentrations, with enhancement apparent in a few industrial, marina, and freshwater-influenced stations. Little is known at this time regarding threshold concentrations of concern related to this class of constituents.

As documented in this report, there are a variety of physical confounding factors in addition to chemical composition that need to be carefully considered when making final conclusions related to benthic community condition and resulting integrated SQO scores. Consideration of temporal and small-scale spatial variability is also important as documented herein. Where impairment is observed, an understanding of the most likely cause(s) and variability will be important prior to developing appropriate management considerations at any given location.

What are the long-term trends in water and sediment quality?

The San Diego regional harbors appear to have reached a relatively steady state with small improvements in overall sediment quality relative to 2008, compared with the much larger improvements noted for data collected prior to 2008. Sediments considered to be unimpacted or have low impact increased from 64 to 72% between 2008 and 2013. One notable change over the years has been the decreased incidence of sediment toxicity compared surveys prior to 2008 with 100% of samples in 2013 considered to be non-toxic or have low toxicity. As the SQO approach continues to be used, future trend assessments will be able to use this methodology and rely less on prior single line of evidence screening methodologies such as the ER-L/ ER-M guidelines. Previous and developing regulations, a variety of significant source controls, and dredging and other cleanup activities have made tremendous improvements over the past few decades in the harbors. The areas of particular concern remain primarily within marinas and around industrial/port and some freshwater-influenced regions. These are the areas that will warrant continued attention. More focused assessments should be able to discern whether the impacts to benthic communities in these areas are related to watershed inputs, or some other chemical or physical factor.

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APPENDICES

(PROVIDED ON CD)

- Appendix A Sampling Station Maps and Tables
- Appendix B Chemicals Analyzed and Methods
- Appendix C SQO Criteria Summary Tables
- Appendix D Threshold References
- Appendix E Field Water Quality Profiles
- Appendix F Chemistry Data
- Appendix G Toxicity Data
- Appendix H Benthic Infauna Data
- Appendix I Demersal Community
- Appendix J SQO Calculations
- Appendix K Statistical Analyses
- Appendix L Chemistry Validation Report
- Appendix M Sediment Photo Log
- Appendix N Trawl Photo Log
- Appendix O COC Documents
- Appendix P Letter to the RWQCB from RHMP Agencies Regarding the 2013 Experimental Design Questions

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