SEDIMENT ASSESSMENT STUDY FOR THE MOUTHS OF CHOLLAS AND PALETA CREEK, SAN DIEGO

PHASE I DRAFT REPORT

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EXECUTIVE SUMMARY

This report details an investigation of the nature and extent of impaired sediments at the mouths of Chollas and Paleta Creeks where they enter San Diego Bay. The investigation represents Phase I of a three-phase assessment program which also includes TMDL actions (Phase II), and sediment cleanup actions (Phase III). The investigation was prompted by the designation of these two sites by the San Diego Regional Water Quality Control Board as having contaminated sediments and aquatic life impacts. The study was a cooperative effort of the Toxic Hot Spot Workgroup including the Regional Board, the City of San Diego, the Port of San Diego and the US Navy, and was conducted by personnel from the Space and Naval Warfare Systems Center San Diego and the Southern California Coastal Water Research Project.

Based on a conceptual site model developed for the two sites, the primary beneficial use concern is the impairment to health of benthic organisms (Aquatic Life), focusing on invertebrates such as crustaceans, polychaetes and molluscs that live in and on the sediment. There is also potential for exposure and impact to fish and birds that prey on these benthic organisms (Aquatic Dependent Wildlife) as well as potential exposure to humans that may occur through fishing activities (Human Health). The conceptual approach taken in this study was to use multiple measures of sediment quality including chemistry, toxicity, benthic community composition, and bioaccumulation to assess the potential for impairment to each of these three beneficial uses.

Based on historical data, the contaminants of concern measured were the metals: arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc, and organic compounds: PAHs, PCBs, Chlordanes, and DDTs. Ancillary measures of sediment grain size and total organic carbon were also made. Three measures of sediment toxicity were made including survival of amphipod exposed to whole sediment, normal development of sea urchins exposed to the sediment-water interface, and fertilization of sea urchins exposed to sediment porewater. Benthic community composition was determined by counting the number and kinds of organisms in the sediment. Bioaccumulation of contaminants was measured by exposing clams to sediments and measuring the uptake into their tissues.

Sampling was conducted in July and August 2001. Samples were collected from six bay reference stations, 14 stations at the Chollas study site, and 17 stations at the Paleta study site. Surface sediment grabs collected at each station were homogenized and split for use for chemical analyses, bioaccumulation exposures, and two of the three toxicity analyses. Separate core samples were collected for the sediment-water interface toxicity test. A separate grab sample was used in determining benthic community composition. Results of each measurement were evaluated for quality. Results of the amphipod toxicity tests showed high variability that required adjustment for outliers. There was also evidence of ammonia effects in the sediment-water interface test that required adjustment for outliers.

A weight of evidence approach was used to assess the potential impact to the Aquatic Life beneficial use. This approach used lines of evidence derived from measures of sediment chemistry, sediment toxicity, and benthic community composition. Screening level ecological and human health risk assessments were used to assess potential impacts to Aquatic Dependent Wildlife and Human Health beneficial uses, respectively. Contaminant bioaccumulation in clams was used as the primary measurement for the risk screening evaluations. A key requirement in the determination of impairment was that risk must be present at a level greater than that observed at sites in the bay not directly impacted by

contaminant sources. This site-specific evaluation therefore compared conditions at each site to a baseline condition that was defined as the existing ambient condition characterized by a pool of reference stations meeting the requirements of remoteness from source and having similar habitat.
The Baseline Pool used to represent the baseline condition consisted of data from 18 reference stations: five stations from the Chollas/Paleta study, four stations from the Phase I Shipyard study, and nine stations from the Bight'98 study. This pool was designed to provide an unbiased set of reference stations that had comparable measures of sediment quality, similar benthic habitat, and lacked contamination or toxicity from site-specific activities. Data from each study site station were compared to the upper (i.e. for concentration) or lower (i.e. for survival) 95th-percentile prediction limit computed for each parameter from the Baseline Pool to determine if conditions differed from the baseline condition.

Aquatic Life Beneficial Use Impairment
Impairment to the aquatic life beneficial use was determined using the weight of evidence from the chemistry, toxicity, and benthic community measurements. These data were used to assign a level of impairment into three categories of ”Likely”, “Possible”, or “Unlikely”.

Mouth of Chollas Creek: Most stations within the Chollas site were classified in the range of likely to possible impairment, indicating that contamination by CoPCs was substantially greater than the baseline condition and at levels of concern to aquatic life. Biological effects at this site were indicated by both the sediment toxicity and benthic community analyses. Two stations near the inner/outer creek boundary (C8 and C11) showed benthic community impacts co-occurring with exceptionally low fines and low contamination levels. Recurring sediment physical disturbance associated with ship engine tests performed at the NASSCO shipyard may contribute to the observed benthic community impacts in this area.

The greatest magnitude of likely impairment was present at the inner creek Chollas stations (C12, 13 and C14). The increasing gradient of impairment toward the inner creek stations was spatially consistent with a source of contaminants entering the site either from Chollas Creek itself, or from the shoreline activities adjacent to the site. The high fines content of the sediments at the inner creek stations indicate that this area is highly depositional, while the enriched TOC levels indicate organic matter loading higher than normal for the bay and most likely related to urban runoff from the creek.

Based on comparison of CoPC levels at likely stations with unlikely and possibly impaired stations, exceedance of SQGs, and correlation between chemistry and toxicity, CoPCs that appear most likely to be responsible for observed aquatic life impairment include PAH, PCB, chlordane and DDT.

Mouth of Paleta Creek: The frequency and magnitude of impairment to aquatic life at the Paleta site was less than at the Chollas site. None of the outer Paleta Creek sites were classified as having likely impairment. The classification of some outer Paleta stations as possibly impaired was driven by the co-occurrence of elevated chemistry and benthic community impacts; sediment toxicity at the outer stations was not elevated relative to the baseline conditions.

The area of likely impairment for aquatic life at the Paleta site was restricted to a subset of four inner creek stations (P11, P15, P16, and P17). The increasing gradient of impairment toward the inner creek stations was spatially consistent with a source of contaminants entering the site either from Paleta Creek itself, or from the shoreline activities adjacent to the site. The high fines content of the sediments at the inner creek stations indicate that this area is highly

depositional, while the enriched TOC levels indicate organic matter loading higher than normal for the bay and most likely related to urban runoff from the creek.

Based on comparison of CoPC levels at likely stations with unlikely and possibly impaired stations, exceedance of SQGs, and correlation between chemistry and toxicity, CoPCs that appear most likely to be responsible for observed aquatic life impairment include lead, PAH, PCB, chlordane and DDT.

Aquatic-Dependent Life Beneficial Use Impairment
The likelihood of aquatic dependent wildlife impairment at the Chollas and Paleta sites was categorized as either "Unlikely" or "Possible" based on a screening-level ecological risk assessment. For this assessment, bioaccumulation of CoPCs in the clam *Macoma nasuta* was used to estimate exposure for representative wildlife receptors including surface feeding birds (Least Tern and Brown Pelican), diving birds (Surf Scoter and Western Grebe), and marine mammals (California Sea Lion).

Mouth of Chollas Creek: Potential for impairment to aquatic dependent wildlife at the Chollas site was categorized as unlikely for all receptors with respect to all CoPCs with the exception of copper for the Least Tern and Brown Pelican. A station-by-station assessment indicted three of the fourteen Chollas stations (C07, C10 and C11) were categorized as possibly impaired. The higher bioaccumulation of copper at C07 and C11 appears to be related to higher bioavailability associated with the low binding (TOC and fines) characteristics of this sediment. The higher bioaccumulation at C10 appears to relate primarily to higher copper concentrations in the sediment. On the basis of this analysis, a limited area of the Chollas site in the regions described above was classified as possibly impaired for potential effects of copper to aquatic dependent wildlife.

Mouth of Paleta Creek: Potential for impairment to aquatic dependent wildlife at the Paleta site was categorized as unlikely for all receptors with respect to all CoPCs.

Human Health Beneficial Use Impairment
The likelihood of human health impairment at the Chollas and Paleta sites was categorized as either "Unlikely" or "Possible" based on a screening level human health risk assessment. For this assessment, bioaccumulation of CoPCs in the clam *Macoma nasuta* was used to estimate exposure for humans from the consumption of fish or shellfish exposed to site sediments.

Mouth of Chollas Creek: Potential for impairment to human health at the Chollas site was categorized as unlikely for all CoPCs with the exception of Benzo(a)pyrene (BAP) and TPCB. The possible impairment was related to cancer risk. The estimated risk level for BAP based on the maximum concentration for the site exceeded the TSL by a factor of 21, while the estimated risk level for TPCB exceeded the TSL by a factor of 2.2.

From the station-by-station analysis, all of the fourteen Chollas stations were categorized as possibly impaired for BAP, and twelve of the fourteen were categorized as possibly impaired for TPCB. Spatially, the highest magnitude of impairment related to BAP was found in the mid-inner Creek area (C12-C13) and near the base of Pier 1 (C09-C10). In general, the areas with higher magnitude of impairment related to BAP corresponded closely with high levels in the sediment, but were not strongly related to the distribution of TOC or fines. The highest magnitude of impairment related to TPCB was found near the base of the NASSCO pier (C07) and the end of Pier 1 (C02-C03), while the inner Creek area (C13-C14) had tissue concentrations below the TSL. The higher bioaccumulation of TPCB in at C07 appeared to be related to higher

bioavailability associated with the low binding characteristics of this sediment. Higher bioaccumulation at C02-C03 appears to relate primarily to higher TPCB concentrations in the sediment.

On the basis of this analysis, the entire Chollas site was classified as possibly impaired for potential human health effects related to the consumption of BAP in fish and shellfish, and the majority of the Chollas site, excepting the inner Creek area, was classified as possibly impaired for potential human health effects related to the consumption of PCBs in fish and shellfish.

Mouth of Paleta Creek: Potential for impairment to human health at the Paleta site was categorized as unlikely for all CoPCs with the exception of BAP and TPCB. The possible impairment was related to cancer risk. The estimated risk level for BAP based on the maximum concentration for the site exceeded the TSL by a factor of 16, while the estimated risk level for TPCB exceeded the TSL by a factor of 3.6.

From the station-by-station analysis, all of the seventeen Paleta stations were categorized as possibly impaired for both BAP and TPCB. Spatially, the highest magnitude of impairment related to BAP was found along the northern extent of the inner Creek area (P11, P13, P15 and P17). In general, the higher magnitude of impairment in the inner Creek area related to BAP corresponded with high levels in the sediment, as well as higher levels of TOC. The highest magnitude of impairment related to TPCB along the northern extent of the inner Creek area (P11, P13, P15 and P17) and at station (P05) near the Mole Pier. In general, the areas with higher magnitude of impairment related to TPCB corresponded with high levels in the sediment.

On the basis of this analysis, the entire Paleta site was classified as possibly impaired for potential human health effects related to the consumption of BAP and TPCB in fish and shellfish.

Recommendations

Recommendations were developed based on the findings and conclusions from the Phase I Chollas and Paleta study. The recommendations were made in the context of the existing framework that was developed collaboratively by the Toxic Hot Spot Workgroup. It is recommended that:

- The Phase II TIE work be completed to validate the findings of the Phase I study and guide the TMDL source quantification and control efforts.

- The Phase II source evaluation studies be completed to determine the strength and origin of sources for identified CoPCs that are driving the impairment.

- Following identification and control of sources, the Workgroup develop and conduct Phase III sediment cleanup studies including (1) Refinement of the wildlife risk assessment for copper and the human health risk assessments for BAP and TPCB using tissue concentrations from resident fish and shellfish and site-specific exposure parameters, (2) development of cleanup thresholds based on aquatic life, aquatic-dependent wildlife, and human health related impairments, and (3) delineation of potential cleanup boundaries including vertical and horizontal extent.

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LIST OF ACRONYMS

BCA	Benthic Community Analysis
BRI	Benthic Response Index
Bight'98	Southern California Bight 1998 Regional Marine Monitoring Survey
BPJ	Best Professional Judgment
BPTCP	Bay Protection and Toxic Cleanup Program
BSAF	Biota-Sediment Accumulation Factors
BTAG	Biological Technical Assistance Group
CBSQG	Consensus-Based Sediment Quality Guideline
CNRSW	Commander Navy Region Southwest
CoPC	Contaminants of Potential Concern
CSM	Conceptual Site Model
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DQO	Data Quality Objectives
EPA	Environmental Protection Agency
ERL	Effects Range Low
ERM	Effects Range Median
ERMQ	Effects Range Median Quotient
GC/ECD	Gas Chromatograph/Electron Capture Detector
GC/MS	Gas Chromatograph/Mass Spectrometer
HMWPAH	High Molecular Weight PAH
HPLC	High-Pressure Liquid Chromatography
HQ	Hazard Quotient
LMWPAH	Low Molecular Weight PAH
LOE	Line of Evidence
MSD	Minimum Significant Difference
NASSCO	National Steel and Shipbuilding Company
NAVSTA	Naval Station San Diego
NPDES	National Pollutant Discharge Elimination System
PAH	Polynuclear Aromatic Hydrocarbons
PCB	Polychlorinated biphenyls
PEL	Probable Effects Level
PELQ	Probable Effects Level Quotient
PPB	Parts per billion
PPM	Parts per million
PPPAH	Priority Pollutant PAH
PPT	Parts per thousand
RSD	Relative Standard Deviation
QA/QC	Quality Assurance/Quality Control
SAP	Sampling and Analysis Plan
SCCWRP	Southern California Coastal Water Research Project
SDRWQCB	Regional Water Quality Control Board, San Diego Region
SIM	Selective Ion Monitoring
SQG	Sediment Quality Guideline
SSC-SD	SPAWAR Systems Center San Diego
SWRCB	State Water Resources Control Board
TCHLOR	Total Chlordane
TDDT	Total DDT

TEL	Threshold Effects Level
THS	Toxic Hot Spot
TIE	Toxicity Identification Evaluations
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
TPAH	Total PAH
TPCB	Total PCB
TRV	Toxicity Reference Values
TSL	Tissue Screening Level
UCL	Upper Confidence Limit
WOE	Weight of Evidence

1.0 INTRODUCTION

This report describes results of an investigation into the potential impairment of beneficial uses at the mouths of Chollas Creek and Paleta Creek (also known as Seventh Street Channel) where they enter San Diego Bay. The goal of the investigation was to develop a comprehensive weight of evidence (WOE) evaluation of the impairment of aquatic life beneficial uses as well as a screening level evaluation of wildlife and human health beneficial uses at both sites. The investigation was prompted by the designation of these two sites by the Regional Water Quality Control Board, San Diego Region (SDRWQCB) based on chemical contamination of sediments and aquatic life impacts. Additionally, the SDRWQCB also initiated development of a Total Maximum Daily Load (TMDL) assessment to address potential source reduction requirements at these two sites because of benthic community degradation and sediment toxicity. This investigation was a joint effort by the SDRWQCB, Commander Navy Region Southwest (CNRSW), and the City of San Diego. A joint working group formed from the above agencies and the San Diego Unified Port District along with their contractors developed the conceptual approach, study design, and sampling and analysis plans to carry out this investigation. Personnel from the Southern California Coastal Water Research Project (SCCWRP), Space and Naval Warfare Systems Center San Diego (SSC-SD), MEC Analytical, Inc. along with their subcontractors executed the technical sampling and analyses. Personnel from SCCWRP and SSC-SD performed the final technical assessment and evaluation.

2.0 HISTORICAL BACKGROUND

2.1 THE TOXIC HOT SPOT PROGRAM

The California State legislature established the Bay Protection and Toxic Cleanup Program (BPTCP) in 1989 with four major goals: (1) to provide protection of present and future beneficial uses of the bays and estuarine waters of California; (2) identify and characterize toxic hot spots (THS); (3) plan for THS cleanup or other remedial or mitigation actions; and (4) develop prevention and control strategies for toxic pollutants that will prevent creation of new THS or the perpetuation of existing ones within the bays and estuaries of the State. Subsequent to the legislation the State Water Resources Control Board (SWRCB) adopted a Guidance on the Development of Regional Toxic Hot Spots Cleanup Plan (SWRCB, 1998), which provides definitions, rankings, and suggested contents of the regional cleanup plans. The guidance was used by the SDRWQCB to develop a Regional Toxic Hot Spots Cleanup Plan (SDRWQCB, 1998a) for the San Diego Region which was adopted into the Consolidated Statewide Toxic Hot Spots Cleanup Plan in 1999 (SWRCB, 1999). Using data compiled by Fairey et al., (1996), the regional plan identified five candidate THS sites within the San Diego Bay Region that met the State's designation criteria and were subsequently adopted as known THS in the State's consolidated plan. Two of these sites are at the mouth of Chollas Creek and Paleta Creek where they enter San Diego Bay (Figure 2-1).

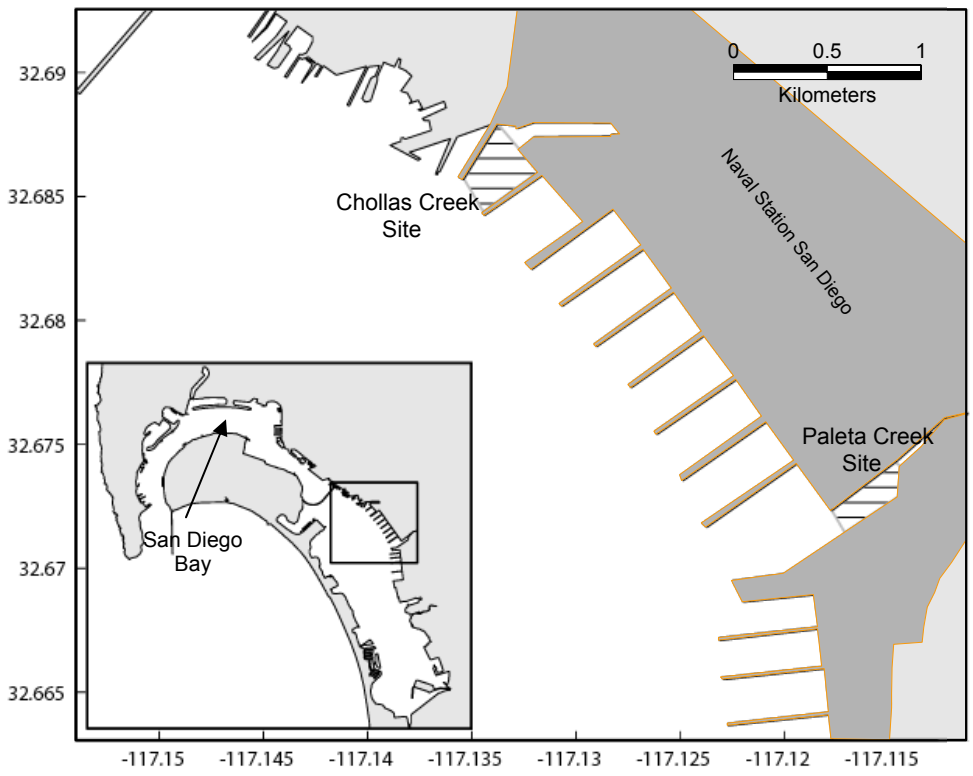


Figure 2-1. Location of Chollas Creek and Paleta Creek Toxic Hot Spot strata (crosshatch areas) designated under the Bay Protection Toxic Cleanup Program (Fairey et al., 1996).

2.2 FORMATION OF TOXIC HOT SPOT WORK GROUP

The regional cleanup monitoring plan calls for re-testing candidate sites for confirmation of effects. Because these two sites lie at the mouths of creeks and storm drains discharging from the City of San Diego and are adjacent to U.S. Navy property, the City of San Diego and the U. S. Navy formed a Toxic Hot Spot Work Group to fully reassess the two sites. Because two of the other hot spot sites planned for concurrent monitoring were adjacent to San Diego Unified Port District property, the Port also became a member of the work group. (Monitoring plans for the fifth candidate site adjacent to National Steel and Shipbuilding Company and Southwest Marine Inc. property were already underway). Subsequent to the formation of the work group both the Chollas and Paleta sites were listed on the State's 303d list (SWRCB, 1998b) as impaired water bodies, leading to formal requirements for the establishment of TMDL for those sites. Because both the THS and TMDL assessments require a similar comprehensive description of the spatial extent and magnitude of impairment to initiate cleanup and source reduction actions, the SDRWQCB became a member of the working group. As such, the scope of the working group expanded so that information collected could be used for both the THS and TMDL assessments.

2.3 HISTORICAL DATA REVIEW

BPTCP data used to characterize sediments in San Diego Bay are found in Fairey et al., (1996). Six sediment samples were collected and analyzed at the Chollas site. Three samples were collected and analyzed at the Paleta site. The Chollas site was designated as a moderate priority hot spot on the basis of benthic community impacts and elevated chlordane and total chemistry observed at three sampling locations. The Paleta site was designated as a high priority hot spot on the basis of recurring sediment toxicity, benthic community impacts, and elevated chlordane, dichlorodiphenyltrichloroethane (DDT), polynuclear aromatic hydrocarbons (PAH) and total chemistry at three sampling locations. Both sites were characterized as representing between one and ten acres of impaired sediment.

The first step taken by the work group was to compile and review historical sediment and contaminant source data for the two hot spots to provide: (1) a review of chemical and ecological characteristics of the Paleta and Chollas sites based on historical monitoring data (last ten years), and (2) a review of source loading data for potential chemicals of concern at the two sites. Specific goals included:

- Determine the extent of measurement data already available for the two sites
- Determine if the findings of the BPTCP study are consistent with other studies in the area
- Determine if sufficient data are available to evaluate spatial and temporal trends
- Identify contaminants of potential concern (CoPCs) for the two areas
- Determine if continuing sources of CoPCs are present at the sites
- Identify the type and quantity of additional data to complete the assessment of the sites and sources

The historical review was provided to the SDRWQCB in August of 2000 (SSC-SD, 2000). A summary of the report findings is highlighted below.

2.3.1 Chollas

The historical data generally showed slightly elevated sediment chemical concentrations in the Chollas Creek THS area relative to ambient levels found in a suite of bay wide reference samples (Chadwick et al., 1999). Copper, lead, antimony, and zinc, PAH, and DDT showed elevations above ambient but were below the Effects Range Median (ERM) benchmark. Chlordane was found at highly elevated (4X ERM) levels. There were typically insufficient data to characterize the spatial extent or temporal variability for most chemicals.

The reviewed biological studies findings showed evidence of toxicity, bioaccumulation, and degraded benthic communities. However, the data showed sporadic results and were spatially limited. It could not be ascertained whether toxic effects or physical disturbance was the cause of the degraded benthic community. The inner creek area was most recently dredged in 1997.

Storm water is an ongoing major contributor of copper, lead, and zinc to the Chollas Creek Toxic Hot Spot. Leaching of ship hull coatings and anodes are a minor contributor for copper and zinc. The storm water source is predominantly from the urban upstream portion of the watershed with less than 6% of the total loading derived from Naval Station outfalls. There are currently no source data on chlordane or antimony.

2.3.2 Paleta

The historical data generally showed elevated sediment chemical concentrations in the Paleta Creek THS area relative to ambient. Contaminant levels at this THS were also generally elevated above levels found at the Chollas Creek THS. Mercury, lead, zinc, and PAH were elevated above ambient but were below the ERM benchmark. Polychlorinated biphenyls (PCB) and DDT were found above the ERM benchmark but below the 4X ERM level. Chlordane was found at highly elevated (4X ERM) levels. Recent screening data suggest that metal levels from the BPTCP study are fairly representative of the entire Paleta Creek strata but that PAHs and pesticides show significant heterogeneity. In general, the chemical data were insufficient to characterize the spatial extent or temporal variability for most chemicals. A single core available at the Paleta site showed fairly uniform metal levels to a depth of about 45 cm.

Similar to the Chollas site the reviewed biological studies findings showed evidence of toxicity, bioaccumulation, and degraded benthic communities. However, the data showed sporadic results and were spatially limited. It could not be ascertained whether toxic effects or physical disturbance was the cause of the degraded benthic community. About half the region south of Pier 8 bordering the outer creek was most recently dredged in 1993.

Storm water is also an ongoing major contributor of copper, lead, and zinc to the Paleta Creek THS. Leaching of ship hull coatings and anodes are a significant contributor for copper (75%) and zinc (60%). While the storm water source is predominantly from the upstream urban portion of the watershed, Navy storm water outfalls were estimated to introduce 14% of the copper, 27% of the lead, and 16% of the zinc. Chlordane, DDT degradation products, and PCBs were detected in one upstream storm event though the limited nature of the data does not confirm an ongoing source of these compounds. There were no antimony or mercury data from which to assess storm water as a potential source of these contaminants.

2.4 SAMPLING PLAN DEVELOPMENT

The historical data were insufficient to fully characterize the spatial extent of contamination, toxicity, benthic community degradation, or degree to which bioaccumulation is occurring at the two THS sites. Further, the data sets were unable to resolve relationships between contaminant levels and deleterious effects. There were also gaps in the historical data with regards to contaminant sources. Given this outcome of the historical review, the work group developed a sampling plan to gather the appropriate data to fully characterize and assess sediment quality in these two hot spots. The sampling plan was designed to address data gaps regarding the present status and spatial extent of impairment to aquatic life at each study site as well as to provide an initial screening of wild life and human health impacts. The sampling study is the first phase of a multi-phased approach to completing requirements under the TMDL and cleanup plans for the study areas (Figure 2-2).

The sampling plan follows the general approach of BPTCP and the Southern California Bight 1998 Regional Marine Monitoring Survey (Bight'98) in measuring multiple indicators of sediment quality and using a weight of evidence approach to identify areas of impaired sediment quality (SCCWRP, 1998). This approach is also similar to ongoing and planned studies at other Toxic Hot Spots in San Diego Bay (Exponent, 2001). Included in this effort are determinations of the spatial distribution of:

- Sediment physical/chemical characteristics (e.g., grain size)
- Sediment chemical contamination
- Sediment and interstitial water toxicity
- Bioaccumulation of contaminants by a marine invertebrate
- Benthic community analysis

The data collected under the Phase I sampling was used to identify areas of greatest concern for detailed investigations in the development of total maximum daily loads (TMDLs) in Phase II. Though not described in detail here, Phase II studies will include laboratory research to identify causes of sediment toxicity (toxicity identification evaluations or TIEs), assessment of temporal patterns in the data, and an evaluation of sources of the contaminants of concern. Results from Phase I and Phase II will be used to help derive numerical cleanup levels and, along with measures of contaminants with depth of sediment, identify clean up boundaries in Phase III. Elements of Phase II and Phase III studies are still evolving under the guidance of the SDRWQCB.

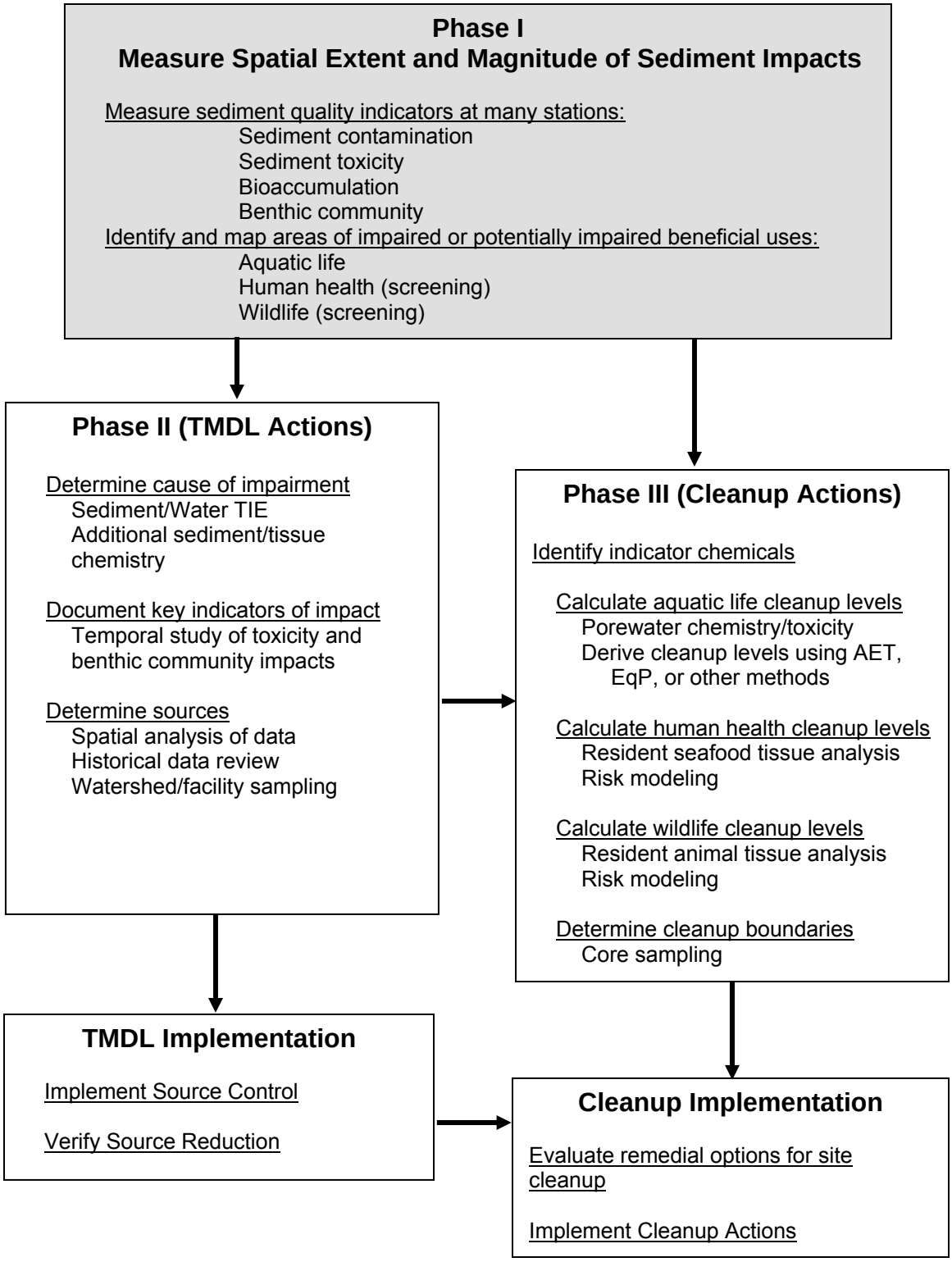


Figure 2-2. Phased sampling and analysis approach showing the relationship of Phase I sampling plan to potential subsequent TMDL and cleanup activities at the study sites.

3.0 CONCEPTUAL APPROACH

The conceptual approach taken in this study was to use multiple measures of sediment quality to provide a weight of evidence to support or refute the presence of impairment to beneficial uses at Toxic Hot Spot sites. The conceptual approach for this investigation was based on recent Environmental Protection Agency (EPA) guidance (USEPA, 2000) and was consistent with that of the BPTCP as well as other comprehensive sediment quality evaluations occurring throughout the nation. The approach was based on four key assumptions. First, that the determination of biological impairment is best assessed through the measurement of biological effects associated with the study site (e.g., toxicity, bioaccumulation, and benthic community degradation). Second, that there must be multiple indicators of sediment quality (WOE approach) measured in order to provide a confident assessment of impacts because no single test or parameter is a consistently reliable, accurate, or predictive indicator of impairment. Third, that site-specific information is needed to accurately assess impacts because there may be unknown site-specific factors in the study areas that will significantly affect causal relationships between contamination and effects. And finally, that the evaluation of impairment be made relative to sediment quality measured at a set of designated reference locations that represent an acceptable level of sediment quality.

3.1 CONCEPTUAL SITE MODEL

Based on results from the historical review, a generic conceptual site model (CSM) was developed to describe and visualize the known, expected, and/or predicted relationships between site CoPCs and ecological receptors. The model provides a framework for understanding the dominant processes that control sediment quality at each site including linkages amongst ongoing and historic contaminant sources, exposure pathways, and biological receptors (Figure 3-1). The framework is thus applicable for evaluating site data for both TMDL and site cleanup purposes. Since both sites share similar characteristics they share the same site conceptual model. They both have been identified as having impaired sediments, nearby storm water inputs from upland and shoreline sources, as well as shoreline industrial activities. Both sites are also relatively deep-water environments, which has important implications for the potential exposure pathways that may exist.

The primary contaminant sources and pathways are the discharge of contaminants from the near shore into the surface water and their eventual settling out on particles into the sediments (Figure 3-2). These include storm water from the upland watershed that enters the site via creek drainage, storm water from the neighboring Navy facilities and shipyards that enter the site primarily via small storm drains, and in-water sources primarily from ships via release from antifouling coatings and zinc cathodic protection systems. A significant fraction of this source material is likely to either enter the site in association with particulate matter but can also be adsorbed onto particulate matter once in the receiving environment. For this reason, along with the weak currents in these areas, it is anticipated that the majority of the source material that enters the site will deposit to the sediment bed within the site rather than being transported to the remainder of the bay. Based on historical Installation-Restoration data (Chadwick et al. 1999) and preliminary groundwater measurements (PRISM, 2002), groundwater is not considered a significant source of contaminants to these sites.

The primary beneficial use concern in these sites is the impairment to health of benthic organisms, primarily invertebrates such as crustaceans, polychaetes and molluscs that live in

and on the sediment (Fairy et al., 1996). Benthic organisms are exposed to these contaminants by direct contact with, or ingestion of near-surface sediment. Contaminant concentrations in bay waters are almost always below water quality criteria and thus does not pose a threat A second level of ecological exposure may occur for bottom feeding fish that prey on benthic invertebrates. Existing survey data suggests that in these areas exposure would be primarily to species such as the California Halibut, Round Stingray, and Barred Sand Bass (U.S. Navy/SDUPD, 2000).

Because of the depth of these sites, it is unlikely that transfer to other ecological niches would occur. Diving birds and surface feeding birds generally limit their activities to shallow water areas, and there are few upper level receptors such as sea lions that feed directly on the bottom fish species mentioned above. However, the potential for exposure and impact to wild life beneficial uses was addressed in a screening level evaluation.

Exposure to humans can occur through fishing activities that involve direct take of bottom fish. However, fishing activity is generally not permitted within the direct confines of the sites, and the exposure pathway to humans is not likely. The mobility of the fish through the site could provide a pathway to fishing activities that occur outside the site are therefore kept as a possible route of exposure. The potential for exposure and impact to human health beneficial uses was addressed in a screening level evaluation.

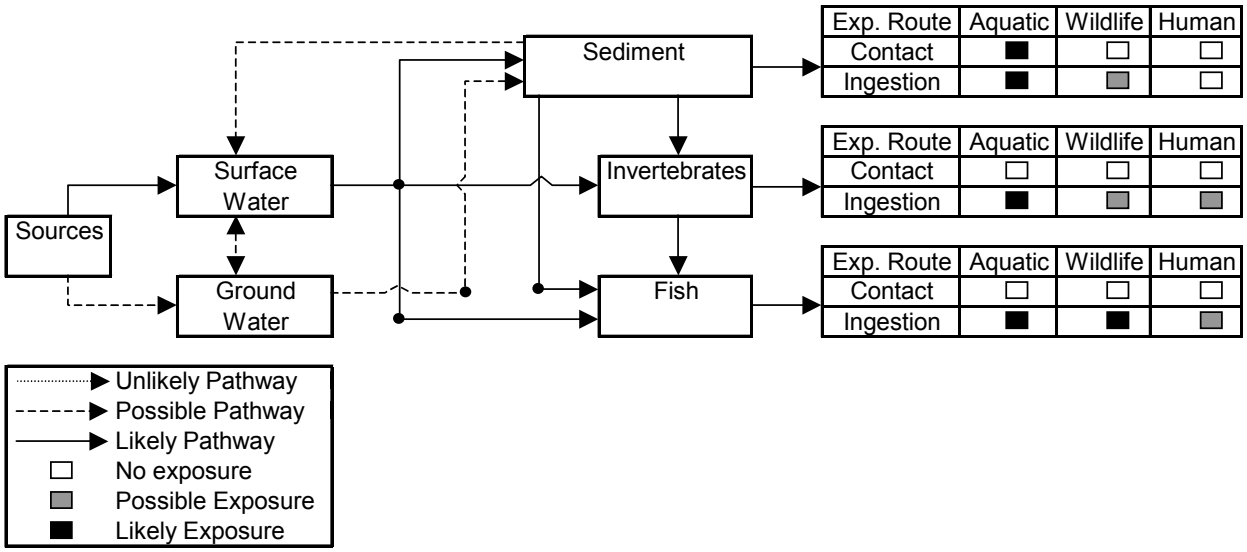


Figure 3-1. Generic conceptual site model for the Chollas and Paleta study site showing sources, transport pathways, exposure routes, and receptors of concern.

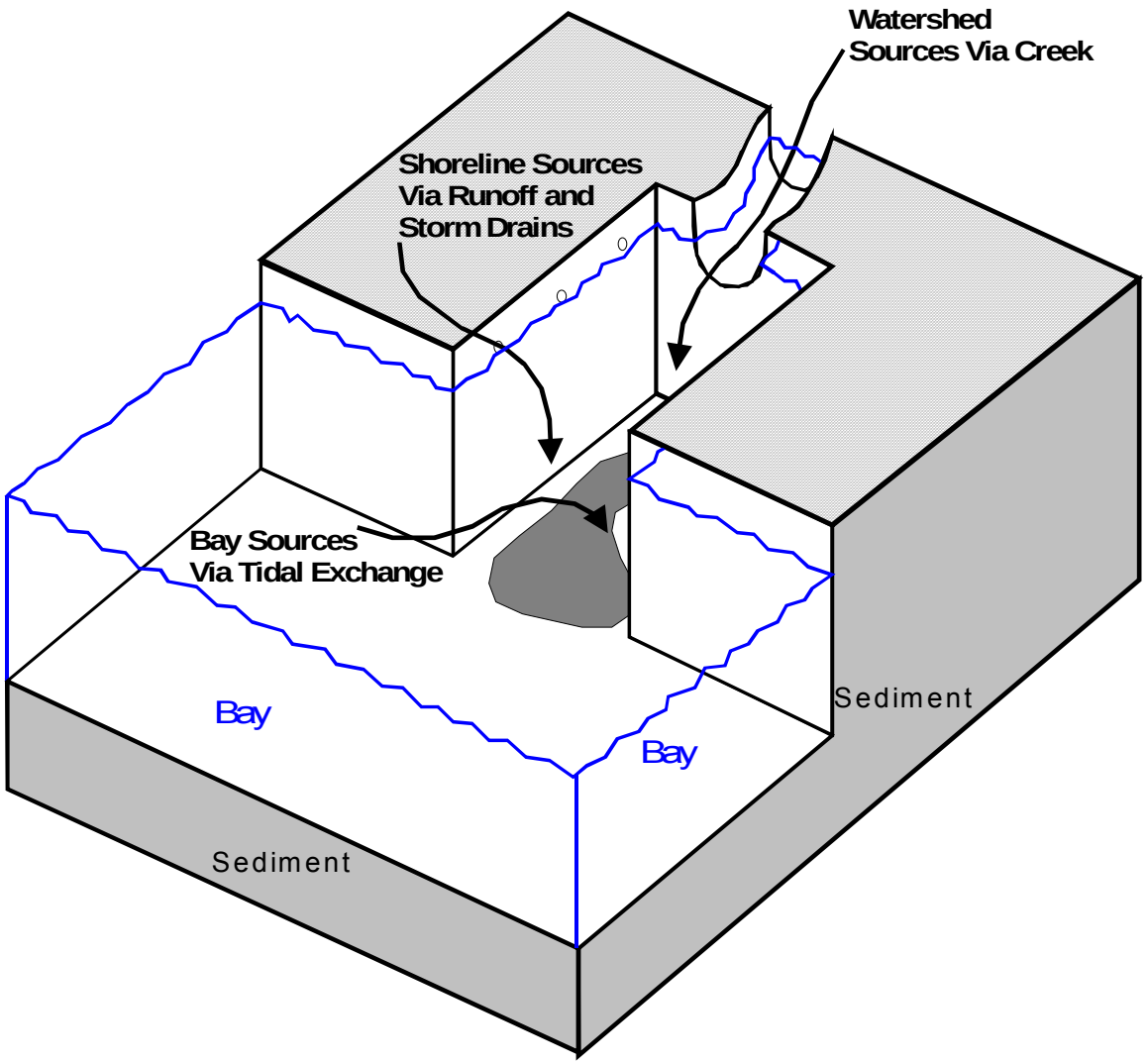


Figure 3-2. Conceptual site model of potential contaminant sources and pathways to the sediment at the Chollas and Paleta study sites.

4.0 TECHNICAL APPROACH

4.1 FIELD MEASUREMENT PROGRAM

The technical approach taken for the Phase I study was to synoptically collect surface sediment throughout both study stations and at designated bay reference stations and then analyze them for a suite of sediment quality parameters. The study design entailed the collection of near-surface sediment at 37 stations including 6 reference stations from background areas throughout the bay, as well as 14 Chollas stations and 17 Paleta stations arranged in a grid pattern within each hot spot area. Multiple lines of evidence (LOE) for sediment quality were measured at each station. The three key LOE of sediment quality used to assess aquatic life impairment (sediment triad) included measures of sediment chemical contamination, sediment toxicity, and benthic community composition. The key measure used to evaluate wildlife and human health impairment was contaminant bioaccumulation in clams. Sediment characteristics including grain size and total organic carbon (TOC) were also measured to help interpret contaminant bioavailability and confounding effects that might be related to physical characteristics rather than contamination. The key LOE used to characterize sediment quality in this study are described below.

Sediment Chemical Contamination. Concentrations of a suite of metals, PAHs, PCBs, and chlorinated pesticides were measured in the bulk surface (0 to 2.5 cm) sediment. These sediment chemical contamination measurements were used to document the extent, spatial pattern, and magnitude of sediment contamination at each study site.

Sediment Toxicity. Acute and sublethal toxic effects of bulk sediment, porewater, and contaminants fluxing across the sediment-water interface were measured using a variety of tests. Acute toxicity was assessed by measuring survival of the amphipod crustacean, *Eohaustorius estuarius,* after 10 days of exposure to bulk sediment. Sublethal sediment toxicity was assessed by measuring the effects of a 20-minute exposure of porewater on fertilization of the sea urchin (*Strongylocentrotus purpuratus*). The presence of sublethal effects and potential impacts of contaminated sediments on the water column was assessed by measuring the effects of a 3-day exposure to water from the sediment-water interface on sea urchin embryo development. The sediment toxicity tests were used to document the spatial pattern and magnitude of toxic effects in the sediments at each study site.

Benthic Community Analysis (BCA). The numbers and kinds of benthic invertebrates present in sediment samples were used to document the health of the benthic communities at the study sites.

Bioaccumulation. Concentrations of a suite of metals, PAHs, PCBs, and chlorinated pesticides were measured in clams (*Macoma nasuta*) before and after a 28-day exposure to site and reference station sediment. The bioaccumulation tests were used to evaluate the potential for contaminant uptake and subsequent food chain transfer of organic chemicals and metals from the sediment.

4.2 EVALUATING IMPAIRMENT TO BENEFICIAL USES

Individual LOE were integrated to evaluate the potential for site-specific impairment to aquatic life, aquatic-dependent wildlife, and human health beneficial uses related to CoPCs at each site. For each LOE, consideration was given to measures of both absolute risk (i.e. comparison to known toxicity thresholds), and to site-specific relative risk (i.e. comparison to conditions at

stations not directly influenced by sources). A sediment triad approach was used to assess impairment to the aquatic life beneficial use (Chapman et al., 1987). Ecological and human health screening risk assessments were used to address wildlife and human health impairments, respectively. These evaluations addressed each of the pathways and receptors described in the CSM (Figure 3-1). The steps for each of these assessments are described below.

4.2.1 The Baseline Condition

A key requirement in the determination of impairment at the study sites was that risk must be present at a level greater than that present at sites in the bay that are not directly impacted by contaminant sources. Ideally, these sites are physically and biologically similar to the study site, but lack the contamination due to site-specific activities (e.g., port operations or storm water discharge). Some degree of contamination may be present at the sites, however, due to non-point source inputs or past discharges that have been dispersed throughout the area. In the course of characterizing this condition, three important definitions were developed and are applied consistently throughout this report.

Reference Station- A reference station was defined as a station in the bay known to be remote from the direct influence of contaminant sources and where previous studies had shown low contaminant levels, minimal toxicity, and similar habitat to the study sites. Six reference stations were characterized as part of this study, and additional reference stations were evaluated from the Bight'98 study (SCCWRP, 1998) and the Shipyard study (NASSCO and Southwest Marine, 2003).

Reference Condition- The reference condition was defined as the optimum ambient condition in the bay. This condition was based on a pool of reference stations meeting specific thresholds of acceptability for toxicity and benthic condition (e.g., amphipod survival >85%). The stations included in the Reference Pool were located in areas judged to be remote from specific sources of contamination. Because some reference stations were excluded from the pool on the basis of elevated toxicity and impacted benthos, the Reference Pool is a measure of the best existing conditions in the bay and may not represent the full range of variability in the ambient condition for some parameters. The stations comprising the Reference Pool were specified by the SDRWQCB following discussion with SCCWRP, SPAWAR and stakeholders and are described in Appendix F.

Baseline Condition- The baseline condition was defined as the existing ambient condition in the bay. This condition was based on a pool of reference stations selected to meet requirements of remoteness from source and similar habitat to the study sites. This condition acknowledges the potential presence of background contamination as well as natural variability in toxicity and benthic condition. Reference stations were excluded from this pool if there was an indication of contamination or toxicity that appeared to be related to a nearby source. However, stations were not excluded from this pool based on specific biological response thresholds. Development of the Baseline Pool is described below and in Appendix E, and its application is discussed further throughout the remainder of the report. The Baseline Pool was the primary benchmark used in this study to assess site-specific levels of relative risk.

The baseline condition for the sediment quality LOE for the study sites was established using data from reference stations pooled from three independent studies including the present study, the Phase I Shipyard study (NASSCO and Southwest Marine, 2003), and the Bight'98 regional survey (Bight'98 Steering Committee, 2003). Identification of the six candidate reference

stations for the present study is described in detail in Section 5 and included five initial stations, and the addition of a sixth station after the first sampling round. The locations of the five candidate reference stations for the Phase I Shipyard study were identical to the initial five stations from the present study. Twenty-two candidate Bight'98 reference stations were selected from 46 randomly located stations in San Diego Bay by using a distance-from-shore analysis to identify stations that were unlikely to be influenced by site-specific contamination gradients (Appendix E1).

Selection of the Baseline Pool stations from the candidate reference stations was based upon a review of the data and consideration of the following factors: low contaminant concentrations representative of baseline conditions, comparable habitat to the study sites, adequate sample size for statistical analysis, and data comparability. On this basis, five stations were selected from the six candidate stations in the present study and four stations were included from the five candidate stations from the Phase I Shipyard study (see Appendix E2). In addition, nine Bight'98 stations were selected from 22 candidate stations in San Diego Bay (see Appendix E1). The locations of the stations used for characterizing the baseline condition are shown in Figure 4-1.

The resulting Baseline Pool included a similar number of reference stations (18) as the Reference Pool (22), but differed in the proportion of stations from each study and in the criteria used for selection. One half of the Baseline Pool stations were selected from the present study and the shipyard study in order to provide greater temporal and methodological comparability to the site data; less than 25% of the stations in the Reference Pool were sampled during the same year (2001). A greater proportion of 2001 stations (present study and Shipyard Phase I study) were also needed in order to provide an adequate sample size for statistical analysis for parameters that were not measured or not detected during the Bight'98 study (e.g., PCBs and sediment-water interface toxicity). The Bight'98 stations selected for the Baseline Pool were all located in the same region of San Diego Bay that included the Chollas and Paleta Creek Sites in order to provide improved comparability in habitat characteristics such as currents, water temperature, and ambient contamination levels (Figure 4-1). Thresholds for sediment toxicity and benthic community health were not used in the selection of reference stations for inclusion in the Baseline Pool, as representation of the typical variability in toxicity and benthos in San Diego Bay was considered to be an important characteristic of the Baseline Pool. The amphipod toxicity data was also adjusted by the exclusion of outlier values thought to represent testing artifacts; outlier exclusion resulted in a more precise dataset with a greater statistical power to detect differences among the stations. The resulting Baseline Pool was used to represent the baseline condition that would be expected to exist at the Chollas and Paleta sites in the absence of direct influence from contaminant sources. Characteristics of the Baseline Pool are described in Section 11, and additional details regarding the selection of specific stations for the Baseline Pool are included in Appendix E.

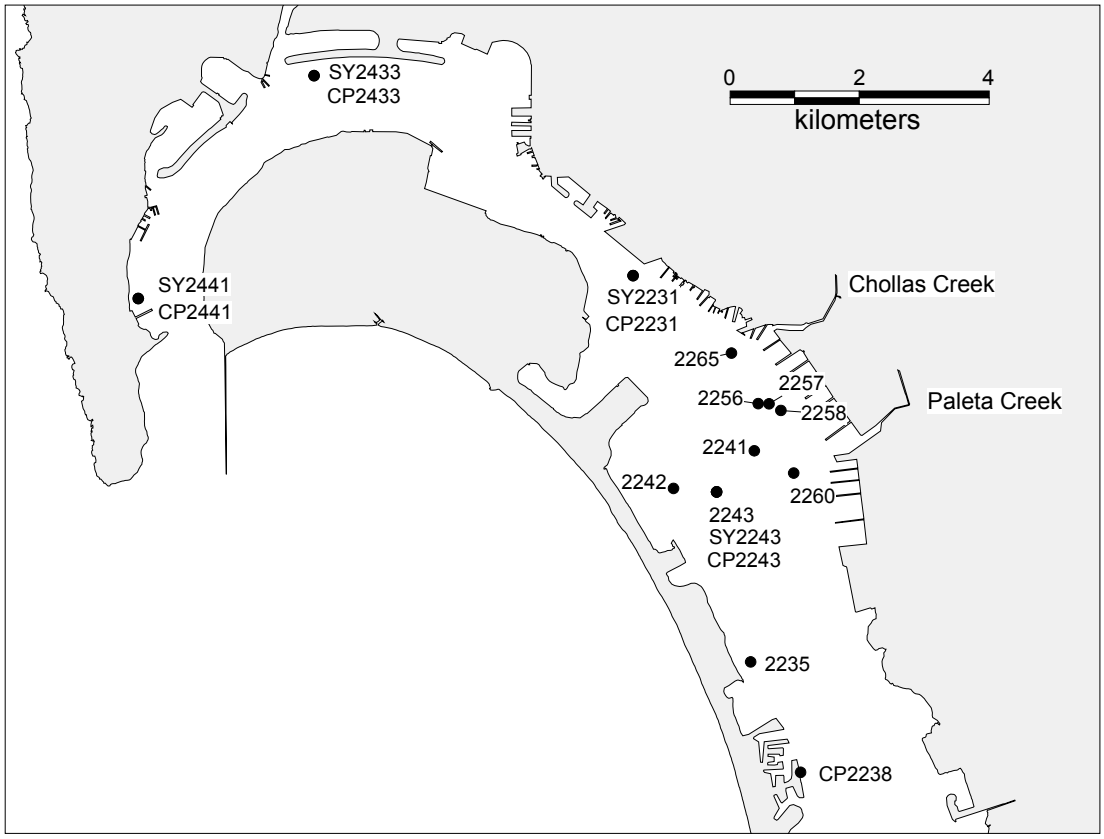


Figure 4-1. Location of reference stations included in the Baseline Pool. The station identifiers indicate whether the station was sampled during the present study (CP prefix), the shipyard study (SY), or the Bight'98 survey (no prefix).

4.2.2 Aquatic Life Impact

The sediment triad approach to assessing aquatic life impact relied on the three principal LOE that included measures of sediment chemistry, sediment or interstitial water toxicity, and benthic community composition. The three LOE were individually evaluated to determine the presence of significant impacts at each station by using a three-step process. First, the data quality of each LOE was assessed relative to predetermined objectives such as accuracy and precision for sediment and tissue chemical analyses, control performance and confounding factors in the toxicity tests, and sorting efficiency and identification accuracy for the benthic analyses. Second, the data were compared to published thresholds, guidelines, or controls that indicate whether a significant response was obtained. Finally, the data were compared to the study baseline condition to assess the site-specific impact. This approach is based on the framework for evaluating sediment quality developed by the EPA for application in the St. Louis River Area of Concern (USEPA, 2000). The degree of impact indicated by each LOE was then be integrated into a weight of evidence (WOE) evaluation to provide an overall assessment of potential for aquatic life impairment (USEPA, 1997).

4.2.2.1 Sediment Chemistry

Bulk sediment chemical concentrations measured at each station were evaluated relative to sediment quality guidelines (SQGs) as well as to the baseline condition. SQGs have been established as one of the most effective methods for attempting to relate sediment chemistry to their observed toxic effects (Long et al., 1995; Long et al., 1998). The evaluation in this study compared CoPCs relative to their individual ERM for metals (effects range-median, Long et al., 1995), consensus midrange effects concentration for PAHs and PCBs (MacDonald et al., 2000: Swartz 1999), PEL for chlordane (probable effects level, MacDonald et al., 1996), and organic carbon normalized DDT effects value (Swartz et al., 1998) and their respective 95 percentile predictive limit calculated from the Baseline Pool data. The magnitude of impact was addressed by counting the number of CoPCs that exceeded each of their individual benchmarks, by evaluating them as a group against a mean SQGQ1 quotient benchmark (Fairey et al. 2001), and by counting the number or parameters that exceeded the Baseline Pool predictive limit.

The relative magnitude of potential site-specific impact from bulk sediment CoPCs was classified into three ordinal ranking categories of low, moderate, or high likelihood of impact. The ranking was based on a semi-quantitative measure that give increasing weight to a greater number and magnitude of chemicals exceeding a threshold, similar to the method used by Long et al. (1998). The breakpoints in the ranking levels were established using best professional judgment (BPJ), again, following Long et al. (1998). The ranking criteria were based on two key assumptions. First, that there is a low likelihood of impact from CoPCs if all chemicals at a station are less than relatively low SQGs and less than the established baseline condition. Second, that there was a high likelihood of impact from CoPCs when many of the chemicals at a station exceed a relatively high SQG, and exceed the baseline condition. The category ranking criteria for bulk sediment chemistry are summarized below.

Low- The mean SQGQ1 was less than 0.25 or all chemicals were less than the 95% predictive limit calculated from the Baseline Pool. Additionally, there must not be any single chemical that exceeded either its SQG or Baseline Pool predictive limit value whichever was higher. To meet this category, all chemicals present at the site, either individually or summed must have been lower than a relatively low SQG and have been below the baseline condition.

Moderate- The mean SQGQ1 was between 0.25 and 1.0 and greater than the 95% predictive limit calculated from the Baseline Pool. Additionally, a station was classified into this category if there were five or less individual chemicals that exceeded their respective SQG or Baseline Pool predictive limit, whichever was higher. To meet this category, some (five or less) chemicals either individually or when summed exceeded a moderate level SQG and/or the baseline condition.

High- The mean SQGQ1 for all chemicals was greater than or equal to 1.0 and was greater than the 95% predictive limit calculated from the Baseline Pool data. This category was also assigned if more than five chemicals exceed their individual SQG or the baseline condition, whichever was higher. To meet this category, the baseline condition as well as a relatively high SQG must have been exceeded when chemicals are considered as a group, or that there were at least six individual chemicals exceeding a SQG or the baseline condition.

4.2.2.2 Sediment Toxicity

The three toxicity test results were compared to their negative controls (collection site sediment or laboratory seawater) as well as to the 95% lower prediction limit calculated from the Baseline Pool to determine the relative magnitude of station toxicity for this LOE. The magnitude and

consistency of responses was used to classify station sediments as having a low, moderate, or high degree of toxic effects. The rankings were based on the combined toxic response from all three tests.

Similar to the chemistry LOE, the ranking method employed a semi-quantitative assessment of the data that reflected both the presence and magnitude of toxicity. It was assumed that there was no, or a low degree of, toxic effects if the results of all three toxicity tests were not significantly different from their controls or they had a statistically lower level of toxicity than observed under the baseline condition. Each of the three toxicity tests were given equal weight for classifying a sample as moderately toxic; the presence of significant toxicity in any one test was sufficient to classify a sample as moderately toxic. A high degree of sediment toxicity was indicated when survival of amphipods was less than 50% and significantly different from the control and baseline. A high toxicity ranking was also assigned when both of the sublethal tests measured a greater level of toxicity than the baseline condition.

The amphipod test result was given greater weight for the high toxicity category because the acute survival endpoint of this test was assumed to have a higher degree of association with ecological impacts than the sublethal tests. The sea urchin fertilization and sea urchin embryo development test results were given less weight because these are sublethal critical life stage tests that are more susceptible to confounding factors and their association with ecological impacts is less certain. The category ranking criteria for sediment toxicity are summarized below.

Low- There were no or a low degree of toxic effects if results of all three bioassays were not significantly different from their controls or they had a statistically lower level of toxicity than observed under the baseline condition.

Moderate- The sediments were considered moderately toxic if any one of the bioassay results was statistically different from its control and was less than the baseline condition. There was an additional requirement that amphipod survival must have been greater than 50%, regardless of the result relative to controls or baseline.

High- There were multiple criteria that can result in a categorization of the sediments as having a high degree of toxicity: 1) If survival of amphipods at a station was less than 50% and was statistically different than controls and statistically less than baseline. 2) If the amphipod test together with any one of the other bioassays both has a result that was statistically different from control and was statistically less than baseline. 3) If both the porewater and sediment-water interface test results were less than 50% of the control values and were statistically less than the controls and baseline.

4.2.2.3 Benthic Community Composition

Four metrics were used to assess community health at each station: total abundance, total number of species, the Shannon-Wiener (SW) Diversity Index, and the Benthic Response Index (BRI) developed by SCCWRP (Ranasinghe et al., 2003). The Benthic Community LOE compared station data against the Bight'98 BRI response level benchmarks as well as to the 95% lower (upper for BRI) prediction limit of each of the metrics calculated for the Baseline Pool. Consideration was given first to the overall BRI ranking and then to the individual metrics. The BRI was given this higher weighting because it is a more comprehensive measure of community health.

Similar to the other LOE, this evaluation was based on a semi-quantitative measure that integrated the responses and the application of ranking criteria based on BPJ. It was assumed that no, or a low degree of benthic community degradation is present when the station BRI is level I (< response II) or is statistically similar to the baseline condition and abundance, number of taxa and the SW Diversity Index are all statistically similar to the baseline condition. Conversely, a high degree of impact to community health at a station is assumed to be present when there is a BRI response of level IV (> response III) or the other indicators also show impacts. The category ranking criteria for benthic community impacts are summarized below.

Low- Benthic community health at a station had no or a low degree of degradation if the BRI is less than response level II and when abundance, number of taxa, and the SW Diversity Index were all statistically similar to the baseline condition.

Moderate- There was a moderate degree of impact to community health at a station if the BRI was either response level II or III and was statistically greater than the baseline condition or if any one of the other benthic community metrics was statistically lower than the baseline condition.

High- There was a high degree of impact to benthic community health at a station if the BRI was greater than response level III or the BRI response was greater than level II, statistically greater than the baseline condition, and at least one of the other benthic community metrics was also statistically less than baseline.

4.2.2.4 Triad Analysis of Impairment to Aquatic Life Beneficial Use

The three LOE described above were integrated into an overall WOE assessment focused on identifying the likelihood that site-specific aquatic life beneficial use is impaired at a given station due to the presence of a known CoPC related to the site. The approach follows the general principles of WOE analysis described by Chapman (1990, 1996) and others. Potential combinations of the ordinal rankings for individual LOE were assessed and assigned a relative overall likelihood of impairment using three categories “Unlikely”, “Possible”, and “Likely” based on consideration of four key elements as described by Menzie et al., (1996):

- the level of confidence or weight given to the individual LOE
- whether the LOE indicates there is an effect
- the magnitude or consistency of the effect
- the concurrence among the various LOE

For example, a station with a high ordinal ranking for chemistry, toxicity and benthic community would indicate a high likelihood of site-specific aquatic life impairment because each LOE indicates an effect, the magnitude of the effect is consistently high, and there is clear concurrence among the LOE. Alternatively, a station with a low ordinal ranking for chemistry, and moderate or high rankings for toxicity and benthic community would indicate unlikely site-specific aquatic life impairment from site CoPCs, because there is no concurrence with site CoPCs. This does not mean that there is no impairment, but that the impairment is not clearly linked to site related contamination. The framework shown in Table 4-1 was used to interpret the results and is consistent with other published WOE frameworks.

Table 4-1. Weight of evidence analysis framework for the aquatic life impairment assessment. For each LOE (chemistry, toxicity and benthic community), the symbols indicate the degree of impact including low (O), moderate (⊙), or high (●).

Aquatic Life Impairment Table			
Chemistry	**Toxicity**	**Benthic Community**	**Site-specific Impairment from CoPCs**
●	●	●	Likely impairment from CoPCs
●	●	⊙	
●	⊙	●	
⊙	●	●	
●	●	O	
●	O	●	
●	⊙	⊙	
⊙	●	⊙	
⊙	⊙	●	
⊙	⊙	⊙	
●	⊙	O	
●	O	⊙	
⊙	●	O	Possible Impairment from CoPCs
⊙	O	●	
⊙	⊙	O	
⊙	O	⊙	
●	O	O	
O	●	●	Unlikely impairment from CoPCs
O	●	⊙	
O	⊙	●	
O	⊙	⊙	
O	O	●	
O	●	O	
O	O	⊙	
O	⊙	O	
⊙	O	O	
O	O	O	

4.2.3 Aquatic-Dependent Wildlife Impairment

A screening level risk assessment was performed to assess potential impairment to aquatic-dependent wildlife. For this assessment, bioaccumulation of CoPCs in the clam *Macoma nasuta* exposed to site sediments was used to estimate exposure for representative wildlife receptors including surface feeding birds and marine mammals. For the screening level assessment, conservative exposure assumptions included 100% dietary fraction from the site, 100% area use factor for the site, and the low toxicity reference value.

The screening level risk assessment for aquatic-dependent wildlife was based on the following procedure. First, chemical concentrations in clam tissue were compared to measurements made on control samples to detect the presence of contaminant bioaccumulation. For those stations with chemicals demonstrating bioaccumulation, clam tissue concentrations were used to estimate contaminant doses to a range of representative wildlife receptors including surface feeding birds (Least Tern and Brown Pelican), diving birds (Surf Scoter and Western Grebe), and marine mammals (California Sea Lion). These receptors are common to San Diego Bay (U.S. Navy/SDUPD, 2000) and provide a breadth of potential exposure pathways and sensitivities to the CoPCs at the site. Although it is acknowledged that clams are not the primary food source for several of these receptors, these results provide a conservative assessment of impairment because the clams (*M. nasuta)* are surface deposit filter-feeders and are therefore directly exposed to CoPCs in the surface sediments. For chemicals with doses exceeding the Toxicity Reference Values (TRV), tissue concentrations of clams exposed to study site sediments were compared with the 95% upper predictive interval of tissue concentrations from the Baseline Pool.

Finally, for those chemicals with doses exceeding the TRV and tissue levels greater than the Baseline Pool, a station-by-station assessment was made following a similar procedure as described above, but using the individual station tissue concentration instead of the 95% upper confidence limit of all stations at the site. For stations where bioaccumulation was not measured, tissue concentrations were estimated based on site-specific Biota-Sediment Accumulation Factors (BSAFs) calculated from tissue and sediment concentrations at stations where bioaccumulation was measured. This analysis was used to develop a spatial description of potential aquatic-dependent wildlife impairment related to CoPCs.

Because the evaluation of aquatic-dependent wildlife is a highly conservative screening level assessment, sites or stations were assigned a relative likelihood of impairment ranging only from "unlikely" to "possible". The category ranking criteria for site-specific aquatic-dependent wildlife impairment is summarized below. Note that within these classifications, the presence of risk (Hazard Quotient (HQ)>1) does not necessarily equate with site-specific aquatic dependent wildlife impairment, because impairment is also measured relative to the baseline condition.

Unlikely - Impairment to wildlife from the consumption of aquatic prey exposed to site sediments is unlikely for a CoPC if: (1) the bioaccumulation measured at the site is not statistically different than observed in controls or (2) the estimated HQ is less than 1 or (3) the bioaccumulation is not statistically different from the baseline condition.

Possible - Impairment to wildlife from the consumption of aquatic prey exposed to site sediments is possible for a CoPC if: (1) the bioaccumulation measured at the site is statistically different than observed in controls and (2) the estimated HQ is greater than 1 and (3) there is statistically different bioaccumulation relative to the baseline condition.

4.2.4 Human Health Impairment

The screening level risk assessment for human health followed a similar procedure as that described above for aquatic-dependent wildlife. Station bioaccumulation data were first compared to controls, then to published toxicity or cancer risk thresholds, and then to the baseline condition. First, chemical concentrations in clam tissue were compared to measurements made on control samples and a sub-sample of clams collected at the start of the

experiment (T_0) to detect the presence of contaminant bioaccumulation. Stations with clam data showing no significant accumulation relative to controls were considered non-impacted.

For those stations with chemicals demonstrating bioaccumulation, clam tissue concentrations were used to estimate human ingestion doses based on conservative assumptions for uptake including 100% of seafood consumption from the site, 100% of seafood contaminated at the 95% upper confidence limit of all site stations, and a conservative seafood consumption rate. Estimated doses were then compared to EPA toxicity and cancer thresholds. For chemicals exceeding EPA human health thresholds, tissue concentrations of clams exposed to study site sediments were compared with the 95% upper predictive interval of tissue concentrations from clams in the Baseline Pool.

For those chemicals that exceeded EPA human health thresholds and had tissue levels greater than the Baseline Pool, a station-by-station assessment was made following the same procedure as described above, but using the individual station tissue concentration instead of the 95% upper confidence limit of all stations. For stations where bioaccumulation was not measured, tissue concentrations were estimated based on site-specific BSAFs calculated from tissue and sediment concentrations at stations where bioaccumulation was measured. This analysis was used to develop a spatial description of potential human health impairment related to CoPCs.

Because the evaluation of human health is a highly conservative screening level assessment, sites or stations were assigned a relative likelihood of impairment ranging from “highly unlikely” to “possible”. The category ranking criteria for site-specific human health impairment is summarized below. Note that within these classifications, the presence of risk does not necessarily equate with site-specific human health impairment, because impairment is also measured relative to the baseline condition.

Unlikely - Impairment to human health from the consumption of fish or shellfish exposed to site sediments is unlikely for a CoPC if: (1) the bioaccumulation measured at the site is not statistically different that observed in controls or (2) the concentration in the fish or shellfish is less than the screening level tissue screening level (TSL) or (3) the bioaccumulation is not statistically different from the baseline condition.

Possible - Impairment to human health from the consumption of fish or shellfish exposed to site sediments is possible for a CoPC if: (1) the bioaccumulation measured at the site is statistically different that observed in controls and (2) the concentration in the fish or shellfish is greater than the TSL and (3) there is statistically different bioaccumulation relative to the baseline condition.

5.0 METHODS

5.1 STUDY SITES

The sampling design for this study was to collect and analyze near-surface sediments from a grid pattern of stations within each Toxic Hot Spot and at designated reference stations. A total of 14 sites were placed more or less uniformly within the Chollas site bounded by National Steel and Shipbuilding Company (NASSCO) to the north and Pier 1 of Naval Station San Diego (NAVSTA) to the south (Figure 5-1). The total area represented by these stations is 100600 m^2 thus each sampling site is representative of roughly 7200 m^2 or ~1.8 acres. Eleven of these stations were placed within the original BPTCP stratum (Outer Chollas Site). An additional three stations were placed in the inner portion of the creek area (Inner Chollas Site), between the BPTCP stratum and the creek mouth to potentially capture source information.

A total of 17 stations were placed more or less uniformly within the Paleta site bounded by Pier 8 and Pier 9 (also referred to as Mole Pier) at NAVSTA (Figure 5-2). The total area represented by these stations is 261,000 m^2 thus each sampling site is representative of roughly 15,000 m^2 or ~3.7 acres. Nine sites were placed in the original BPTCP stratum in the inner portion of the creek area (Inner Paleta Site). An additional eight sites were placed to the area southwest of the stratum within the pier area at NAVSTA (Outer Paleta Site) to potentially capture transport information.

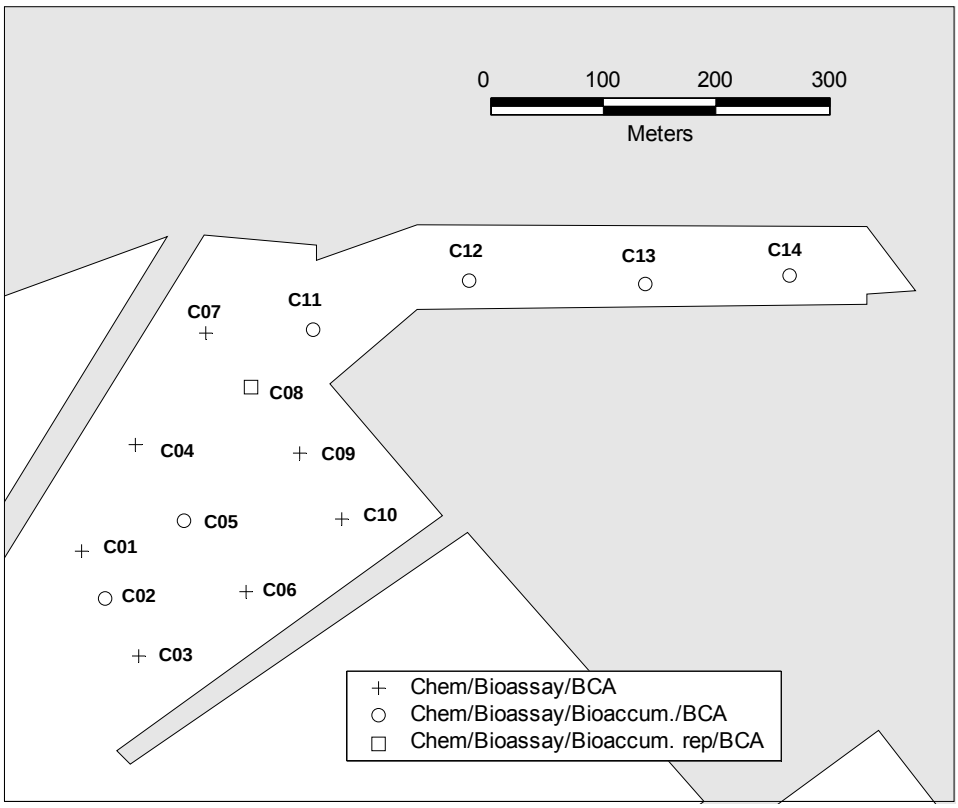


Figure 5-1. Chollas site showing sampling stations for chemistry, bioassays, bioaccumulation, and benthic community assessment.

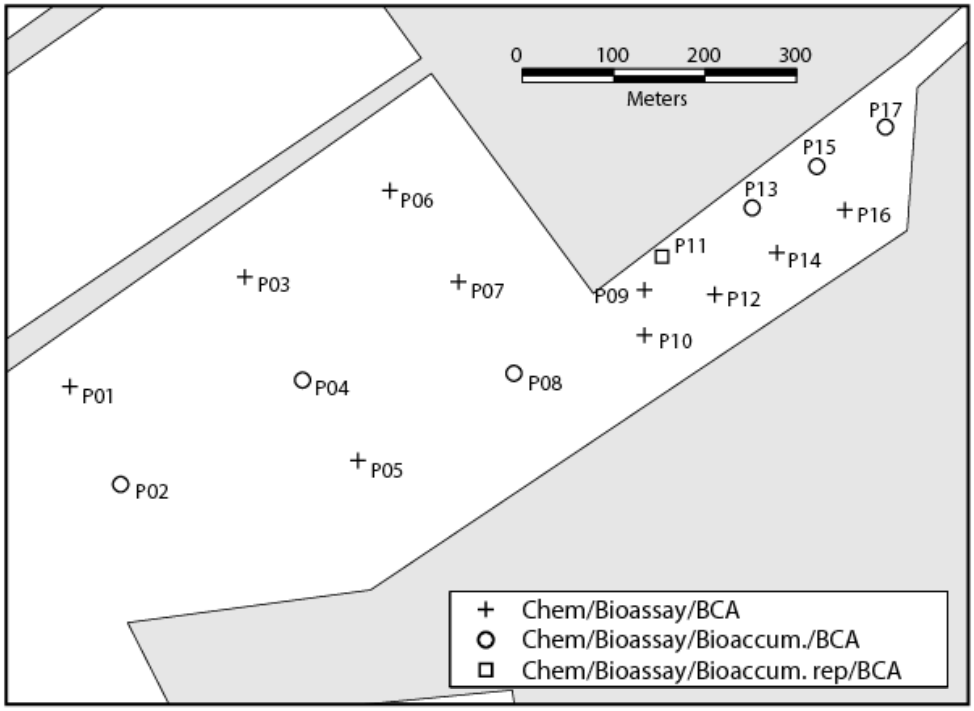


Figure 5-2. Paleta site showing sampling stations for chemistry, bioassays, bioaccumulation, and benthic community assessment.

5.2 REFERENCE STATION SELECTION

The study design required that a set of five bay reference stations be sampled simultaneously for the same parameters as the study sites. The purpose of the reference stations was to establish the background conditions for each of the sediment quality indicators used in this study. A reference station selection process was developed to identify sites that best matched two key attributes: similarity to the study sites and representative of present-day background contamination levels in San Diego Bay. Physical and biological similarity of the reference sites to the study site conditions was needed to compensate for potentially confounding variations in sediment chemistry, toxicity, or benthic communities that may be caused by habitat changes (e.g., grain size) instead of contaminant discharge. The San Diego Bay reference stations were expected to contain elevated concentrations of some contaminants relative to pristine areas in southern California, because of historical and current discharges into the bay (e.g., storm water). The selection of reference stations that accurately represent this background contamination was an important component of the study design, because the goal of this project was to identify THS sites that contain contamination and sediment quality impairment that is that is above background levels and thus likely associated with specific sources. A pool of sites containing these attributes was identified using a multi-step screening procedure (Figure 5-3) based on the four characteristics listed below:

- **Located within San Diego Bay** to reflect bay background contamination levels and that are within normal regional-scale variations in physical/biological conditions.
- **Similar physical habitat to the study sites** to minimize variation in biology and chemistry due to differences in sediment type, depth, time of year, etc.

- **Best sediment quality present in San Diego Bay** to provide sites with background conditions that are representative of the lowest contamination levels, least toxicity, and healthiest benthos present in the bay.
- **Proximity to the study sites** to ensure that sites have a similar ecological habitat.

The selection procedure used data from the most recent synoptic survey of sediment quality in San Diego Bay, the Bight'98 regional survey. In the first level screening step, all 46 San Diego Bay stations from the Bight'98 survey (Figure 5-4) were evaluated on the basis of desired habitat characteristics including a percent fines range of 23.8 to 84.5, a TOC range of 0.3 to 3.5%, lack of acute toxicity (survival >80%), low overall contamination based on the mean Effects Range Median (ERM) quotient (ERMq), and diverse benthos (high number of species present). This first step identified five of the cleanest/healthiest stations among the Bight'98 dataset. However, the range in grain size and TOC for the level 1 screen stations was relatively limited at 31-50% and 0.5-0.9%, respectively (Table 5-2) when compared to the historical ranges observed at the hot spot sites. Also, none of the five sites were located in the central part of San Diego Bay.

The second step in the selection procedure focused on extending the range of TOC and grain size range from the initial Bight'98 pool. This process differed from first step in that only 22 stations containing relatively high percent fines were included. The cleanest third of stations in this group resulted in a slightly higher level of contamination with an ERMq of 0.20. This screen produced an additional five candidate sites (screen level 2) though it still did not identify reference stations in the central bay.

To satisfy the proximity objective, a third screening step was conducted to identify candidate reference stations closer to the Chollas and Paleta study sites. This step used only 16 of the Bight'98 stations that were located in the central region of the bay between the northern border of Chollas Creek and southern border of Paleta Creek. In this step, the full historical range in TOC and grain size range at the sites and an ERMq < 0.2 were used. Two candidate stations were identified in this 3rd level screen.

Locations of the 12 candidate sediment reference stations produced from this process are shown in Figure 5-4. Site characteristics are shown in Table 5-2. Also included in both the figure and table are comparable data for three sediment reference stations currently used for national pollutant discharge elimination system (NPDES) monitoring in San Diego bay. The 12 candidate sites were compared to the NPDES reference stations to establish that they had historically comparable chemical levels (only data available), particularly when sites were in close proximity.

Though any of the 12 candidate sites might be considered suitable, final selection of five was based on professional judgment to best satisfy the objectives of low contamination, low toxicity, healthy benthos, appropriate range in physical characteristics, and proximity to the sites to maintain similar ecological conditions. The five Bight'98 sites chosen as sediment reference stations for this study were 2441, 2433, 2440, 2231, and 2243 (in spatial order moving from the mouth to the head of the bay-see Figure 5-4). Examples of reasons for excluding sites in the final selection process include the potential for physical impacts from boating activities within a marina (station 2225), high levels of a particular contaminant (e.g., PAH at station 2442), or because a site was too similar in characteristics or proximity (station 2227) to other candidate sites.

In the middle of the field effort for this study an initially high toxicity and highly unusual benthic community was observed in the sample collected at station 2231 near the Coronado Bay Bridge. Because of this, an additional reference station 2238 was chosen from the candidate pool to ensure a large enough reference stations dataset. This sixth site is shown in Figure 5-4 and as bolded text in Table 5-2. A discussion of the addition of this station to the suite of reference stations is discussed in detail in the results section.

A final note on reference stations is that the station names used in this study's planning documents, draft results, and on original custody sheets and laboratory reports have been changed back to their original Bight'98 designations to be consistent with other hot spot studies and to maintain a connection to the historical Bight'98 data set. The original Bight'98 designations and names used for planning purposes are shown in Table 5-1 below. These sites were also sampled in a separate study conducted by National Steel and Ship Building Company (NASSCO) and Southwest Marine Shipyard. The designation for those sites are shown in Table 5-1 and used whenever they are cited in this report.

Table 5-1. Reference station naming clarification. Bight'98 site, names used in the SAP, and final reference designation for samples collected in this study.

Bight'98 Site Designation	Planning Document Names	Final Designation for Chollas/Paleta Study	Final Designation for Shipyard Study
2231	R01	CP 2231	SY 2231
2243	R02	CP 2243	SY 2243
2433	R03	CP 2433	SY 2433
2440	R04	CP 2440	SY 2440
2441	R05	CP 2441	SY 2441
2238	R06	CP 2238	SY 2238

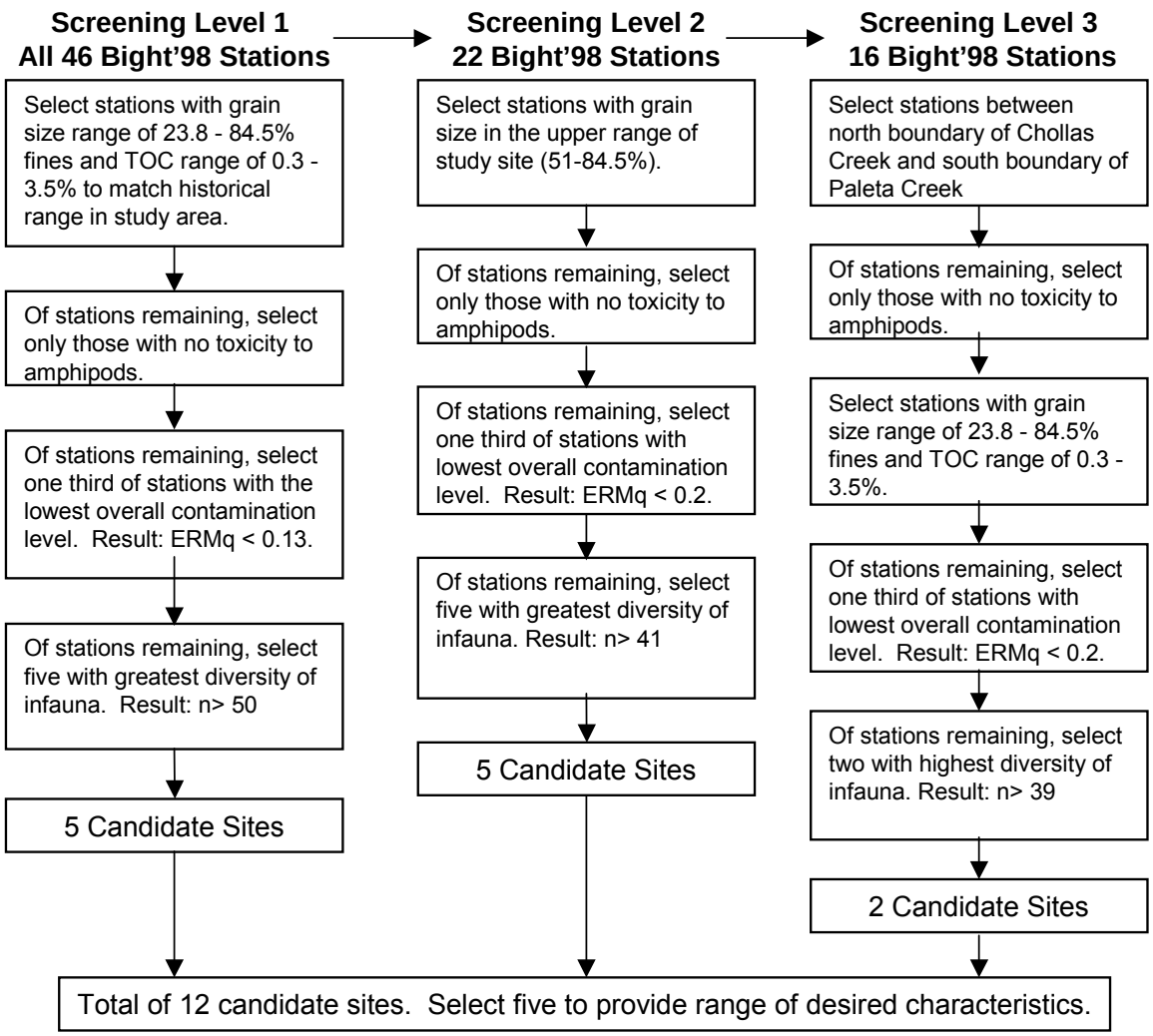


Figure 5-3. Overview of stepwise screening procedure for choosing sediment reference stations for this study.

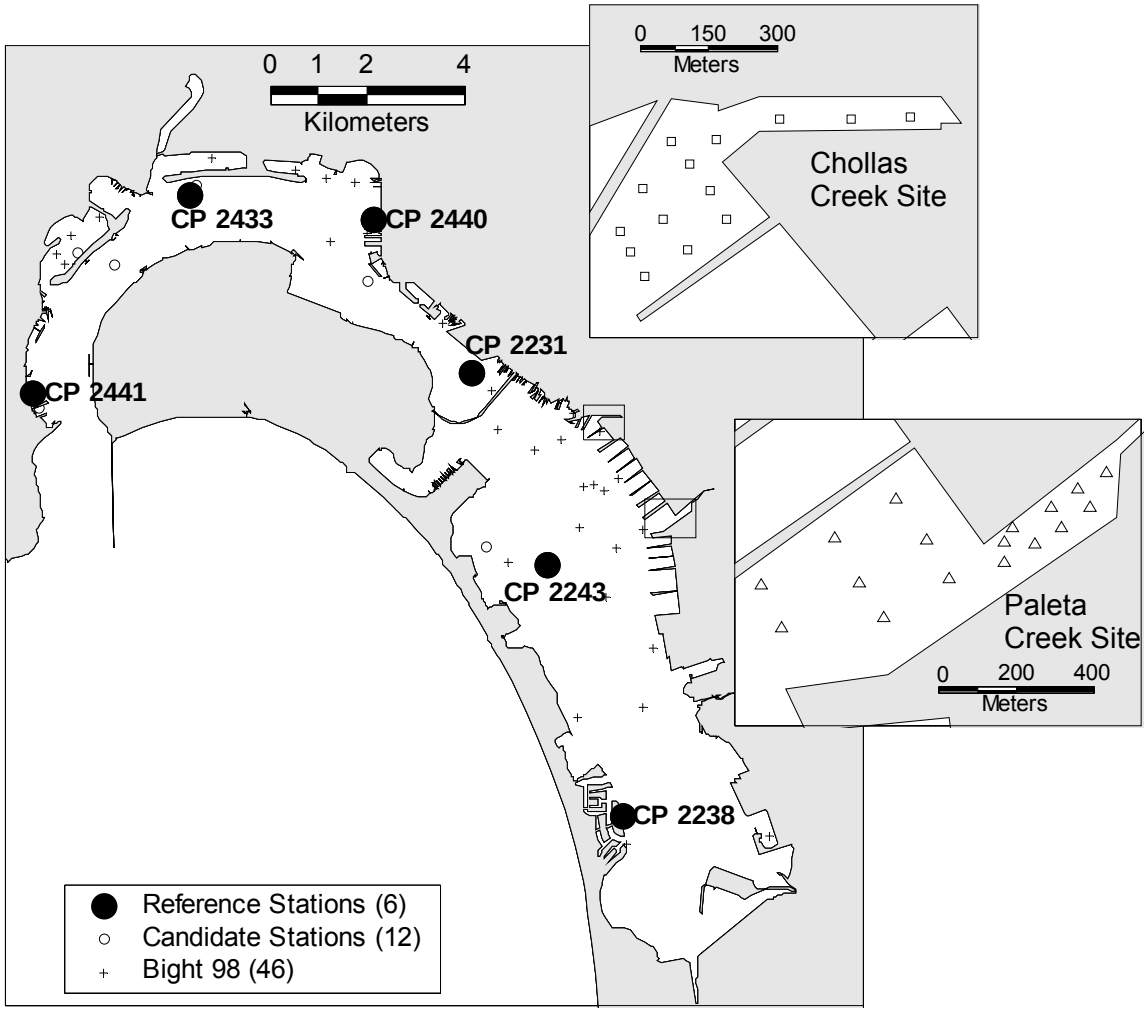


Figure 5-4. Spatial distribution of 46 potential sediment reference stations screened from Bight'98 monitoring survey in San Diego Bay (plus signs). The 12 candidate sites that made it through three screening levels are labeled as small open circles (one completely hidden by large circles). The six sites chosen for use in this study are shown as large, closed circles. The two blow-up maps show the station locations for the Chollas site and the Paleta site.

Table 5-2. Characteristics of candidate sediment reference stations for San Diego Bay. Included are the historical ranges of characteristics observed in the Chollas and Paleta study areas and for three sites used in the San Diego Bay NPDES sediment monitoring program. Shading indicates the six reference stations used in this study. Station 2238 is bolded because it was added after sampling started.

Station/ Area	Data Source	Screen Level	Fines (%)	TOC (%)	Cu (mg/kg)	Zn (mg/kg)	PPPAH (μg/kg)	ERMq	# Species
Chollas	Historical		33-84	0.7-3.5					
Paleta	Historical		24-81	0.3-2.3					
REF-01	NPDES		38	NA	16.6	49.4	902	NA	NA
REF-02	NPDES		42	NA	179	226	72	NA	NA
REF-03	NPDES		65	NA	99.1	159	5957	NA	NA
2227	Bight'98	1	50	0.9	53.9	112	324	0.12	52
2435	Bight'98	1	49	0.5	28.4	64.4	234*	0.07	59
2229	Bight'98	1	43	0.9	58.9	99.3	970	0.12	62
2440	Bight'98	1	38	0.5	41.8	81.1	234*	0.09	58
2231	Bight'98	1	31	0.6	58.1	92.5	258	0.10	70
2441	Bight'98	2	79	2.0	71.8	123	1061	0.13	84
2225	Bight'98	2	57	1.0	127	130	146*	0.19	69
2433	Bight'98	2	71	1.2	71.6	126	240	0.14	58
2442	Bight'98	2	79	2.0	77.7	139	4950	0.14	52
2238	**Bight'98**	**2**	**57**	**1.0**	**55.1**	**143**	234*	**0.12**	**41**
2243	Bight'98	3	35	0.5	38.8	81.2	234*	0.09	47
2240	Bight'98	3	44	0.5	47.4	103	85	0.11	40

* All values were non-detect.

5.3 FIELD METHODS

Field sampling at the Chollas THS and reference stations 2441, 2433, 2440, 2231, and 2243 was conducted on 17 and 18 July 2001. Field sampling at the Paleta THS and at reference station 2238 was performed on 27 and 28 August 2001. The general sampling chronology was to perform all coring first and then collect benthic organism grabs interspersed with sediment grabs at each site. Coring was generally completed on the first day along with a few grabs, with the remaining grabs generally completed on the second day. The weather during each sampling period was typical of San Diego summer conditions with sunshine and light winds present between early morning and late afternoon clouds.

All field sampling was performed aboard the US Navy's RV ECOS with personnel from SCCWRP, SSC-SD, and SDRWQCB. Sample locations were determined using a differential Global Positioning Navigation System (Trimble Model 4000 RLII+NavBeacon XL) with an accuracy of 1 to 3 meters. The navigation antenna was positioned directly above the samplers used. Water depths were determined with a digital fathometer (InnerSpace Model 445) with a resolution of 0.1 m.

5.3.1 Sediment Collection - Grabs

Bulk sediment was collected at all stations using a 0.1 m^2 Van Veen grab sampler with a closed top. The top two centimeters of sediment in a grab was scooped out with a plastic scoop. Multiple grabs, ranging from 4 to 18, were collected at each site to supply enough sediment for all analyses planned for the particular site. Sediment from the multiple grabs was combined and homogenized by placing it in a large plastic bowl and manually stirring with a plastic spoon. At three stations where field replicates were collected, each replicate was homogenized separately. Large shells, rocks, plastic, or other large debris were manually excluded from the samples. The homogenized sediment was then split into multiple pre-cleaned glass jars or plastic bags depending on the type of analysis. The sample splits were as follows: 0.5 L for grain size, TOC, and metal chemistry, 0.5 L for PAHs, 0.5 L for PCBs and chlorinated pesticides, and 3-L for toxicity tests. An additional 5 to 8 L of sediment was placed into plastic bags at sites designated for bioaccumulation. All samples were immediately placed on ice and kept cold until arrival at the analytical laboratory.

Personnel handling the sediments all wore pre-cleaned plastic gloves. All sampling materials were cleaned with site water before and after each grab. All scoops, spoons, and bowls were cleaned with site water prior to sampling a new station.

5.3.2 Sediment Collection - Cores

An Ocean Instruments Inc. multicorer was used to collect sediment cores at all sites for use in the sediment-water interface testing of sea urchin development. This corer was used because its design produces intact cores with little or no disturbance to the very top surface layer of sediment. The multicorer takes four simultaneous cores up to 30 cm in length. The cores are taken approximately at the corners of a square pattern that is about 25 cm on a side. The corer was set to collect cores with a nominal length of ~20 cm so that about 10 cm of overlying water would still be present. Though most cores collected were about 20 cm, core lengths varied from 6 to 29 cm.

All core tubes were pre-cleaned in a series of soap wash, 10% nitric acid soak, and methanol rinse. Distilled water was used for the in-between and final rinse. On occasions when the multicorer was not successful in obtaining a core of the correct length, the unit and cores were cleaned with site water before redeployment. The multicorer unit itself was cleaned with site water before each deployment.

Once the multicorer was recovered, the four cores were removed, their outsides rinsed with site water and the ends sealed with plastic endcaps. The end caps were secured with black tape. The cores were placed into coolers with specially built holders to maintain them in an upright position and kept cool until arrival at SCCWRP's laboratory for analysis.

5.3.3 Benthic Community Organism Collection

Benthic organisms were collected using a 0.1 m^2 Van Veen grab sampler with a closed top. All sediment from a single grab was dumped into a 1.0 mm screened box and the sediment washed out using site water. All organisms remaining within the screen were manually removed, placed into 1-L plastic jars containing a $MgSO_4$ relaxant solution, and preserved using 10% sodium borate buffered formalin.

5.3.4 Sampling Summary

A total of 240 sediment grabs and 148 cores were collected at 37 sites during the field effort. These totals reflect one set of field triplicates made at reference station 2433, Chollas station 8, and Paleta station 11. Sediments from all stations were analyzed for all parameters with the exception of bioaccumulation, which was measured at all reference stations but only at a subset of Chollas and Paleta stations (see Figure 5-1 and Figure 5-2). The location of each station sampled is shown in Table 5-4. The positions shown are the average of all grabs and cores taken at a station.

Table 5-3. Field sampling summary including number of stations, sediment grabs, and cores taken.

	Reference	Chollas Site	Paleta Site
Total Stations	6	14	17
Stations within original BPTCP strata	NA	11	9
Field Replicate Stations	1	1	1
Bioaccumulation Stations	6	7	7
Sediment Grabs	47	94	99
Sediment Cores	24	56	68

Table 5-4. Site locations in longitude and latitude. The locations represent the average position of all grabs and cores taken at a site. Station size is derived by calculating the distance of the furthest actual position from the average position.

Station	Latitude (deg N)	Longitude (deg W)
Reference Stations		
CP 2231	32.69463	-117.15658
CP 2238	32.66456	-117.14276
CP 2243	32.72238	-117.20919
CP 2433	32.71846	-117.17485
CP 2440	32.69129	-117.23803
CP 2441	32.62537	-117.12869
Chollas Creek Stations		
C01	32.68573	-117.13539
C02	32.68540	-117.13520
C03	32.68500	-117.13493
C04	32.68646	-117.13495
C05	32.68594	-117.13456
C06	32.68545	-117.13407
C07	32.68723	-117.13439
C08	32.68686	-117.13403
C09	32.68641	-117.13364
C10	32.68595	-117.13330
C11	32.68726	-117.13353
C12	32.68760	-117.13229
C13	32.68758	-117.13088
C14	32.68763	-117.12971
Paleta Creek Stations		
P01	32.67153	-117.12407
P02	32.67069	-117.12357
P03	32.67247	-117.12234
P04	32.67158	-117.12177
P05	32.67089	-117.12123
P06	32.67321	-117.12091
P07	32.67243	-117.12023
P08	32.67164	-117.11969
P09	32.67236	-117.11840
P10	32.67197	-117.11840
P11	32.67265	-117.11822
P12	32.67232	-117.11770
P13	32.67306	-117.11733
P14	32.67268	-117.11709
P15	32.67342	-117.11669
P16	32.67305	-117.11642
P17	32.67376	-117.11601

5.4 ANALYTICAL METHODS

5.4.1 Sediment Grain Size and Total Organic Carbon

Grain Size. Sediment samples were analyzed for grain size by Battelle's Sequim, WA laboratory. Samples were analyzed for grain size according to the methods of Plumb (1981). Samples are wet sieved through a No. 230 (0.0625 mm) U.S. Standard Sieve. The fine fraction (silt and clay) is collected in a 1-Liter graduated cylinder. Sediment retained on the No. 230 sieve is washed with distilled water into labeled, pre-weighed beakers and oven-dried for 24 hours at 105°C. After drying, the soil is sieved using a No. 10 (2.00 mm) sieve to determine the percent gravel, and a No. 230 (0.0625 mm) sieve to determine percent sand by weighing. Sediment passing the No. 230 sieve is added to the fine fraction in a graduated cylinder. The fine fraction is stirred and aliquots taken to determine the percent silt (0.0625 mm to 0.0039 mm) and clay (<0.005 mm) using hydrometers as described in ASTM D-422 (1990).

TOC. Sediment samples were analyzed for TOC by Battelle's Sequim, WA laboratory. Samples were analyzed for TOC following procedures described in EPA 9060 (USEPA, 1981). In this method samples are dried, homogenized, and then acidified to remove carbonates and bicarbonates. The samples are then combusted in a high-temperature furnace in a stream of oxygen to form carbon dioxide (CO_2). Interferents such as halogens, sulfur, nitrogen oxides, and water, were removed by chemical scrubbers prior to CO_2 quantification. Carbon dioxide is measured by sweeping the gas stream into a coulometer cell. The coulometer cell is filled with a partially aqueous medium containing ethanolamine and a colorimetric indicator. Carbon dioxide is quantitatively absorbed by the solution and is quantified by titration of the ethanolamine with strong acid until the indicator color fades.

5.4.2 Sediment Chemical Contamination

Bulk sediments and tissues collected as part of the bioaccumulation testing were analyzed for a suite of metals, PAHs, PCBs, and chlorinated pesticides using low-level detection EPA methods. The complete list of analytes is shown in Table 5-5 through Table 5-8. A variety of summed analyte lists are also used when evaluating contamination. These include the sum of all PAH analytes referred to here as Total PAHs (TPAH), the sum of PAH on the EPA's priority pollutant list (PPPAH), the sum of high molecular weight PAH analytes (HMWPAH), the sum of low molecular weight PAH analytes (LMWPAH), the sum of all PCB congeners referred to as Total PCBs (TPCB), the sum of the two chlordane analytes referred to here Total Chlordane (TCHLOR), and the sum of all DDT and its breakdown products DDE, and DDD referred to here as Total DDT (TDDT). The specific analytes making up these summed lists are shown in their respective tables. These summed lists may vary slightly from those in other studies because of differences in the number and kind of analytes measured. A brief description of methods for each category of contaminant is described below.

Metals. Sediment samples were analyzed for the metals shown in Table 5-5 at Battelle's Sequim, WA laboratory. Samples were digested using a strong acid (total metals) digestion technique (NOAA, 1998). All metals, except mercury, selenium, and silver were analyzed by either inductively coupled plasma mass spectrometry following EPA Method 200.8 or inductively coupled plasma atomic emission spectroscopy method 200.7. Silver was analyzed by graphite furnace atomic absorption method 200.9. Mercury was analyzed by cold vapor atomic

absorption following modified EPA Method 245.5. Selenium was analyzed by hydride atomic absorption using flow injection.

Table 5-5. The complete list of metal analytes measured in bulk sediments and in tissues collected in the bioaccumulation testing.

Metal	Symbol	Metal	Symbol
Aluminum	Al	Iron	Fe
Antimony	Sb	Lead	Pb
Arsenic	As	Mercury	Hg
Barium	Ba	Nickel	Ni
Beryllium	Be	Selenium	Se
Cadmium	Cd	Silver	Ag
Chromium	Cr	Zinc	Zn
Copper	Cu		

PAH. Sediment samples were analyzed for the PAHs shown in Table 5-6 at Arthur D. Little Inc.'s Cambridge, MA laboratory. Sediment samples were extracted for semivolatile organic compounds per ADL's standard operating procedure ADL-2819, "Extraction of Polychlorinated Biphenyls and Chlorinated Pesticides from Sediment or Shoreline Soil Samples". The extraction procedure allowed for the simultaneous extraction of PAHs, PCBs, and chlorinated pesticides. After homogenization, a 30 to 50 g aliquot of each sample was transferred into a Teflon® jar along with ~60 g of sodium sulfate, 100 mL of 50:50 dichloromethane/acetone, and then spiked with surrogate compounds. After a three-minute sonication the sample was centrifuged and the organic solvent layer was decanted into a flask. This extraction procedure was repeated 2 more times with fresh aliquots of solvent. After the third sonication, the sample jar was placed on an orbital shaker for 1 hour prior to the final centrifuge.

The three solvent extracts were combined and water was removed by adding approximately 75 g of sodium sulfate. Copper, alumina column, and high-pressure liquid chromatography (HPLC) cleanups were performed on the sample extracts to remove potential contamination that would interfere with sample analysis. All extracts were concentrated to approximately 1 mL using kuderna-danish concentrators and nitrogen evaporation. Extracts were split into archive and working volumes. The working extract volume was further split: one-half was designated for PAH analysis and one-half was exchanged into hexane for PCB/Pesticide analyses (see below).

The sample extracts were analyzed for PAHs per ADL's standard operating procedure ADL-2827, "Determination of Polynuclear Aromatic Hydrocarbons and Selected Heterocyclic Compounds by Gas Chromatography/Mass Spectrometry in the Selected Ion Monitoring Mode." ADL's PAH analysis method is a modified version of EPA's SW-846 Method 8270. The gas chromatograph/mass spectrometer (GC/MS) was operated in selected ion monitoring (SIM) mode to obtain the desired sensitivity that is comparable to that of a GC equipped with an electron capture detector. The GC/MS was tuned with perfluorotributylamine to verify accurate mass assignment and to maximize the sensitivity of the instrument in the mass range of interest (100 to 300 atomic mass units). Average response factors for each target compound and surrogate were calculated from initial calibration standards relative to internal standard compounds added to the sample extracts just prior to instrumental analysis (internal standardization). Calibration standards were analyzed on regular intervals to monitor sensitivity and linearity of the GC/MS. The average response factors generated from the calibrations were

used to calculate the concentrations of target compounds and surrogates. The recoveries of the surrogate compounds spiked into the sample prior to extraction were used to assess sample-specific extraction efficiency. Target compound concentrations were surrogate corrected based on sample-specific surrogate recoveries to correct for differences in extraction efficiency.

A full suite of quality control samples were prepared for every analysis batch including a procedural blank, blank spike, blank spike duplicate, matrix spike, matrix spike duplicate, duplicates, and standard reference material.

Table 5-6. The complete list of PAH analytes measured in bulk sediments and in tissues collected in the bioaccumulation testing. Summed lists of PAH analytes used in contamination evaluation are also shown.

PAH	Identifier	PAH	Identifier
Naphthalene	C0N	Pyrene	PYR
C1-Naphthalenes	C1N	C1-Fluoranthenes/pyrenes	C1F/P
C2-Naphthalenes	C2N	C2-Fluoranthenes/pyrenes	C2F/P
C3-Naphthalenes	C3N	C3-Fluoranthenes/pyrenes	C3F/P
C4-Naphthalenes	C4N	Benzo[a]anthracene	BAA
Acenaphthylene	ACEY	Chrysene	C0C
Acenaphthene	ACE	C1-Chrysenes	C1C
Biphenyl	BIP	C2-Chrysenes	C2C
Fluorene	C0F	C3-Chrysenes	C3C
C1-Fluorenes	C1F	C4-Chrysenes	C4C
C2-Fluorenes	C2F	Benzo[b]fluoranthene	BBF
C3-Fluorenes	C3F	Benzo[k]fluoranthene	BKF
Anthracene	C0A	Benzo[e]pyrene	BEP
Phenanthrene	C0P	Benzo[a]pyrene	BAP
C1-Phenanthrenes/anthracenes	C1P/A	Perylene	PER
C2-Phenanthrenes/anthracenes	C2P/A	Indeno[1,2,3,-c,d]pyrene	INDENO
C3-Phenanthrenes/anthracenes	C3P/A	Dibenzo[a,h]anthracene	DAH
C4-Phenanthrenes/anthracenes	C4P/A	Benzo[g,h,i]perylene	BGP
Dibenzothiophene	C0D	Total PAH[1]	TPAH
C1-Dibenzothiophenes	C1D	Priority Pollutant PAH[2]	PPPAH
C2-Dibenzothiophenes	C2D	Low Molecular Weight PAH[3]	LMWPAH
C3-Dibenzothiophenes	C3D	High Molecular Weight PAH[4]	HMWPAH
Fluoranthene	FLANT		

Total PAH[1] = sum of all listed PAH analytes
Priority Pollutant PAH[2] = sum of C0N, ACEY, ACE, C0F, C0A, C0P, FLANT, PYR, BAA, C0C, BBF, BKF, BAP, INDENO, DAH, BGP
Low Molecular Weight PAH[3] = sum of C0N, C2N, ACEY, ACE, C0F, C0A, C0P
High Molecular Weight PAH[4]= sum of FLANT, PYR, BAA, C0C, BAP, DAH

PCB. Sediment samples were extracted for PCBs simultaneously with PAH as described above at Arthur D. Little Inc.'s Cambridge, MA laboratory. The extracts were analyzed for PCB congeners (Table 5-7) per ADL's SOP ADL-2818, "Determination of Chlorinated Pesticides and PCB Congeners by Gas Chromatography/Electron Capture Detection." This method was used to simultaneously measure chlorinated pesticides. ADL's PCB congener analysis method is a

modified version of EPA's SW-846 Method 8081 using dual, dissimilar columns and dual detectors. A Restek RTX-5 column (or equivalent) was used as the primary column and a DB-17 column (or equivalent) was used as the confirmation column. Average calibration factors for each target compound and surrogate were calculated from initial calibration standards (external standardization). Calibration standards were analyzed on regular intervals to monitor sensitivity, retention time stability, and linearity of the Gas Chromatograph/Electron Capture Detector (GC/ECD).

Average calibration factors generated from the calibrations were used to calculate target compound concentrations. When co-elution occurred between one or more target compounds or when interference occurred on the primary column, the results were reported from the confirmation column for the affected compounds. Compound identification was based on 1) detecting a peak within the established retention time window for a specific compound on both the primary and confirmation columns, and 2) the analyst's judgment. The recoveries of the surrogate compounds spiked into the sample prior to extraction were used to assess sample-specific extraction efficiency. Target compound concentrations were surrogate corrected based on sample-specific surrogate recoveries to correct for differences in extraction efficiency.

A full suite of quality control samples were prepared for every analysis batch including a procedural blank, blank spike, blank spike duplicate, matrix spike, matrix spike duplicate, duplicates, and standard reference material.

Chlorinated Pesticides. Sediment samples were extracted for chlorinated pesticides simultaneously with PAH and PCB as described above at Arthur D. Little Inc.'s Cambridge, MA laboratory. The extracts were analyzed for chlorinated pesticides shown in Table 5-8 simultaneously with PCB per ADL's SOP ADL-2818, "Determination of Chlorinated Pesticides and PCB Congeners by Gas Chromatography/Electron Capture Detection." The analytical method is described above.

Table 5-7. The complete list of PCB congeners measured in bulk sediments and in tissues collected in the bioaccumulation testing. Summed lists of PCB congeners used in contamination evaluation are also shown.

PCB Congener	Congener Number	PCB Congener	Congener Number
2,2',5-Trichlorobiphenyl (Cl3)	18	2,2',3,3',4,4'-Hexachlorobiphenyl (Cl6)	128
2,4,4'-Trichlorobiphenyl (Cl3)	28	2,2',3,4,4',5'-Hexachlorobiphenyl (Cl6)	138
3,4,4'-Trichlorobiphenyl (Cl3)	37	2,2',3,4',5',6-Hexachlorobiphenyl (Cl6)	149
2,2',3,5'-Tetrachlorobiphenyl (Cl4)	44	2,2',3,5,5',6-Hexachlorobiphenyl (Cl6)	151
2,2',4,5'-Tetrachlorobiphenyl (Cl4)	49	2,2',4,4',5,5'-Hexachlorobiphenyl (Cl6)	153
2,2',5,5'-Tetrachlorobiphenyl (Cl4)	52	2,3,3',4,4',5-Hexachlorobiphenyl (Cl6)	156
2,3',4,4'-Tetrachlorobiphenyl (Cl4)	66	2,3,3',4,4',5'-Hexachlorobiphenyl (Cl6)	157
2,3',4',5 -Tetrachlorobiphenyl (Cl4)	70	2,3,3',4,4',6-Hexachlorobiphenyl (Cl6)	158
2,2,4',5 -Tetrachlorobiphenyl (Cl4)	74	2,3',4,4',5,5'-Hexachlorobiphenyl (Cl6)	167
3,4,4',5 -Tetrachlorobiphenyl (Cl4)	81	2,3',4,4',5',6'-Hexachlorobiphenyl (Cl6)	168
3,3',4,4'-Tetrachlorobiphenyl (Cl4)	77	3,3',4,4',5,5'-Hexachlorobiphenyl (Cl6)	169
2,2'3,4,5'-Pentachlorobiphenyl (Cl5)	87	2,2',3,3',4,4',5-Heptachlorobiphenyl (Cl7)	170
2,2',4,4',5-Pentachlorobiphenyl (Cl5)	99	2,2',3,3',4',5,6-Heptachlorobiphenyl (Cl7)	177
2,2',4,5,5'-Pentachlorobiphenyl (Cl5)	101	2,2',3,4,4',5,5'-Heptachlorobiphenyl (Cl7)	180
2,3,3',4,4'-Pentachlorobiphenyl (Cl5)	105	2,2',3,4,4',5',6-Heptachlorobiphenyl (Cl7)	183
2,3,3',4',5-Pentachlorobiphenyl (Cl5)	110	2,2',3,4',5,5',6-Heptachlorobiphenyl (Cl7)	187
2,3,4,4',5-Pentachlorobiphenyl (Cl5)	114	2,3,3',4,4',5,5-Heptachlorobiphenyl (Cl7)	189
2,3',4,4',5-Pentachlorobiphenyl (Cl5)	118	2,2',3,3',4,4',5,5'-Octachlorobiphenyl (Cl8)	194
2,3',4,4',6-Pentachlorobiphenyl (Cl5)	119	2,2',3,3',4,4',5,5',6-Octachlorobiphenyl (Cl8)	201
2',3,4,4',5-Pentachlorobiphenyl (Cl5)	123	2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl (Cl9)	206
3,3',4,4',5-Pentachlorobiphenyl (Cl5)	126	Total PCB[1]	TPCB

Total PCB[1] = sum of all listed PCB congeners

Table 5-8. The complete list of chlorinated pesticide analytes measured in bulk sediments and in tissues collected in the bioaccumulation testing. Summed lists of pesticide analytes used in contamination evaluation are also shown.

Chlorinated Pesticides	Identifier
gamma-Chlordane	g-Chlordane
alpha-Chlordane	a-Chlordane
1-(2-chlorophenyl)-1-(4-chlorophenyl)-2,2-dichloroethylene	2,4'-DDE
1,1-bis(4-chlorophenyl)-2,2-dichloroethylene	4,4'-DDE
1-(2-chlorophenyl)-1-(4-chlorophenyl)-2,2-dichloroethane	2,4'-DDD
1,1-bis(4-chlorophenyl)-2,2-dichloroethane	4,4'-DDD
1-(2-chlorophenyl)-1-(4-chlorophenyl)-2,2,2-trichloroethane	2,4'-DDT
1,1-bis(4-chlorophenyl)-2,2,2-trichloroethane	4,4'-DDT
Total Chlordane[1]	TCHLOR
Total DDT[2]	TDDT

Total Chlordane[1] = sum of g-Chlordane and a- Chlordane
Total DDT[2] = sum of all listed analytes of DDE, DDD, and DDT

5.4.3 Bioaccumulation

Organism Exposure. Bioaccumulation exposure experiments were carried out by MEC Analytical Inc. using the bivalve *Macoma nasuta* over a 28-day test period. *Macoma nasuta* were supplied by John Brezina of Dillon Beach, CA. Bioaccumulation tests were conducted over a 28-day test period in accordance with those procedures outlined in USEPA (1993), and the Ocean Testing Manual (USEPA/USACE 1991). Each of these tests was initiated using test, reference, and control sediment in the same manner as the 10-day solid phase test discussed in the manual. Approximately 20 test organisms were placed onto five liters of test sediments within a 20 L fiberglass tank. The tanks were supplied with a continuous flow (21 mL/min) of clean, filtered (<5 μm), UV sterilized San Francisco Bay seawater (29 to 32 ppt salinity) at 15 ± 2°C. Exposures were conducted under a 16:8 photoperiod and animals were not fed over the 28-day exposure. Water quality measurements, including salinity, pH, dissolved oxygen, and temperature, and ammonia were monitored throughout the tests.

Test organisms were recovered at exposure termination by gently sieving test sediments through a 0.75-mm stainless steel screen. All surviving clams were counted and placed in sediment-free, flow-through aquaria under test conditions for a period of 24 hours to allow the organisms to purge their gut contents. Following gut purging, the animals from each treatment were placed in clean glass jars with teflon-lined lids, frozen, packaged with dry ice in sealed coolers and then sent overnight under chain-of-custody to Arthur D. Little, Inc. for chemical analysis.

Tissue Analysis. Tissue samples were extracted for semi-volatile organic compounds per ADL's SOP ADL-2831, "Extraction of Semi-volatile Hydrocarbons, PCBs, and Chlorinated Pesticides from Biological Tissue Samples." Samples were macerated at high speed for 2 minutes using a tissue extraction probe. After homogenization, a 5 to 15 g aliquot of tissue sample was transferred into a Teflon® jar along with ~60 g of sodium sulfate, 100 mL of dichloromethane, and then spiked with surrogate compounds. The remainder of the sample preparation and analysis follows that described above for sediments.

5.4.4 Sediment Toxicity

Bulk Sediment. The amphipod survival test was used to evaluate toxicity of the whole sediment samples. The amphipods, *Eohaustorius estuarius*, were collected from Yaquina Bay near Newport, Oregon. The animals were held in the laboratory on their native (home) sediment for one to four days before testing began. The tests were conducted in 1 L Mason jars containing 2 cm of sediment (approximately 150 ml) and 800 ml of water. Five replicates were used for each sample. The overlying water was adjusted to a salinity of 20 g/kg, and the exposures conducted at 15°C. The sediment was added to the jars and overlying water added with aeration one day before the animals were added, in order to provide a 24 hr equilibration period. After equilibration, 20 amphipods were added to each beaker for an exposure period of 10 days. The beakers were monitored daily for visible changes to the sediment or death of the animals. At the end of the exposure period, the sediment from the beakers was passed through a sieve to recover the animals, and the number of surviving animals counted. Samples of amphipod home sediment were tested as negative controls. Water quality parameters (temperature, pH, dissolved oxygen, ammonia, and salinity) were measured on the porewater and overlying water of surrogate water quality beakers at both the beginning and end of the exposure period.

Pore Water. The purple sea urchin fertilization test was used to evaluate porewater toxicity (USEPA 1995). This test measures toxic effects on sea urchin sperm, as a reduction in their

ability to fertilize eggs. The porewater was extracted by centrifuging the sediment at 3000 g for 30 min. The purple sea urchins (*Strongylocentrotus purpuratus*) used in the tests were collected from the intertidal zone in northern Santa Monica Bay. The test consisted of a 20-minute exposure of sperm to samples of 25, 50, or 100% porewater diluted with seawater. Eggs were then added and given 20 minutes for fertilization to occur. The eggs were then preserved and examined later with a microscope to assess the percentage of successful fertilization. Toxic effects were expressed as a reduction in fertilization percentage. The tests were conducted in glass shell vials containing 10 mL of solution at a temperature of 15°C. Four replicates were tested for each sample. A seawater blank was included as negative control.

Sediment-Water Interface. The sediment-water interface samples were tested using the purple sea urchin development test (USEPA 1995). This test measures the ability of the sea urchin larvae to develop normally from a fertilized egg in test media. The purple sea urchins (*Strongylocentrotus purpuratus*) used in the tests were collected from the intertidal zone in northern Santa Monica Bay and were held in the laboratory. To test the sediment-water interface sample, the overlying water in each core tube was first replaced with clean seawater with aeration. Four replicate cores were used for each sediment type. After equilibration for 24 hours, a polycarbonate cylinder with a fine mesh screen bottom (screen tube) was placed on the sediment inside the core tube. The adult sea urchins were induced to spawn, the gametes were collected and then the eggs were fertilized. The fertilized eggs were added to the screen tube and given 72 hours to develop at 15°C. After the exposure period, the screen tubes were removed from the sediment and the outside rinsed to remove any adhering sediment. The embryos were then rinsed into glass shell vials and preserved and evaluated under a microscope to determine if normal development had occurred. The endpoint for this assay is percentage of normal development. A core tube blank (core with no sediment added) was included as a negative control. Water quality parameters (temperature, pH, dissolved oxygen, ammonia, and salinity) were measured on the overlying water at both the beginning and end of the exposure period.

5.4.5 Benthic Community Analysis

In the benthic laboratory, samples were rinsed and transferred from formalin to 70% ethanol. Samples were then sorted into six major taxonomic categories (annelids, arthropods, molluscs, ophiuroids, other echinoderms, and other phyla). Specimens were then identified to the lowest practicable taxon and enumerated. Laboratory quality control procedures included resorting 10% of the samples, with at least 1 sample resorted per sorter.

Analysis of the data fell into four categories: comparison of species abundances among species, cluster analysis of species assemblages, evaluation of community characteristics, and calculation of the magnitude of community disturbance. The species abundance data (number of individuals/grab) was summed within each of the three station types (reference, Chollas, and Paleta) and ranked to determine the most common species. The abundance of four indicator species for each station was also compared. The indicator species included two polychaete worms (*Capitella capitata* and *Streblospio benedicti*) an ostracod (*Euphilomedes carcharodonta*), and amphiuridae (brittlestars).

Cluster analysis of the stations from all three study sites was conducted using flexible sorting of Bray-Curtis dissimilarity values with ß=-0.25 (Bray and Curtis 1957, Lance and Williams 1967, Clifford and Stephenson 1975). The abundances were square root transformed and then standardized by the species mean of values higher than zero to reduce the influence of dominant species (Smith 1976, Smith et al., 1988). The step-across distance re-estimation

procedure (Williamson 1978, Bradfield and Kenkel 1987) was applied to dissimilarity (distance) values over 0.80 to reduce the distortion of ecological distances caused by joint absences of a high proportion of species; the distortion occurs due to the common non-monotonic truncated nature of species distributions along environmental gradients (Beals 1973). Prior to cluster analysis, species contributing little information were excluded by eliminating species occurring at fewer than 5 sites.

Three metrics were calculated in order to describe the overall characteristics of the macrofaunal community: abundance, number of taxa, and Shannon-Wiener diversity (using natural logarithms) (Pielou 1969).

The magnitude of disturbance shown by the benthic assemblage at each station was described using the embayment Benthic Response Index (BRI). The embayment BRI measures the abundance-weighted pollution tolerance of species present (Ranasinghe et al., 2003) and is based on a similar index developed for coastal assemblages (Smith et al., 2001. Both indices define five level of biotic response along a pollution gradient. The response levels were based on the loss of 5-25%, 25-50%, 50-80% and >80% of potential species. The BRI is a measure of the magnitude of disturbance, but cannot determine the cause of the disturbance because natural and anthropogenic factors may affect the benthos in a similar manner.

6.0 DATA QUALITY RESULTS

6.1 SEDIMENT AND BIOACCUMULATION CHEMISTRY

Arthur D. Little, Inc. was the primary contractor hired to perform all chemical analyses on sediments and tissues. They performed all organic analyses in-house while their sub-contractor, Battelle Sequim Laboratory performed all metal, grain size, and TOC analyses. The chemistry contract identified all data quality objectives (DQO) including the use of low detection limit methods. The project DQO are shown in Table 6-1 through Table 6-3. The laboratories each conducted their own internal quality assurance/quality control (QA/QC) evaluations to address whether or not DQO were met based on chain-of-custody, sample temperature and holding time, blank and blank-spike duplicates, sample analysis duplicates, surrogate recoveries, matrix-spike and matrix-spike duplicates, reference material analyses, instrument calibrations, and internal reference standards. The laboratories generated reports that identified all instances when data were outside the DQO for the project and identified what corrective actions were taken, if any.

All chemistry results including the narrative reports were reviewed at SSC-SD. All grain size and TOC measurements met the project DQO. For the most part the chemistry data met the project DQOs and low detection requirements. This provides a robust dataset with a minimum of non-detect data (7.28%). Only two samples required corrective action and were successfully re-extracted and re-analyzed for organic chemistry. The first was for the sediment sample taken at Paleta station P08 and the second was for a tissue sample for reference station 2238. Even with the efforts taken to thoroughly homogenize sediment samples there was some evidence of sample inhomogeneity in the analysis of organic compounds in sample replicates C10 and P16.

During the SSC-SD data review a “&” data qualifier was added to all sample data that were potentially affected by a result outside a DQO, including results of an associated QA/QC sample (e.g., blank spike). The narrative reports were then reviewed for trends and persistent analytical problems. Based on this review results for naphthalene in sediments may potentially be considered biased low because of persistent low recovery results relative to standard reference materials and for sample surrogates. PCB77 measured in tissues may potentially be considered biased high because of persistent high recovery results relative to standard reference materials and in the matrix spikes and duplicates. Likewise, PCB198 measured in tissues may potentially be considered biased high because of persistent high recovery results identified to be likely the result of matrix effects.

The chemistry dataset was finalized by inserting the value of an analyte’s method detection limit when the data were identified as non-detect (U qualifier). Additionally, results of field duplicates were averaged to provide a single result for each sample though only the first result of a laboratory duplicate was used for the final data tables. The final chemistry data files generated for the project underwent a final QA/QC check that reviewed 10% of the data and their qualifiers. The final chemistry dataset is shown in Appendix A. These data were also transferred electronically to SCCWRP in their sediment data format.

Table 6-1. Data Quality Objectives and Criteria for metal analyses. One laboratory duplicate was run within each batch with a QC limit of ±30%

Metal	Reference Method	Range of Recovery	SRM Accuracy	Relative Precision	Target Detection Limit (μg/g)	Achieved Detection Limit (μg/g)
Aluminum	ICP-AES	70-130%	≤30%	≤30%	6	2.4
Antimony	ICP-MS	70-130%	≤30%	≤30%	0.2	0.03
Arsenic	ICP-MS	70-130%	≤30%	≤30%	0.1	0.07
Barium	ICP-AES	70-130%	≤30%	≤30%	0.01	0.02
Beryllium	ICP-MS	70-130%	≤30%	≤30%	0.01	0.02
Cadmium	ICP-MS	70-130%	≤30%	≤30%	0.01	0.02
Chromium	ICP-AES	70-130%	≤30%	≤30%	1	0.5
Copper	ICP-AES	70-130%	≤30%	≤30%	2	0.24
Iron	ICP-AES	70-130%	≤30%	≤30%	5	0.6
Lead	ICP-MS	70-130%	≤30%	≤30%	0.1	0.2
Mercury	CVAF	70-130%	≤30%	≤30%	0.001	0.002
Nickel	ICP-MS	70-130%	≤30%	≤30%	0.2	0.2
Selenium	FIAS	70-130%	≤30%	≤30%	0.01	0.067
Silver	GFAA	70-130%	≤30%	≤30%	0.3	.08
Zinc	ICP-MS	70-130%	≤30%	≤30%	1.0	0.6

CVAF- Cold Vapor Atomic Absorption
FIAS- Flow Injection Atomic Absorption
GFAA- Graphite Furnace Atomic Absorption
ICP-AES- Inductively Coupled Plasma-Atomic Emission Spectrometry
ICP-MS- Inductively Coupled Plasma-Mass Spectrometry
SRM- Standard Reference Material

Table 6-2. Nominal method detection limits for PAH, PCB, and chlorinated pesticides analyses.

	PAH (μg/kg)	PCB (μg/kg)	Chlorinated Pesticides (μg/kg)
Sediment	0.05 – 0.18	0.02 – 0.06	0.02 – 0.07
Tissues	0.2 – 1.6	0.12 – 0.45	0.14 – 0.25

Table 6-3. Data Quality Objectives and Criteria, PAH Method 8270M-SIM, PCB Congener and Chlorinated Pesticide Method 8081A – modified.

Element or Sample Type	Minimum Frequency	Data Quality Objective/ Acceptance Criteria
Initial Calibration	Prior to every batch sequence.	5 point curve. %RSD ≤25% for 90% of analytes and ≤35% for all analytes.
Continuing Calibration	Must end analytical sequence and every 12 field samples or 16 hours, whichever is more frequent.	%RSD ≤25% for 90% of analytes. %RSD ≤35% for all analytes.
Procedural Blank	Every batch/every 20 field samples.	No more than 2 analytes to exceed 5x PQL unless analyte not detected in associated sample(s) or associated sample analyte concentration is > 10x blank value.
Blank Spike Sample	Every batch/every 20 field samples.	50-150% recovery, RPD ≤35%.
SRMs (SRM 1941a for sediment, 1974a for tissue).	Every sediment or tissue batch/every 20 field samples.	Values ±35% difference of true value for all certified analytes, two may exceed.
Matrix Spike, Matrix Spike Duplicate Sample	Every sediment or tissue batch/every 20 field samples.	45-150% recovery, RPD ≤35%.
Recovery/Surrogate Standards	Every Sample	40-125% d8-napththalene, d10-acenaphthene, d10-phenenthrene 40-135% d12-benzo[a]pyrene 40-125% DBOFB, PCB-103, PCB-198 with one out of criteria.
Instrumental SRM (SRM 1491)	One set per batch of samples after every ICAL.	Values ≤15% difference of true value for all certified analytes.
Control Oil (North Slope Crude)	One set per batch of samples after every ICAL (PAH only).	Values ≤35% difference of laboratory average values.

DBOFB- 1,2,3-Trichlorobenzene and 4,4'-Dibromooctafluorobiphenyl
ICAL- Instrument Calibration
PQL- Practical Quantitation Limit
RPD- Relative Percent Difference
RSD- Relative Standard Deviation
SRM- Standard Reference Material

6.2 TOXICITY

The toxicity test results were assessed for sediment holding time, testing methods, water quality conditions, negative control response, and positive control response (Table 6-4). Exceedance of a data quality objective did not automatically invalidate a test. Rather, the data were examined to see if the exceedance had affected the interpretation of the results. The sediment samples were analyzed in two batches of experiments; Chollas site sediments were collected and analyzed in July 2001, while Paleta site sediments were collected and analyzed in August 2001. Because there were two batches of experiments, there are separate data quality evaluations presented below.

6.2.1 Bulk Sediment

Most of the data quality objectives were met for the amphipod exposures to Chollas and Paleta site sediments. The sediment holding time objective was met for both experiments. The animal acclimation period was met for the experiment with Chollas THS sediments. Amphipod survival in the control sediments for both experiments was greater than 90%. The response curve was normal for amphipods exposed to ammonia in the reference test accompanying the Paleta sediment exposures. Proper exposure temperature was maintained for both site sediment exposures. Temperature, salinity, dissolved oxygen, pH, and ammonia measurements were made on all Paleta and most Chollas site sediments.

A few exceptions to the data quality objectives were identified for exposures with Paleta and Chollas sediments. One deviation was that the animals in the experiment with Paleta sediments were acclimated for one day before the start of the test, which is short of the recommended acclimation period of 2-3 days. This shortened acclimation period does not appear to have affected the test, however, since amphipod survival was high in the home sediment (94%), variability was low (CV = 7%), and a normal dose response was achieved in the reference toxicant test.

A second data quality objective deviation was that there was no significant mortality in any of the ammonia concentrations in the reference toxicant conducted concurrently with the Chollas sediment exposure. The range of the ammonia concentrations used in this test was lower than what is required to produce significant mortality to *Eohaustorius estuarius*, according to subsequent tests that used higher concentrations of ammonia. Therefore the sensitivity of this batch of animals could not be determined.

Some of the water quality measurements were incomplete. An insufficient amount of porewater was collected from the home sediment and two of the Chollas sediments for water quality analysis at the initial and final time points. However, amphipod survival in these sediments was high (90-94%), and the water quality parameters were within acceptable ranges for the porewater in the accompanying sea urchin fertilization test. Therefore, the lack of water quality measurements did not affect the interpretation of the results.

There were also variations in pH in the reference toxicant tests. The pH of the initial solutions in both reference tests conducted with the site sediments was slightly below the desired level of 7.8 for all treatments, ranging from 7.3-7.7. Because there was no significant mortality in the control, the pH readings did not affect the outcome of the test.

In a few samples, more than 20 amphipods (the initial number of animals) were found alive at the end of both the Paleta and Chollas site sediment exposures. It was concluded that additional animals were added at the beginning of the experiment. When additional animals were found, the initial counts used in the statistical analysis were based on the number of amphipods found at the end of the experiment.

Bulk Sediment Test Outliers. Some stations had a high variability in amphipod survival among test replicates. In the majority of these cases, there were replicates with high survival and a couple of replicates that had very poor survival. The replicates with very poor survival appeared to be outliers that did not represent the toxicity at these stations. The cause of the aberrant survival in each outlier replicate was not known, but may have been related to dying infauna in the sediments, resulting in poor water quality.

A threshold screening approach was used to identify and remove these outlier data. Outliers were identified as those values which were ≥30 percentage points below the next highest value, working from highest to lowest values. For example, Chollas Station C01 had replicates with 0, 15, 45, 60, and 70% survival. The value of 15 was removed as an outlier because it was 30 percentage points below 45. The value of 0 was then removed because it was more than 30 percentage points from 45. The remaining replicates for Station C01 had 45, 60 and 70% survival.

Outlier replicates were found in six Chollas stations, five Paleta stations and three of the CP reference stations. Stations C04, C09, P05, P10, P12, P13, P14 and CP2441 each had one outlier, while Stations C01, C10 and CP2243 had two outliers, and Stations C13, C14 and CP2231 each had three outliers. One outlier replicate was also identified in the home sediment treatment used with the Chollas site sediments.

The exclusion of outlier values has both advantages and disadvantages in this study. The primary advantage of excluding outliers is that variability in the data is reduced, with an associated increase in statistical power to detect differences from the control or baseline condition. In addition, exclusion of outliers should provide a more accurate measure of the toxicity of the sample. The disadvantages of using an outlier exclusion method include a possibility of erroneously identifying a replicate as an outlier and biasing the results by discarding accurate information. The small number of replicates that are tested complicates the detection of outlier values in a toxicity test. The decision to identify and exclude outliers in this study was based on two factors. First, the level of variability among test replicates was higher than normal for the amphipod toxicity test, indicating the potential presence of outliers. Second, the exclusion of outliers was judged to be appropriate because of the reliance on statistical comparisons to the control for classifying a sample as toxic. Reducing the excessive variability in survival for a test sample would likely improve the statistical power of the data analyses (comparison to control) and thus provide a more environmentally protective comparison.

6.2.2 Sediment-Water Interface

Most of the data quality objectives were met for the sediment-water interface experiments. The sediment holding time objective was met for both Chollas and Paleta samples. Sea urchin embryo development in the seawater control was good in the experiment with Chollas site sediments. The responses in both reference toxicant experiments were within the control chart limits. Temperature, salinity, and dissolved oxygen were all maintained within the proper ranges.

A few exceptions to the data quality objectives were identified in the sediment-water interface tests with Chollas and Paleta sediments. The Paleta test did not meet the objective for normal development; the mean normal development was 75% for the control instead of >80%. The sea urchin embryos were determined to be of good quality, since the concurrent copper reference toxicant test had high normal development in the control (93%), and a normal dose-response.

Water quality measurements were made for only one time point in the reference toxicant test associated with the Chollas site test. Moreover, it was not recorded whether the measurements were from the initial or final time points. In the reference toxicity test associated with the Paleta test, no water quality parameters were measured. However because normal development was high in the seawater control (93%), variability was low (CV = 3.9%), and the EC50 was within control chart limits, the water quality data in this test were believed to be within the desired ranges.

The initial pH of one replicate for the control in the Paleta site exposure was slightly elevated (pH = 8.42). The final pH reading for this replicate was within the normal range. Because normal development in this replicate was similar to that of the other replicates, it was concluded that the initial pH of the sample did not affect the test.

Several stations had a reduced number of replicates. An insufficient amount of sediment was collected from Stations CP2231, C01, C03, C05, and P16. Therefore, these stations had three replicates tested instead of four. Stations CP2440, CP2441, C01 and C07 each had one replicate where defects in the screen tubes allowed the embryos to leak out of the tube; these replicates were excluded from the data set.

Sediment-Water Interface Test Ammonia Influence and Outliers. Additional data were removed on the basis of unionized ammonia. Ammonia concentrations >0.067 mg/L NH_3 were believed to be responsible for all of the toxicity in samples that had <80% normal development (see Appendix C for a complete description of the process used to identify outliers and adjust for ammonia influence). No information regarding the toxicity of other constituents could be obtained in these samples, and these replicates were removed as outliers. One Chollas station, seven Paleta stations and three CP reference stations had at least one replicate with ammonia concentrations high enough to be classified as outliers. Stations CP2440, CP2433, C09, P08, P11 and P14 each had one replicate that was an outlier, while Station CP2441 had two outliers, and Stations P12, P13, CP2231 and CP2243 had three outliers. All four replicates from Station P10 were outliers and no usable data were obtained from this station.

The amount of ammonia influence could be corrected for in other samples to enable the evaluation of the amount of toxicity due to other constituents. Samples with ammonia concentrations between 0.033 and 0.067 mg/L NH_3 that had sea urchin embryo development <80% of the control were adjusted for ammonia influence (see Appendix C for a discussion of the process). Four Chollas stations, nine Paleta stations and one reference station had at least one replicate that was influenced by ammonia, and the percent development adjusted accordingly. Stations C08, C12, P07, P08, P12, P13, P15, P17 and CP2238 each had one replicate that was influenced by ammonia, while C03 and P05 had two replicates influenced by ammonia, and Stations P11 and P14 each had three replicates that were influenced by ammonia. All four replicates from Station C04 were influenced by ammonia.

Adjustment of the embryo development data for the influence of ammonia has been used in a previous study of pore water toxicity (Bay, 1995). Adjustment of the data for ammonia toxicity is desirable in this study because it reduces the impact of a confounding factor not associated with

chemical contamination. It is possible that chemical contamination may have impacted embryo development in some of the samples that were excluded as an outlier due to high ammonia. The presence or absence of such effects cannot be determined, due to the high level of toxicity caused by ammonia.

6.2.3 Pore Water

Most of the data quality objectives were met for the experiments with Chollas and Paleta site porewater samples. The sediment holding time objective was met for both Chollas and Paleta samples. The response in the reference toxicant experiment accompanying the Chollas porewater exposures was within the control chart limits. Temperature, salinity, pH and dissolved oxygen were maintained within the proper ranges for all porewater samples.

A few exceptions to the data quality objectives were identified for the tests with Chollas and Paleta site porewater. There was poor fertilization (36%) in the seawater control in the Chollas sediment porewater test. However the seawater control from the reference toxicant test met the objective for control fertilization (>70%), and was subsequently used for statistical analysis with the porewater samples. Water quality measurements were within acceptable ranges for the controls, indicating that the toxicity was due to contamination of laboratory glassware.

One replicate in the seawater control for the Paleta site test also had low fertilization. This replicate was judged to be an outlier, and the data from this replicate was removed before statistical analysis was performed.

Fertilization was poor in all treatments of the reference toxicant test associated with Paleta stations, including the control. However, fertilization was acceptable for the control in the concurrent porewater test, indicating that the sea urchin gametes were of good quality. Therefore, it was concluded that the reference toxicant test system was contaminated, and no useable data were obtained from this test.

The water quality measurements were incomplete for some experiments. The concentrations of ammonia were not measured in any of the Paleta porewater samples. However, ammonia concentrations were measured in porewater from the accompanying amphipod test that used these same sediments, and these concentrations of ammonia were below the threshold that is likely to affect sea urchin fertilization. Therefore the lack of ammonia measurements probably had no effect on the interpretation of the results. No water quality parameters were measured in the reference toxicant test that accompanied the Paleta test. However, salinity, pH, and dissolved oxygen were measured for the seawater control in the concurrent porewater test (the same seawater used to make up each of the reference toxicity test solutions) and were within acceptable ranges. Therefore the lack of these measurements in the reference toxicant test did not affect the interpretation of the results.

6.3 BENTHIC COMMUNITY ANALYSIS

Quality control procedures for processing the benthic samples included resorting 10% of the samples, with at least 1 sample resorted per sorter. The sorting efficiency for both of these quality control procedures was >95%. In addition, the benthic data was reviewed by a third party for consistency with the nomenclature, standardized by Southern California Association of Marine Invertebrate Taxonomists. Data from all of the benthic samples were determined to be acceptable.

Table 6-4. Summary of toxicity test data quality objectives. * = Comparisons would normally be made to the control chart mean, however only a limited number of reference toxicant tests have been performed at SCCWRP using ammonia with *E. estuarius*.

Parameter	Bulk Sediment	Sediment-Water Interface	Pore water
	Amphipod Survival	Sea Urchin Development	Sea Urchin Fertilization
Sediment holding time	<2 weeks	<2 weeks	<2 weeks
Animal acclimation period	2-3 days	No objective	No objective
Control response	≥90% survival	≥80% normal development	≥70% fertilization
Reference toxicant test	Normal NH_3 response curve*	Cu EC50 within 2 SD of control chart mean (16.7 ± 10.6)	Cu EC50 within 2 SD of control chart mean (34.7 ± 17.8)
Water quality parameters:			
Temperature	15°C ± 2°	15°C ± 2°	15°C ± 2°
Salinity	18-22‰	32-35‰	32-35‰
Unionized Ammonia	<1.15 mg/L	<0.03 mg/L	<0.44 mg/L
Dissolved Oxygen	>5 mg/L	>5 mg/L	>5 mg/L
pH	7.8-8.2	7.8-8.2	7.8-8.2

7.0 SEDIMENT CHEMISTRY RESULTS

7.1 PHYSICAL CHARACTERISTICS

Physical characteristics including water depth, TOC and percent fines were characterized at all reference and study stations. These parameters are important factors in characterizing the type of benthic habitat present at the sites. TOC and grain size are also important in regulating the binding of organic and inorganic contaminants within the sediment. Metal variation with grain size can also be useful in establishing non-anthropogenic background. Results for physical properties at reference, Chollas, and Paleta stations are summarized below.

7.1.1 Reference

Physical properties results including water depth, % fines, and TOC for the reference stations are shown in Table 7-1 and Table 7-2. The complete grain size fractionation data are included in Appendix A. Water depths at the reference stations ranged from 3.7 to 15.4 m with the shallowest water at CP2238 and the deepest water at station CP2441 (Figure 7-1). This range of depths is characteristic of the two dominant habitat types in San Diego Bay including shallow sub-tidal areas, and deep shipping channels. The fines fraction for the reference stations ranged from 26 to 83% with the lowest % fines at CP2440 and the highest at CP2441. This range of fines is consistent with the target range identified in the Sampling and Analysis Plan (SAP; Bay and Chadwick, 2001) of 24 to 84% based on the historical data from the Chollas and Paleta sites. The TOC fraction at the reference stations ranged from 0.5 to 1.8 % with the lowest TOC at CP2433 and the highest at CP2441. The range of TOC is somewhat narrower than the target range identified in the SAP of 0.3 to 3.5% based on the historical data from the Chollas and Paleta sites. TOC at the reference stations generally increased with increasing % fines following a similar trend to that observed at the Chollas and Paleta stations (Figure 7-2).

7.1.2 Chollas Site

Physical properties results for the Chollas stations are shown in Table 7-1 and Table 7-2. The complete grain size fractionation data are included in Appendix A. Water depths at the Chollas stations ranged from 2.4 to 10.8 m with the shallowest water at the inner creek area (C14), and the deepest water near the pier head at station C03. This range of depths is characteristic of the inner and outer creek areas and is consistent with the depth range at the reference stations (Figure 7-1). The fines fraction for the Chollas stations ranged from 9.2 to 79.7% with the lowest % fines at the inner/outer Creek boundary (C07) and the highest in the inner creek at C14. In general, the range of fines at the Chollas site is consistent with the range at the reference stations with the exception of three stations at the inner/outer creek boundary (C07, C08, C11) that had very low fines content. The TOC fraction at the Chollas stations ranged from 0.2 to 6.1 % with the lowest TOC at C07 and the highest at C14. In general, the range of TOC at the Chollas stations was comparable to the reference range with the exception of two inner creek stations (C13 and C14) that had TOC levels that exceed the highest levels found at reference stations. TOC at the Chollas stations generally increased with increasing % fines following a similar trend to that observed at the reference and Paleta stations, with the exception of stations C13 and C14 which were clearly enriched in TOC relative to their % fines (Figure 7-2).
The spatial distributions of TOC and fines for Chollas are shown in Figure 7-3 and Figure 7-4 respectively. There is a general decreasing gradient of TOC from the inner to outer creek area. There is also a decreasing gradient of percent fines out to the inner/outer boundary area where the gradient reverses with increasing percent fines with distance from shore. The three stations showing the lowest TOC and lowest percent fines group together just northwest of the

inner/outer creek boundary. In general, the observed distributions of TOC and fines in the inner creek area suggest a highly depositional regime for fine particles with enriched TOC associated with inputs from Chollas Creek. The low fines and TOC in the inner/outer creek boundary area are consistent with higher energy erosion and scour processes, or possibly a localized source of coarser materials. The fact that the shipyard tests ship engines for long periods of time along the adjacent pier could easily explain the lack of fines in the area. Conditions in the outer pier area are more consistent with general low energy depositional conditions along the eastern shore of San Diego Bay.

7.1.3 Paleta Site

Physical properties results for the Paleta stations are shown in Table 7-1 and Table 7-2. The complete grain size fractionation data are included in Appendix A. Water depths at the Paleta stations ranged from 6.9 to 12.7 m with the shallowest water at the inner creek area (P17), and the deepest water near the pier head at stations P01 and P03. This range of depths is characteristic of the inner and outer creek areas and is consistent with the depth range at the reference stations. Water depths at Paleta stations were generally somewhat deeper than those at the Chollas stations (Figure 7-1). The fines fraction for the Paleta stations ranged from 24.7 to 79.1% with the lowest % fines near the inner/outer Creek boundary (P13) and the highest in the mid-outer creek at P05. The range of fines at the Paleta site is consistent with the range at the reference stations. The TOC fraction at the Paleta stations ranged from 0.09 to 2.1 % with the lowest TOC at P09 and the highest at P16. In general, the range of TOC at the Paleta stations was comparable to the reference range with the exception of the P09 station that had somewhat lower TOC than the lowest reference station. TOC at the Paleta stations generally increased with increasing % fines following a similar trend to that observed at the reference and Chollas stations (Figure 7-2).

The spatial distributions of TOC and fines for Paleta are shown in Figure 7-5 and Figure 7-6 respectively. There is a general decrease in TOC from the inner creek area to the outer creek with pockets of low TOC at the inner/outer boundary and along the outer half of pier 8. The spatial trend in percent fines is somewhat the reverse that of TOC, with generally increasing fines from the inner to outer creek with pockets of low percent fines at the inner/outer boundary and along the outer half of pier 8. The observed distribution indicates an active erosion of fine-grained materials at the inner/outer boundary and along the outer half of pier 8.

Table 7-1. Sediment physical data for reference, Chollas, and Paleta stations.

Area	Station	Depth (m)	Fines (%)	TOC (%)	Station	Depth (m)	Fines (%)	TOC (%)
Ref	CP 2231	13.4	41.2	1.0	CP 2433	9.0	38.4	0.5
	CP 2238	3.7	69.0	1.0	CP 2440	10.8	26.4	1.0
	CP 2243	4.0	30.3	0.6	CP 2441	15.4	82.8	1.8
Chollas	C01	10.6	65.0	1.9	C08	7.4	10.9	0.3
	C02	10.5	61.4	1.6	C09	9.1	53.0	1.4
	C03	10.8	62.0	1.7	C10	10.2	53.7	1.5
	C04	10.1	43.2	1.2	C11	7.5	11.7	0.6
	C05	10.1	58.4	1.4	C12	6.4	33.8	1.2
	C06	9.4	63.6	1.8	C13	3.7	64.7	3.0
	C07	8.6	9.2	0.2	C14	2.4	79.7	6.1
Paleta	P01	12.7	31.7	0.4	P10	7.9	40.7	0.8
	P02	12.6	68.3	1.3	P11	8.9	45.0	1.1
	P03	12.7	38.4	0.9	P12	8.7	49.2	1.2
	P04	12.0	74.6	1.5	P13	8.3	24.8	0.6
	P05	9.6	78.8	1.6	P14	9.1	48.8	1.3
	P06	12.2	73.6	1.5	P15	8.7	56.0	1.5
	P07	11.5	79.1	1.6	P16	9.5	65.6	2.1
	P08	7.8	37.5	0.7	P17	6.9	55.7	2.0
	P09	8.3	31.6	0.1				

Table 7-2. Summary Statistics for sediment physical data.

Sum Stats	Reference	Chollas	Paleta
Depth (m)			
Minimum	3.7	2.4	6.9
Maximum	15.4	10.8	12.7
Mean	9.4	8.3	9.8
Std Dev	4.8	2.6	2.0
Fines (%)			
Minimum	26.4	9.2	9.2
Maximum	82.8	79.7	82.8
Mean	48.0	47.9	50.2
Std Dev	22.7	22.8	20.2
TOC (%)			
Minimum	0.5	0.2	0.1
Maximum	1.8	6.1	6.1
Mean	1.0	1.7	1.4
Std Dev	0.5	1.4	1.0

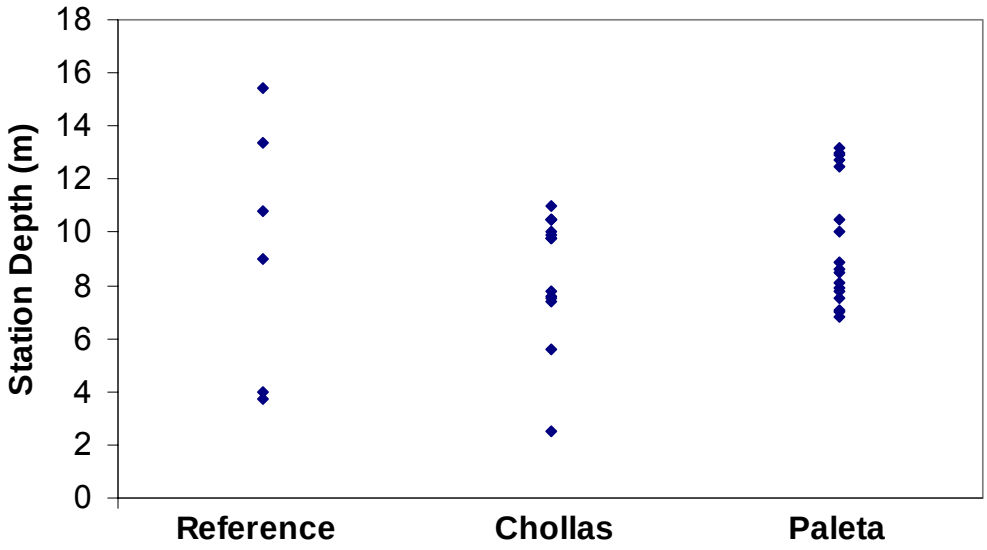


Figure 7-1. Water depths of stations in the study.

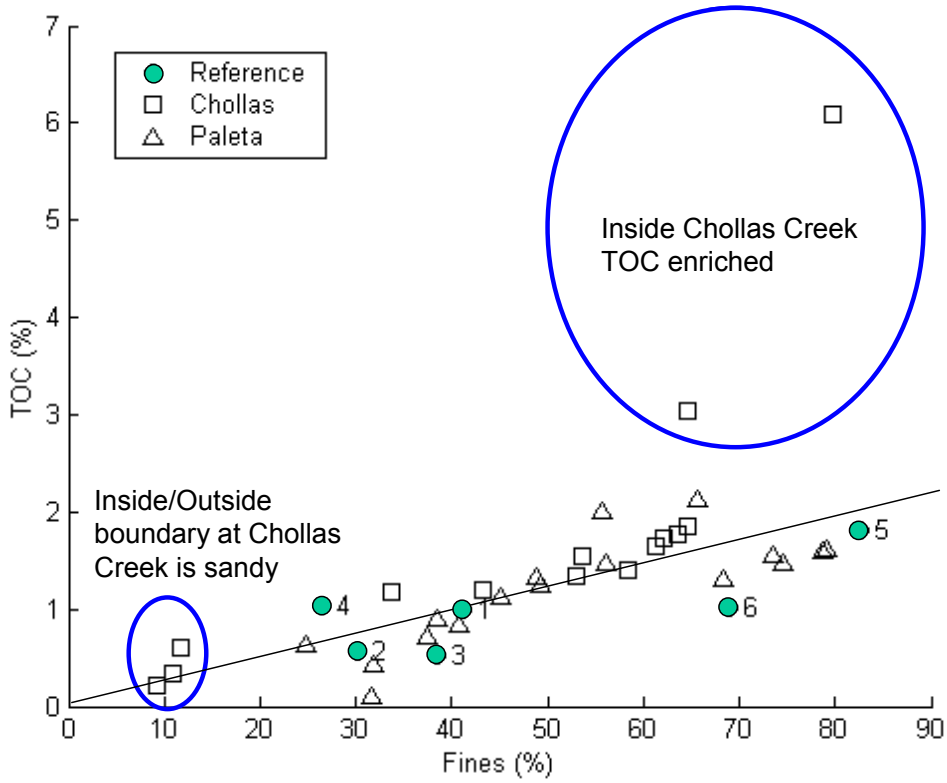


Figure 7-2. Plot of TOC and percent fines at all stations of the study.

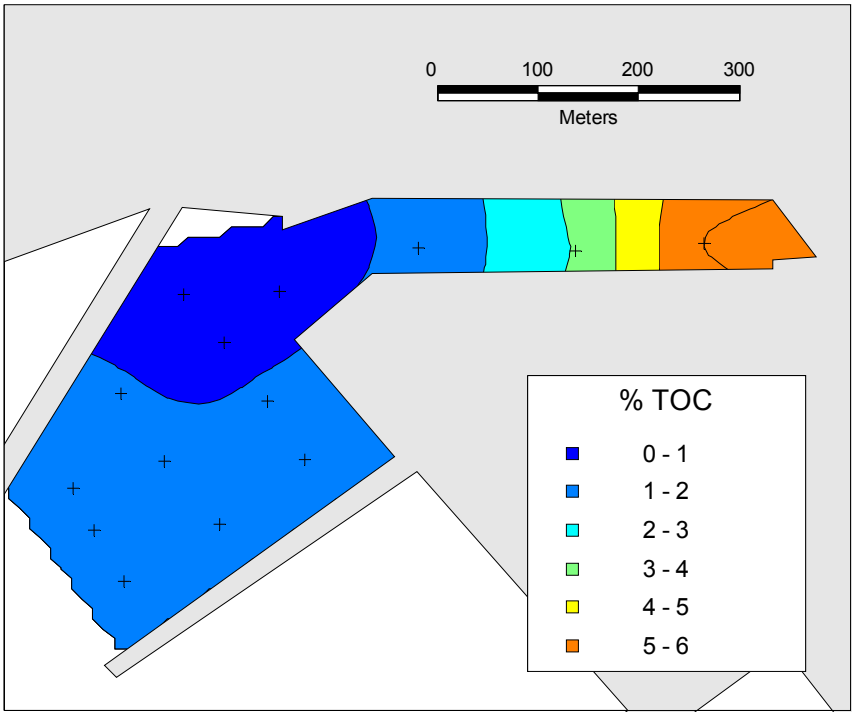


Figure 7-3. Spatial distribution of sediment TOC at the Chollas site.

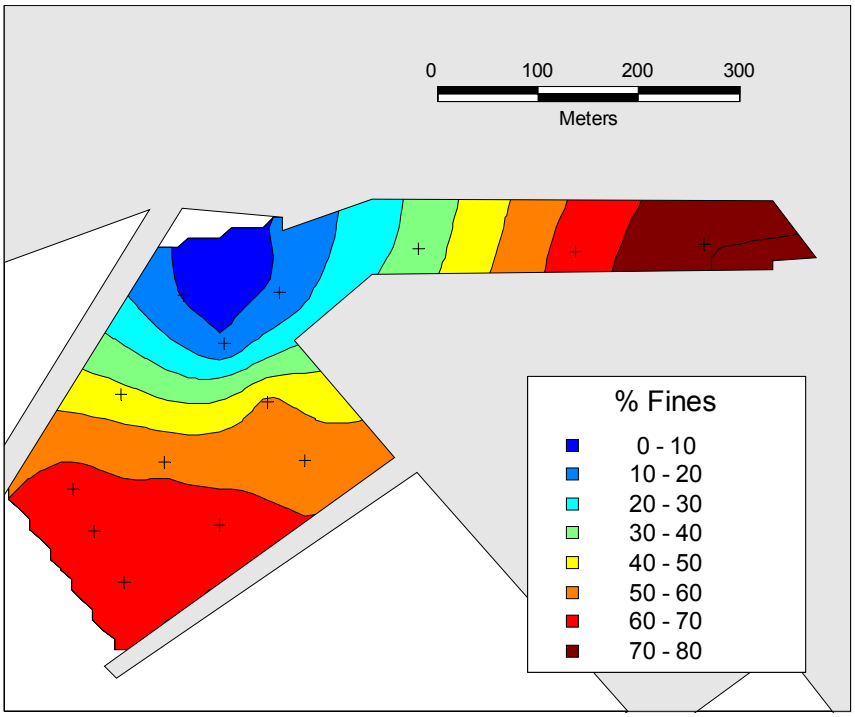


Figure 7-4. Spatial distribution of fines for the Chollas site.

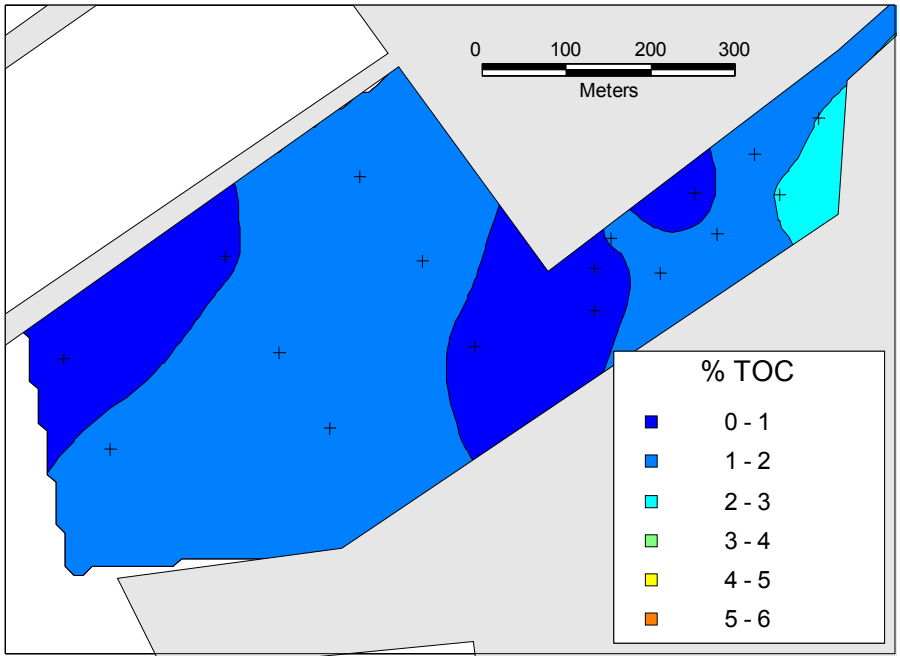


Figure 7-5. Spatial distribution of TOC at the Paleta site.

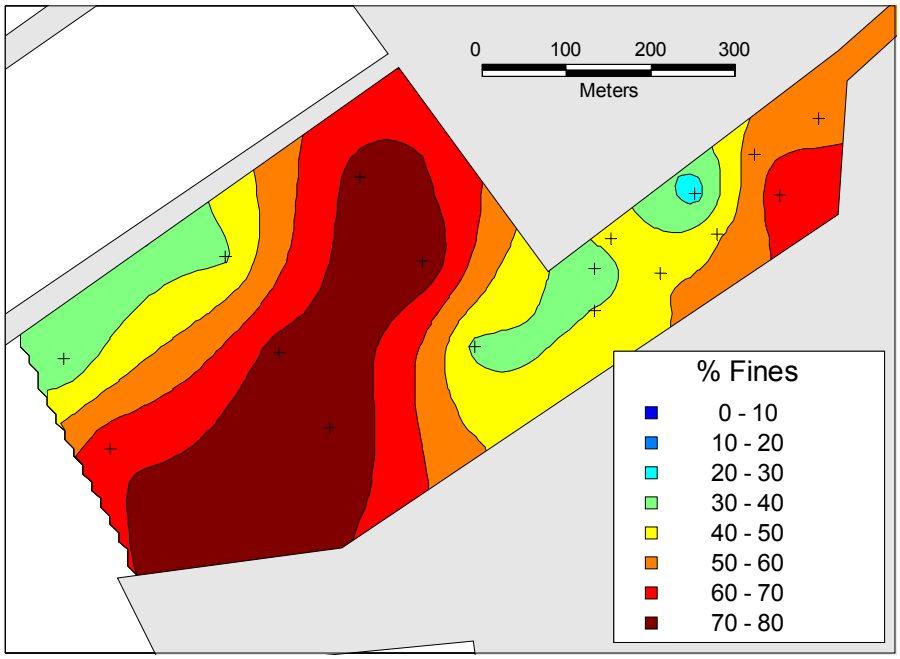


Figure 7-6. Spatial distribution of fines for the Paleta site.

7.2 METALS

Concentrations of total sediment metals including silver, arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc were characterized at all reference and study stations. Total metal concentrations include the influence of both anthropogenic and background (crustal) sources and provides one indicator of potential contaminant exposure for aquatic organisms. Results for sediment metals at reference, Chollas, and Paleta stations are summarized below. The data displayed (in μg/g dry weight) include only those metals that were identified as CoPCs in the historical review. The complete set of data can be found in Appendix A.

7.2.1 Reference

Metals results for the reference stations are shown in Table 7-3 and Table 7-4. Metal concentrations at the reference stations were generally low, and showed minimal variation from station to station. For example, chromium at the reference stations ranged from 38.1 to 59.2 mg/kg, with a relative standard deviation (RSD) of only 18%, and arsenic ranged from 4.65 to 8.82 μg/g with an RSD of only 24%. Cadmium and lead had somewhat higher variation with RSDs of 65% and 42%, respectively. Among the reference stations, CP2441 had the highest occurrence of maximum metal concentrations including arsenic, cadmium, copper and nickel, while station CP2440 had the highest occurrence of minimum metal concentrations including arsenic, chromium, nickel and zinc. However, no metals at any of the stations had maximum concentrations exceeding twice the mean. Comparative ranges for copper (16.6-179 μg/g) and zinc (49.4-226 μg/g) were established for reference stations in the SAP based on the range observed at historical SDRWQCB reference stations. These are consistent with the ranges for copper and zinc detected at the reference stations for this study of 43.3-78.4 μg/g and 114.5-214.3 μg/g respectively. None of the metal concentrations measured at the reference stations exceeded their respective ERM value.

7.2.2 Chollas Site

Metals results for the Chollas stations are shown in Table 7-3 and Table 7-4. Mean concentrations for several metals at the Chollas stations were considerably elevated above the reference mean including cadmium by a factor of 2.9, copper by a factor of 2.0, and lead by a factor of 2.2. Other metals had mean concentrations that were marginally higher than reference including silver, arsenic, nickel and zinc. Mean concentrations for chromium and mercury were comparable to mean concentrations at the reference stations. Variability of metal concentrations at the Chollas stations was generally higher than seen at the reference stations. For example, the RSD for chromium was 36%, about twice that for reference, although the RSD for arsenic was only 20%, about the same as reference. Among the Chollas stations, C03 had the highest occurrence of maximum metal concentrations including silver, chromium, mercury, nickel, lead and zinc, while station C07 had the highest occurrence of minimum metal concentrations including silver, cadmium, chromium, copper, mercury, and nickel. The low concentrations of metals at station C07 are consistent with the low fines and TOC present in this region. Relative to metal SQGs, there was only one exceedance of the copper ERM (C10) and only one exceedance of the zinc ERM (C03) at the Chollas stations. All other metal concentrations were below their respective ERM.

The spatial distribution for some representative metals at the Chollas site are shown in Figure 7-7–Figure 7-10. Spatial patterns of most metals appeared to be influenced both by the distribution of fines, as well as by localized sources. For example, the distribution of lead tends to follow the same pattern as for fines with higher levels in the inner creek, and lower levels at the inner/outer creek boundary (Figure 7-7), However, in the outer creek area, there is a

localized area near the end of Pier 1 where the lead concentration is elevated. Chromium, mercury, and nickel have similar distributions to that of lead, and all of these metals have relatively high, statistically significant correlations ($P<0.05$) with fines (Table 7-5). The distribution of cadmium is also similar to lead, but cadmium is more highly correlated with TOC than with fines. In contrast, the distributions of other metals appear to be primarily influenced by source patterns. For example, the distribution of arsenic is dominated by higher levels along the shipyard pier on the north side of the Chollas site (Figure 7-8), while the copper distribution shows highest levels along Pier 1 (Figure 7-9), and zinc has elevated levels both near the end of Pier 1 and in the inner creek area (Figure 7-10).

7.2.3 Paleta Site

Metals results for the Paleta stations are shown in Table 7-3 and Table 7-4. Mean concentrations for several metals at the Paleta stations were considerably higher than the reference mean including cadmium (factor or 2.0), copper (factor of 2.4) and lead (factor of 1.9). Other metals had mean concentrations that were marginally higher than reference including silver, mercury and zinc. Mean concentrations for arsenic, chromium and nickel were comparable to mean concentrations at the reference stations. Variability of metal concentrations at the Paleta stations was generally higher than seen at the reference stations. For example, the RSDs for cadmium (121%) and arsenic (47%) were about twice that for reference. Among the Paleta stations, P15 had the highest concentrations of cadmium, lead, and zinc, while stations P04-P07 generally had the highest levels of silver, chromium, copper and nickel. Lowest metal levels were consistently found in the region of low fines and TOC at stations P09 and P13. Relative to metal SQGs, there were only four exceedances of the mercury ERM (P5, P6, P7, and P11) at the Paleta stations. All other metal concentrations were below their respective ERMs.

The spatial distribution for some representative metals at the Paleta site are shown in Figure 7-11–Figure 7-13. Spatial patterns of most metals appeared to be highly influenced by the distribution of fines. Common characteristics of these distributions include a swath of higher concentrations running from near the end of the Mole Pier, northward to the base of Pier 7, with lower concentrations to the east and west, but an increasing gradient toward the very inner part of the creek. For example, the spatial pattern of copper is nearly identical to that of fines (Figure 7-11). Silver, arsenic, chromium, mercury, nickel and zinc have similar distributions, and all of these metals have relatively high, statistically significant correlations ($r>0.6$) with fines (Table 7-6). In contrast, the distributions of other metals appear to be primarily influenced by source patterns. For example, the distributions of lead and zinc are both dominated by higher levels in the inner creek area of the Paleta site (Figure 7-12-Figure 7-13).

Table 7-3. Sediment metals data (mg/kg) for reference, Chollas, and Paleta stations. Values highlighted in the table exceeded their respective ERM value.

Area	Station	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Reference	CP 2231	0.29	7.78	0.03	46.6	71.1	0.36	11.5	40.3	129
	CP 2243	0.65	5.94	0.14	40.2	56.4	0.33	10.2	30.7	125
	CP 2433	0.38	5.55	0.29	42.2	43.3	0.25	11.2	23.3	115
	CP 2440	0.39	4.65	0.31	38.1	44.4	0.26	8.7	63.8	115
	CP 2441	0.39	8.82	0.41	54.0	78.4	0.24	17.5	26.7	143
	CP 2238	0.51	7.8	0.13	59.2	71	0.26	16.5	28.8	214
Chollas	C01	0.70	11.8	0.43	56.0	139	0.42	17.5	77.3	235
	C02	0.72	9.4	0.42	52.7	130	0.53	16.1	73.7	212
	C03	0.96	11.4	1.30	101.0	155	0.54	38.5	148.0	418
	C04	0.50	14.9	0.40	44.6	97.4	0.27	13.2	67.7	270
	C05	0.63	8.9	0.51	52.3	108	0.40	15.9	73.3	207
	C06	0.74	10.1	0.40	57.9	141	0.43	17.3	78.4	233
	C07	0.17	10.9	0.29	22.5	47.9	0.10	6.7	43.1	225
	C08	0.23	9.3	0.32	26.6	68	0.13	8.1	41.3	204
	C09	0.70	9.1	0.45	50.3	119	0.38	15.5	65.4	206
	C10	0.81	9.6	0.38	51.9	314	0.43	15.3	72.3	217
	C11	0.47	13.1	1.07	39.9	104	0.22	13.1	96.1	273
	C12	0.42	6.8	0.50	39.7	78.5	0.21	10.8	57.6	166
	C13	0.46	8.9	0.96	48.2	103	0.22	16.2	87.2	248
	C14	0.46	9.4	1.37	51.6	94.9	0.24	22.8	103.0	347
Paleta	P01	0.57	6.7	0.14	42.4	80.2	0.38	13.7	33.7	162
	P02	0.81	10.2	0.17	78.0	170	0.63	19.2	55.2	261
	P03	0.47	6.8	0.01	45.8	98.1	0.35	13.4	36.1	165
	P04	0.90	10.0	0.07	82.5	203	0.65	20.1	64.1	274
	P05	1.08	10.9	0.10	87.0	227	0.71	21.0	72.8	294
	P06	1.13	11.3	0.18	83.1	247	0.72	20.8	68.3	287
	P07	1.15	11.3	0.13	83.4	237	0.76	21.2	73.0	288
	P08	0.71	6.0	0.09	57.7	106	0.44	14.6	42.4	184
	P09	0.06	2.8	0.01	40.2	22.1	0.07	11.7	11.3	89
	P10	0.38	5.4	0.35	71.5	105	0.30	12.3	44.4	242
	P11	0.85	6.5	1.39	72.2	127	1.08	18.4	116.0	304
	P12	0.54	5.9	0.20	61.5	134	0.34	13.9	52.3	180
	P13	0.38	4.2	0.17	33.9	71.9	0.25	10.3	40.7	174
	P14	0.72	6.6	0.57	58.9	138	0.46	15.6	67.2	246
	P15	0.89	7.9	1.59	72.3	157	0.61	18.6	159.1	374
	P16	0.84	7.6	0.89	67.8	181	0.56	18.8	91.4	314
	P17	0.85	19.8	1.27	57.0	157	0.60	18.0	102.8	370
SQG	ERM	3.7	70	9.6	370	270	0.71	51.6	218	410

Table 7-4. Summary Statistics for sediment metals data (mg/kg).

Area	Statistic	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Reference	Minimum	0.29	4.65	0.03	38.1	43.3	0.24	8.7	23.3	114.5
	Maximum	0.65	8.82	0.41	59.2	78.4	0.36	17.5	63.8	214.3
	Mean	0.43	6.76	0.22	46.7	60.8	0.28	12.6	35.6	140.1
	Std Dev	0.13	1.61	0.14	8.3	14.9	0.05	3.6	15.0	37.8
	RSD (%)	29%	24%	65%	18%	25%	18%	28%	42%	27%
Chollas	Minimum	0.17	6.83	0.29	22.5	47.9	0.10	6.7	41.3	166.0
	Maximum	0.96	14.90	1.37	101.0	314.0	0.54	38.5	148.0	418.0
	Mean	0.57	10.26	0.63	49.7	121.4	0.32	16.2	77.5	247.2
	Std Dev	0.22	2.03	0.38	18.1	62.8	0.14	7.6	26.7	65.1
	RSD (%)	39%	20%	60%	36%	52%	44%	47%	34%	26%
Paleta	Minimum	0.06	2.82	0.01	33.9	22.1	0.07	10.3	11.3	89.3
	Maximum	1.15	19.77	1.59	87.0	247.0	1.08	21.2	159.1	373.6
	Mean	0.73	8.22	0.43	64.4	144.8	0.52	16.6	66.5	247.5
	Std Dev	0.29	3.88	0.52	16.6	62.1	0.24	3.6	35.5	78.1
	RSD (%)	41%	47%	121%	26%	43%	45%	22%	53%	32%

Table 7-5. Correlation matrix for the Chollas site physical properties and metals. Values are the correlation coefficient. Grayed out values are statistically significant at P<0.05.

	Depth	Fines	TOC	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Depth	1.00	-0.05	**-0.63**	**0.54**	0.36	-0.51	0.31	0.39	**0.62**	0.11	-0.03	-0.11
Fines		1.00	**0.74**	**0.67**	-0.18	0.33	**0.65**	0.39	**0.66**	**0.63**	0.52	0.33
TOC			1.00	0.14	-0.20	**0.63**	0.29	0.06	0.09	0.44	0.46	0.47
Ag				1.00	0.06	0.18	**0.86**	**0.71**	**0.96**	**0.73**	**0.63**	0.34
As					1.00	0.08	0.10	-0.01	0.02	0.11	0.23	0.43
Cd						1.00	0.51	-0.05	0.05	**0.69**	**0.85**	**0.82**
Cr							1.00	0.43	**0.80**	**0.96**	**0.87**	**0.69**
Cu								1.00	**0.61**	0.31	0.27	0.07
Hg									1.00	**0.65**	0.52	0.24
Ni										1.00	**0.93**	**0.83**
Pb											1.00	**0.87**
Zn												1.00

Table 7-6. Correlation matrix for the Paleta site physical properties and metals. Values are the correlation coefficient. Grayed out values are statistically significant at P<0.05.

	Depth	Fines	TOC	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Depth	1.00	0.36	0.02	0.30	0.07	-0.45	0.24	0.35	0.21	0.34	-0.21	-0.10
Fines		1.00	**0.79**	**0.85**	**0.62**	0.04	**0.89**	**0.95**	**0.65**	**0.93**	0.41	**0.66**
TOC			1.00	**0.78**	**0.73**	0.45	**0.66**	**0.82**	**0.62**	**0.78**	**0.67**	**0.86**
Ag				1.00	**0.66**	0.26	**0.80**	**0.93**	**0.85**	**0.94**	**0.61**	**0.78**
As					1.00	0.29	0.44	**0.64**	**0.51**	**0.66**	0.43	**0.70**
Cd						1.00	0.13	0.08	0.46	0.26	**0.88**	**0.71**
Cr							1.00	**0.88**	**0.73**	**0.87**	**0.48**	**0.68**
Cu								1.00	**0.71**	**0.92**	0.47	**0.71**
Hg									1.00	**0.84**	**0.68**	**0.75**
Ni										1.00	**0.60**	**0.77**
Pb											1.00	**0.89**
Zn												1.00

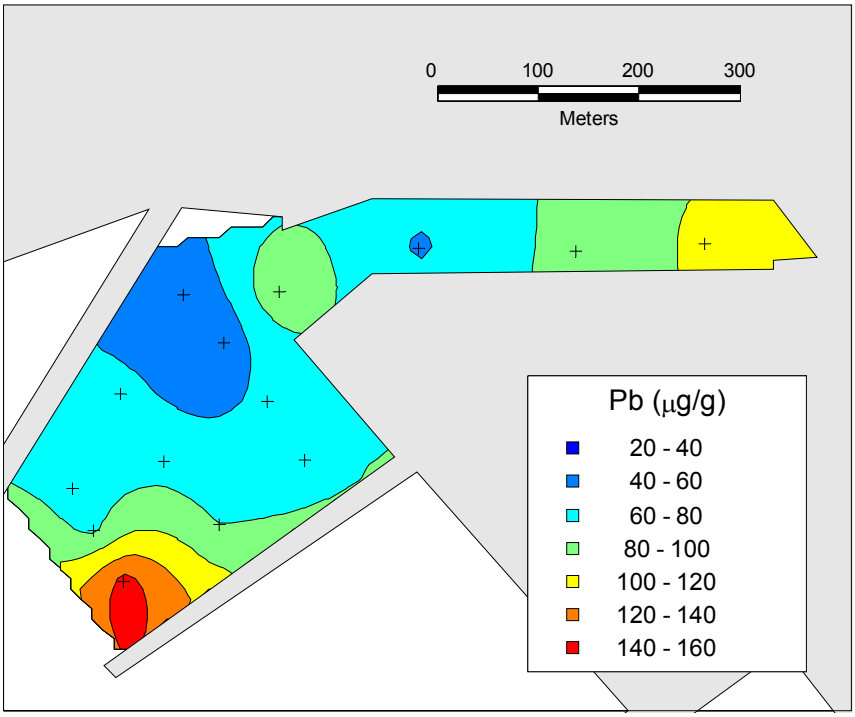


Figure 7-7. Spatial distribution of lead at the Chollas site.

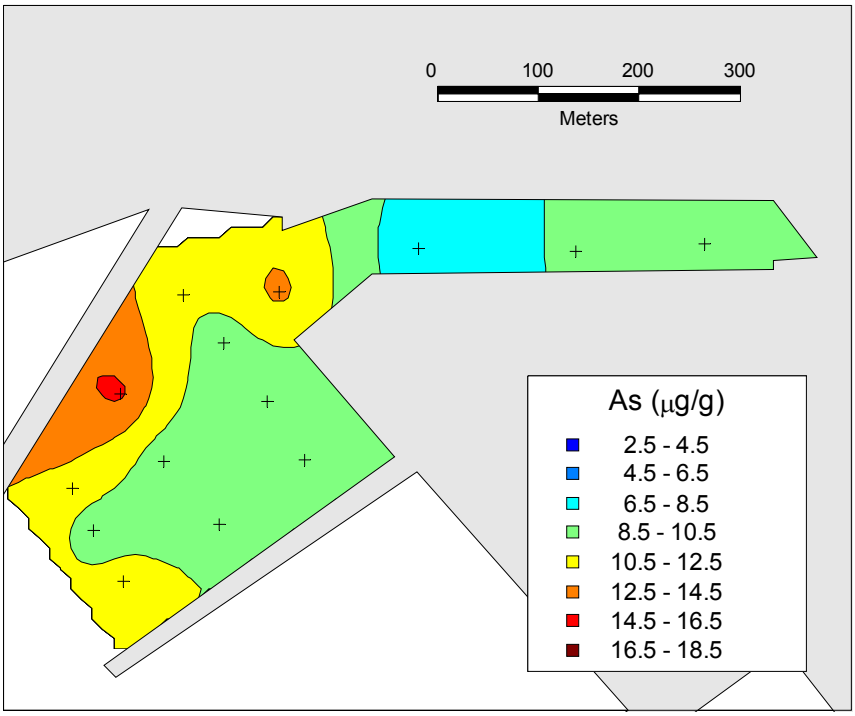


Figure 7-8. Spatial distribution of arsenic at the Chollas site.

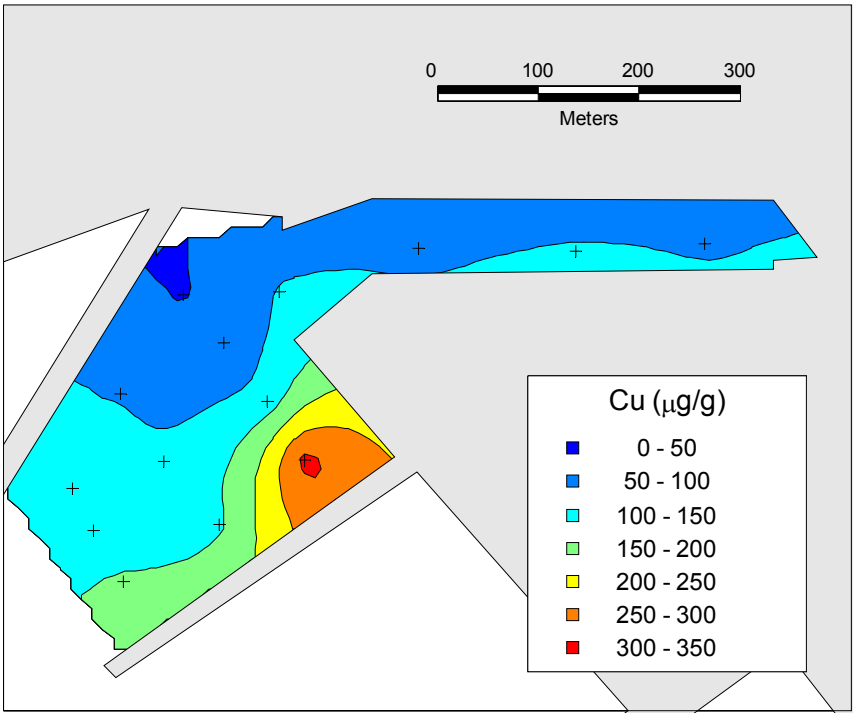


Figure 7-9. Spatial distribution of copper at the Chollas site.

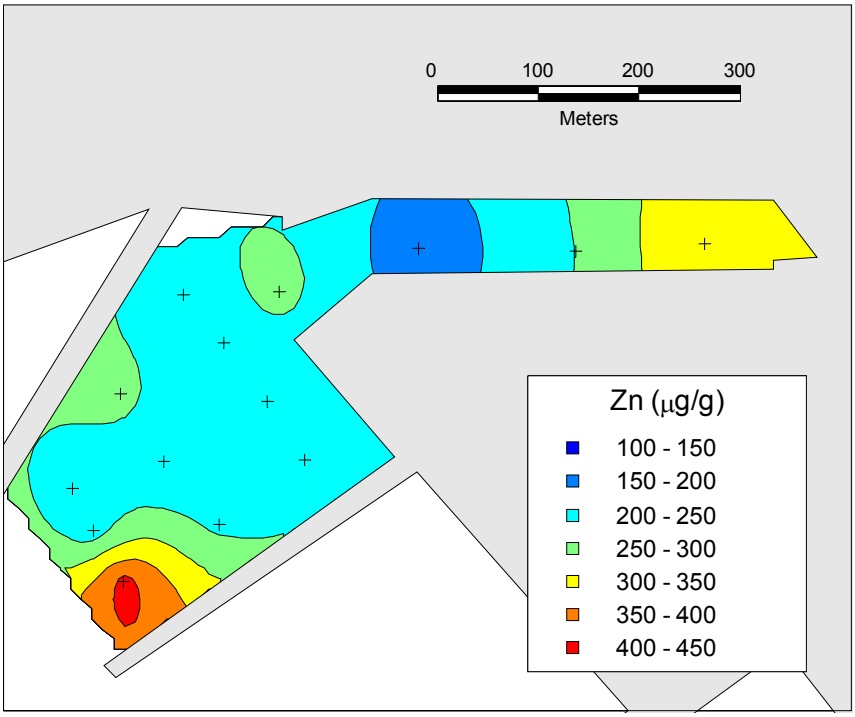


Figure 7-10. Spatial distribution of zinc at the Chollas Creek site.

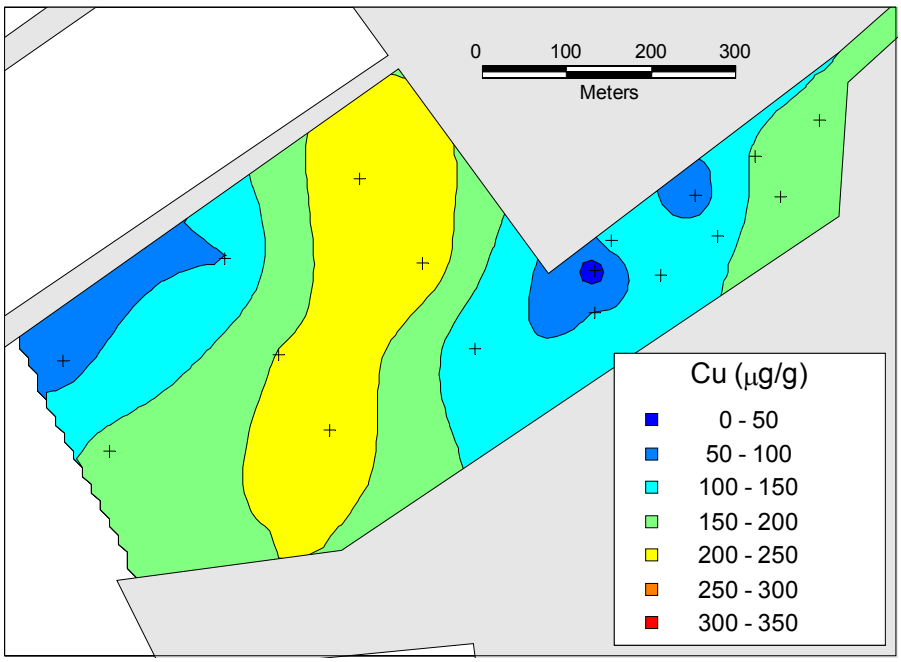


Figure 7-11. Spatial distribution of copper at the Paleta site.

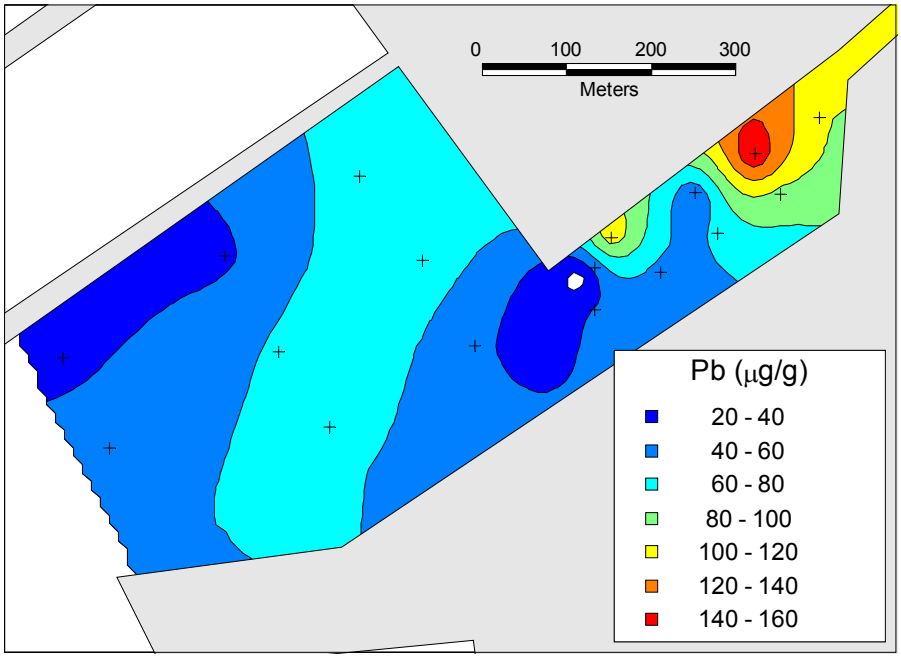


Figure 7-12. Spatial distribution of lead at the Paleta site.

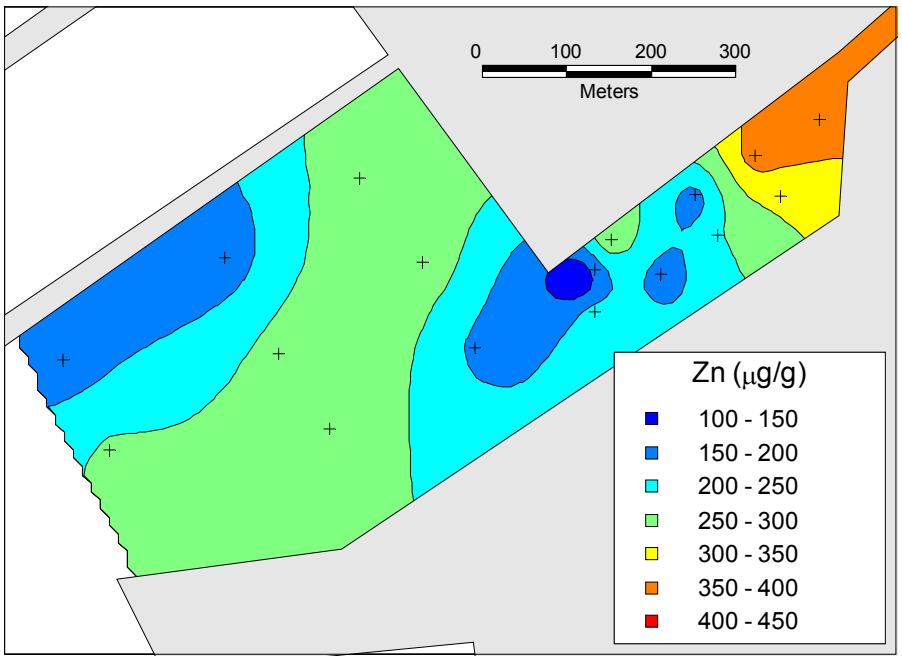


Figure 7-13. Spatial distribution of zinc at the Paleta site.

7.3 PAH

The concentration of 41 individual PAH analytes was measured at all reference and study stations. The analytes measured include the 16 PAH on the EPA's priority pollutant list: naphthalene^{L}, acenaphthylene^{L}, acenaphthene^{L}, fluorene^{L}, anthracene^{L}, phenanthrene^{L}, fluoranthene^{H}, pyrene^{H}, benz(a)anthracene^{H}, chrysene^{H}, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene^{H}, indeno(123-cd)pyrene, dibenz(ah)anthracene^{H}, benzo(ghi)perylene. The additional 25 PAH analytes are measured because they can, in some instances, be used to differentiate hydrocarbon sources. The first six compounds along with 2-methyl naphthalene are commonly grouped together and categorized as low molecular weight PAH (designated by ^{L} above) while six of the remaining ten analytes are commonly grouped together and categorized as high molecular weight hydrocarbons (designated by ^{H} above). The LMWPAH commonly degrade relatively quickly and have a higher acute toxicity while the HMWPAH are typically recalcitrant and have a higher carcinogenicity. Results for the PPPAH, LMWPAH, and HMWPAH are summarized below in Table 7-7 and Table 7-8. All PAH data are provided in Appendix A. Results are reported in μg/kg dry weight.

7.3.1 Reference

Sediment PPPAH concentrations ranged from about 200 to 5400 μg/kg and averaged 1640 μg/kg. The LMWPAH make up only about 10 to 20% of the total PAH at these stations with the HMWPAH making up roughly 50% of the total. The concentrations of PAH found at the reference stations correspond to changing TOC levels with the highest PAH and TOC found at CP2440. This reference station had some of the highest metals as well. The relatively large range in concentrations at the six stations results in station-to-station variability of >120% as measured by a RSD. The LMWPAH had a slightly higher variability, which is consistent with its more reactive nature. While the range in concentrations was reasonably large, there were no

exceedances of the consensus-based organic carbon normalized SQG (CBSQG) value of 1800 μg/g OC.

7.3.2 Chollas Site

Sediment PPPAH data for the Chollas stations ranged from 1350 to 49,000 μg/kg and averaged 8750 μg/kg. The mean concentration for the site exceeded that of the reference stations by a factor of 5. Only three Chollas stations had PPPAH concentrations lower than the mean for the reference stations (C07, C08 and C11). These stations are located just outside the inner/outer creek boundary. The highest concentrations were found at stations C12 and C13 within the inner creek area. Similar to the reference sites, the LMWPAH were typically about 10 to 20% of the total PAH and the HMWPAH were about 50%. The two highest stations however, had a higher percentage of the HMWPAH (~70%). While the range in concentrations is reasonably large, there was only a single station (C12) where there was an exceedance of the CBSQG value of 1800 μg/g OC.

The mean relative distribution of PAH analytes (individual PAH/total PAH) in the samples was relatively similar to that of the reference stations. The distribution fingerprint (Figure 7-14) indicates a fairly ubiquitous pyrogenic source at both site and reference stations. The pyrogenic source is identified by the nearly exponential decrease of methylated PAH relative to their parent compound (e.g., chrysene through C4-chrysene). A slight variation occurs in the general pattern between inner and outer creek stations with the inner creek stations having a higher relative amount of the LMWPAH suggesting a slightly fresher source (Figure 7-15).

The general level and distribution of PAH at the Chollas site correlate reasonably well with percent fines and TOC (Figure 7-16). However, the inner creek stations (C12, C13 and C14) and station C09 do not follow this trend, having data that fall well off this general relationship. Stations C09, C12, and C13 show much greater PAH than would be predicted from the TOC while station C14 shows about half the amount of PAH than would be predicted by its extremely high TOC level. The higher TOC level at C14 likely results from a large amount of terrestrial organic debris such as plant material that is preferentially deposited close to the creek mouth during storms. The elevated PAH relative to TOC at the other three sites suggest an additional, yet unknown source(s) of PAH. While most Chollas stations follow a TOC trend, the overall correlation with TOC was not significant (Table 7-9).

The spatial distribution of PPPAH in the Chollas site is shown in Figure 7-17. The distribution shows a maximum near the inner/outer boundary (Station CP12) with decreasing concentrations away from this site. The distribution suggests a localized source of PAH on top of a general trend of decreasing concentrations from the inner creek. The lowest concentrations (CP7, 8, and 11) were found along the shipyard pier bounding the area on the north associated with low fines and TOC as described earlier.

Table 7-7. Sediment organics data for reference, Chollas, and Paleta stations. Data are included for PAHs, PCBs, Chlordanes and DDTs. Also included are the values calculated values for each station for comparison to CBSQGs. Values highlighted in the table exceeded their respective SQG value.

Station	LMWPAH µg/kg	HMWPAH µg/kg	PPPAH µg/kg	CBSQG-PAH µg/g OC	Total PCB µg/kg	CBSQG-PCB µ/kg	TCHLOR µg/kg	TDDT µg/kg	CBSQG-DDT µg/g OC
CP 2231	86	536	1063	84	43	28	0.9	10.8	1.08
CP 2238	17	103	199	15	11	7	0.2	1.3	0.13
CP 2243	20	118	267	35	21	13	0.2	1.5	0.28
CP 2433	56	415	780	122	27	17	0.6	2.1	0.40
CP 2440	1052	3049	5387	423	283	173	16.2	21.6	2.20
CP 2441	236	1210	2143	105	34	20	0.8	3.8	0.21
C01	326	2184	4433	196	190	115	29.0	28.8	1.56
C02	341	2050	4448	220	422	277	31.0	44.4	2.71
C03	623	2660	6016	286	320	200	37.0	39.0	2.25
C04	266	1787	3467	244	145	86	20.9	22.0	1.85
C05	298	1913	3895	227	234	136	36.0	33.5	2.39
C06	367	2306	4656	215	190	112	29.0	30.3	1.70
C07	130	772	1354	535	60	34	4.6	5.1	2.30
C08	116	775	1405	348	53	31	7.9	7.9	2.30
C09	3048	6020	11722	791	154	87	20.3	22.8	1.69
C10	332	2560	5155	276	202	121	21.7	24.5	1.59
C11	120	1013	1647	238	74	42	10.4	9.6	1.58
C12	7475	36060	49378	4078	167	80	30.0	33.4	2.85
C13	2007	11600	16657	511	255	128	89.0	78.4	2.58
C14	1212	5194	8256	121	212	94	119.0	122.8	2.02
P01	108	432	1165	219	40	26	0.6	4.9	1.17
P02	258	1504	3428	212	79	52	1.8	4.8	0.37
P03	177	808	1872	163	51	33	1.2	3.3	0.37
P04	311	1329	3166	168	101	67	3.7	7.3	0.49
P05	464	2170	4916	246	751	463	3.9	25.5	1.60
P06	428	2110	5024	257	122	77	2.8	10.0	0.65
P07	401	1870	4527	223	114	71	4.2	12.3	0.77
P08	342	2870	5040	627	80	49	3.2	8.1	1.15
P09	24	108	230	212	10	6	0.3	2.0	2.19
P10	196	1326	2469	249	72	43	5.8	8.7	1.05
P11	417	5540	8396	660	369	220	21.5	54.3	4.85
P12	444	3470	5945	414	129	78	9.8	17.9	1.44
P13	99	645	1248	167	53	32	3.2	6.3	1.02
P14	514	2810	5025	331	196	120	16.6	28.6	2.17
P15	400	5440	8817	521	374	225	34.0	51.2	3.48
P16	539	3940	7027	285	192	115	22.1	45.8	2.17
P17	556	4440	7434	326	189	108	14.2	63.9	3.19
				1800		400	4.8		100

Table 7-8. Summary statistics for sediment organics data including PAHs, PCBs, Chlordanes, and DDTs (μg/kg).

Area	Statistic	LMWPAH	HMWPAH	PPPAH	Total PCB	TCHLOR	TDDT
Reference	Minimum	17	103	199	12	0.2	1
	Maximum	1052	3049	5387	283	0.9	11
	Mean	245	905	1640	70	0.6	4
	Std Dev	404	1125	1966	105	0.3	4
	RSD (%)	165%	124%	120%	150%	55%	89%
Chollas	Minimum	116	772	1354	53	5	5
	Maximum	7475	36060	49378	422	119	123
	Mean	1190	5492	8749	191	35	36
	Std Dev	1998	9252	12426	100	32	31
	RSD (%)	168%	168%	142%	52%	91%	86%
Paleta	Minimum	24	108	230	10	0	2
	Maximum	556	5540	8817	751	34	64
	Mean	334	2401	4455	172	9	21
	Std Dev	164	1685	2571	182	10	20
	RSD (%)	49%	70%	58%	106%	110%	98%

Table 7-9. Correlation matrix for Chollas site physical properties and organic contaminants.

	Depth	Fines	TOC	LMWPAH	HMWPAH	PPPAH	TPCB	TCHLOR	TDDT
Depth	1.00	-0.05	-0.63	-0.35	-0.39	-0.36	0.18	-0.73	-0.69
Fines		1.00	0.74	0.00	-0.02	0.03	0.74	0.69	0.71
TOC			1.00	0.06	0.07	0.08	0.38	0.95	0.97
LMWPAH				1.00	0.97	0.98	-0.01	0.14	0.14
HMWPAH					1.00	1.00	0.02	0.17	0.17
PPPAH						1.00	0.05	0.18	0.18
TPCB							1.00	0.40	0.47
TCHLOR								1.00	0.99
TDDT									1.00

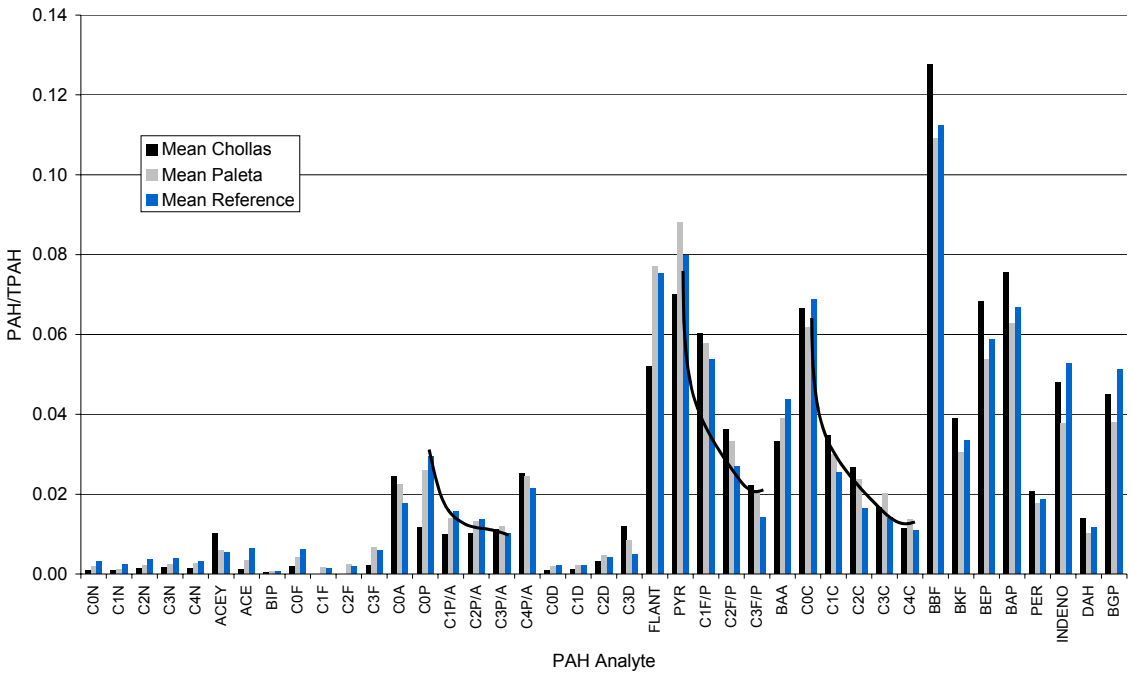


Figure 7-14. Mean relative PAH distribution for Chollas, Paleta, and reference stations. Analyte identifiers were identified in Table 5-6.

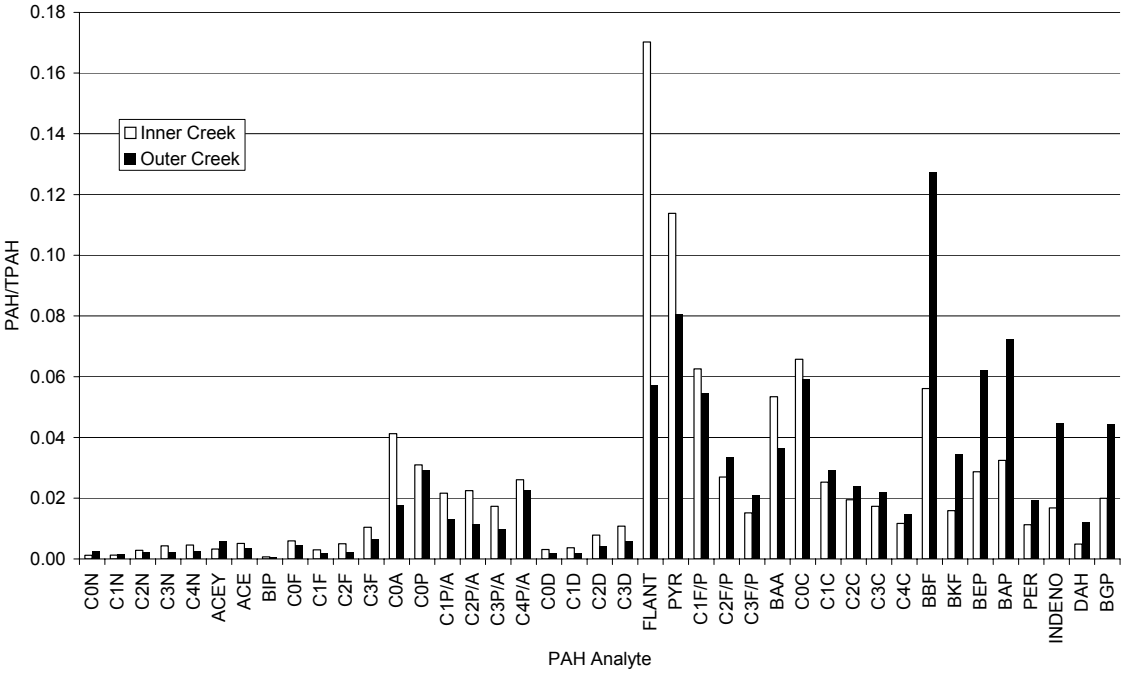


Figure 7-15. Mean relative PAH distribution for inner and outer Chollas Sites. Analyte identifiers were identified in Table 5-6.

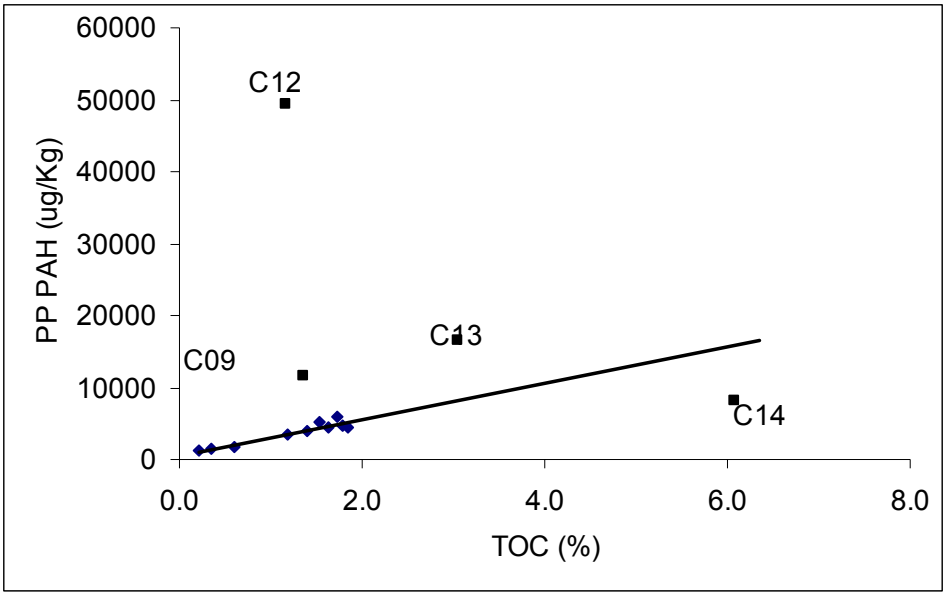


Figure 7-16. PPPAH as a function of TOC for Chollas stations.

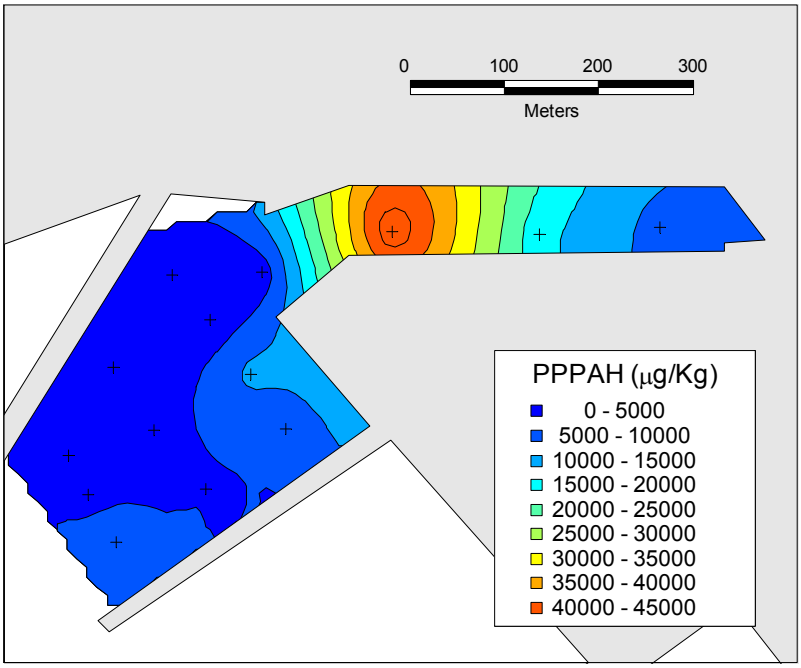


Figure 7-17. Spatial distribution of PPPAH at the Chollas site.

7.3.3 Paleta Site

Sediment PPPAH data for the Paleta stations ranged from 230 to 8800 μg/kg and averaged 4450 μg/kg (Table 7-8). The mean concentration for the site exceeded that of the reference stations by a factor of 3 but was only about half that for the Chollas site. Only three stations had PPPAH concentrations lower than the mean for the reference stations (P01, P09 and P13). These stations are located in areas of lower fines described earlier. The highest concentrations were found at stations in the innermost creek area (P15, P16, and P17) and at station P11 near the inner/outer boundary. Similar to the reference and Chollas stations, the LMWPAH were typically about 10% of the total PAH and the HMWPAH were about 50%. There were no stations where the CBSQG value of 1800 μg/g OC was exceeded.

The relative distribution of PAH analytes (individual PAH/total PAH) in the samples was relatively similar to that seen for both the reference and Chollas stations. The distribution fingerprint (Figure 7-14), like that observed for Chollas and reference stations indicates a pyrogenic source. Like the Chollas site, there is a slight variation in the general pattern between inner and outer creek stations (Figure 7-18) with the inner creek stations having a slightly lower relative amount of the highest and recalcitrant PAH, suggesting a slightly fresher source.

The general level and distribution of PAH in the Paleta site correlate well with TOC (Figure 7-19). As shown in Table 7-10, this correlation is statistically significant. The distribution of PAHs at the inner stations of the Paleta site were approximately two times higher than at outer creek stations suggesting a possible source from the watershed/creek drainage. The spatial distribution of PPPAH in the Paleta site is shown in Figure 7-20. Average PPPAH concentrations in the inner creek area are double those of the outer creek, consistent with a source from the watershed/creek drainage. The better correlation observed here versus that observed at the Chollas site likely results from there being a single creek source of PAH.

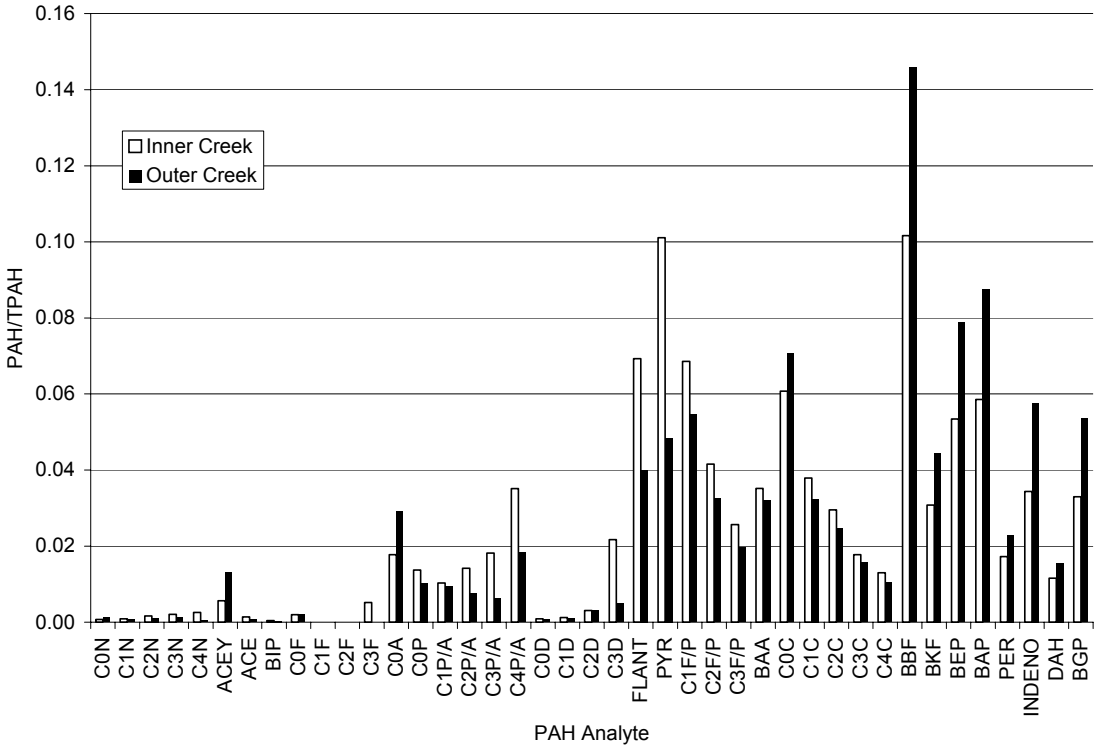


Figure 7-18. Mean relative PAH distribution for inner and outer Paleta Sites. Analyte identifiers were identified in Table 5-6.

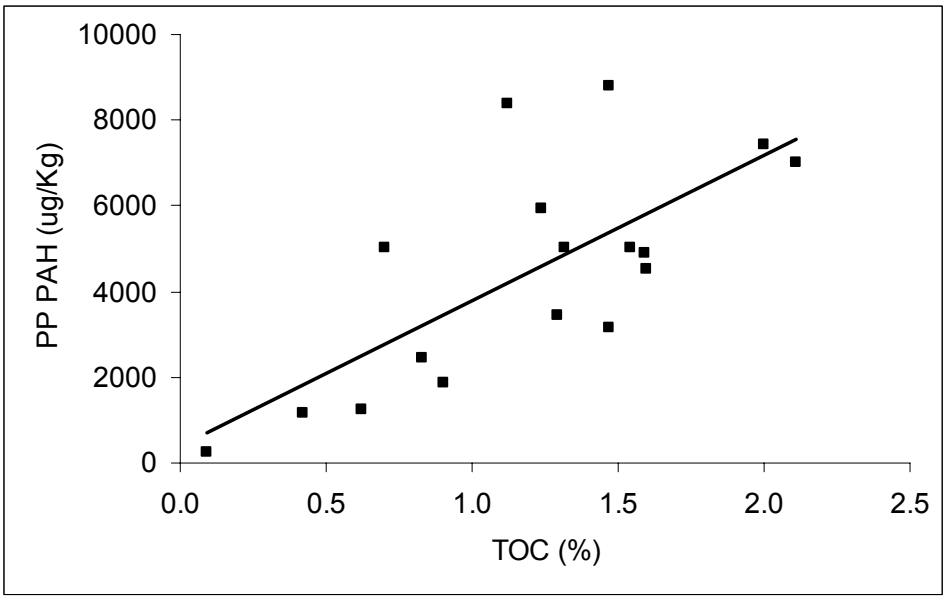


Figure 7-19. PPPAH as a function of TOC for Paleta stations.

Table 7-10. Correlation matrix for Paleta site physical properties and organic contaminants.

	Depth	Fines	TOC	LMWPAH	HMWPAH	PPPAH	TPCB	TCHLOR	TDDT
Depth	1.00	0.36	0.02	-0.21	-0.44	-0.34	-0.19	-0.41	-0.48
Fines		1.00	0.79	0.62	0.23	0.41	0.44	0.10	0.19
TOC			1.00	0.88	0.59	0.72	0.44	0.48	0.62
LMWPAH				1.00	0.77	0.86	0.53	0.58	0.71
HMWPAH					1.00	0.98	0.50	0.87	0.90
PPPAH						1.00	0.55	0.82	0.86
TPCB							1.00	0.42	0.54
TCHLOR								1.00	0.85
TDDT									1.00

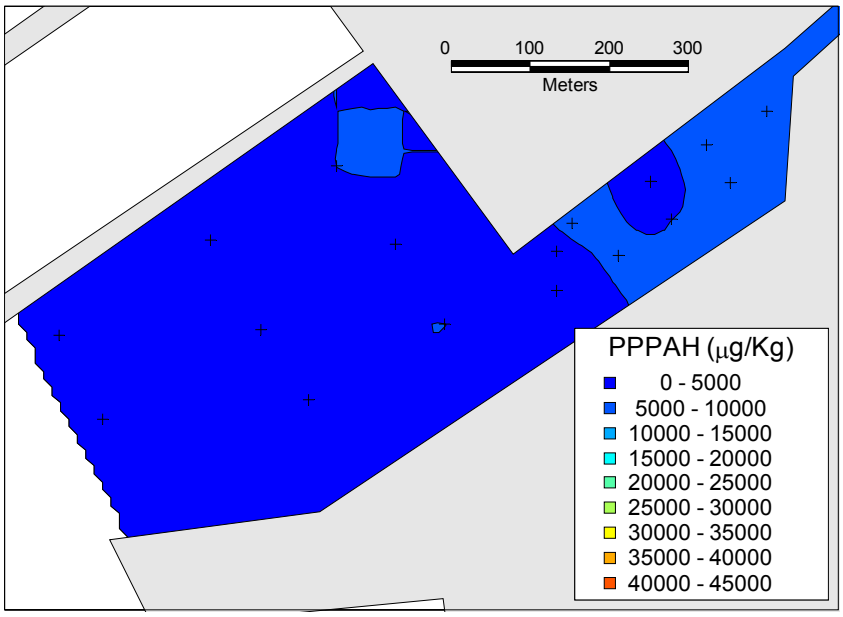


Figure 7-20. Spatial distribution of PPPAH at the Paleta site.

7.4 PCB

Concentrations of PCBs were characterized on the basis of 41 individual congeners at all reference and study stations. Total PCB concentrations were determined as the sum of all individual congeners. PCB concentrations in sediment provide one indicator of potential contaminant exposure for aquatic organisms. Results for sediment PCBs at reference, Chollas, and Paleta stations are summarized below. The data displayed include only the results for total PCBs, however the complete set of data for all individual congeners can be found in Appendix A.

7.4.1 Reference

PCB results for the reference stations are shown in Table 7-7and Table 7-8. PCB concentrations at the reference stations were generally low, and showed minimal variation from station to station, with the exception of station CP2440. Total PCBs at the reference stations (excepting CP2440) ranged from 12 to 43 μg/kg, while CP2440 had a concentration of 283 μg/kg. The mean total PCB concentration (70 μg/kg) and the RSD (150%) were skewed high because of the high concentration at CP2440. Excluding station CP2440 gives a reference mean concentration of 28 μg/kg with an RSD of only 44%. No comparative ranges for PCBs were established for reference stations in the SAP, however, the range of PCBs at the reference stations in this study (including CP2440) was comparable to the range reported at BPTCP reference stations (23-188 μg/kg; mean 72 μg/kg). None of the reference stations exceeded the CBSQG value of 400 μg/kg.

7.4.2 Chollas Site

PCB results for the Chollas stations are shown in Table 7-7and Table 7-8. Mean concentrations for PCBs at the Chollas stations were significantly higher than the reference mean (2.7X). Variability of PCB concentrations at the Chollas stations was lower than seen at the reference stations including CP2440, but comparable to the reference stations excluding CP2440. Among the Chollas stations, C02 had the highest PCB concentration, while the lowest concentration was found at station C08. The low concentrations of PCBs at station C08 are consistent with the low fines and TOC present in this region. None of the Chollas stations exceeded the CBSQG value of 400 μg/kg.

The spatial distribution of PCBs at the Chollas site is shown in Figure 7-21. The spatial pattern appeared to be influenced both by the distribution of fines and TOC, as well as by a creek source and a localized but unknown source out toward the end of the piers. The distribution tended to follow the same pattern as for fines and TOC, with higher levels in the inner creek, and lower levels at the inner/outer creek boundary (Figure 7-7). However, in the outer creek area, there was an area extending across the pier ends, and along the north side of Pier 1 where PCB concentrations were elevated. PCBs had a significant positive correlation with fines at the Chollas stations (Table 7-9), but the correlation with TOC was weak. PCBs were not significantly correlated with any of the other measured organic contaminants.

7.4.3 Paleta Site

PCB results for the Paleta stations are shown in Table 7-7 and Table 7-8. Mean concentrations for PCBs at the Paleta stations were significantly higher than the reference mean (2.5X), but

comparable to the Chollas station mean. Variability of PCB concentrations at the Paleta stations was lower than seen at the reference stations including CP2440, but higher than the reference stations excluding CP2440. Among the Paleta stations, P05 had the highest PCB concentration, while the lowest concentration was found at station P09. The low concentrations of PCBs at station P09 are consistent with the low fines and TOC present in this region. Only Paleta Station P5 had PCB levels that exceeded the CBSQG value of 400 μg/kg .

The spatial distribution of PCBs at the Paleta site is shown in Figure 7-22. The spatial pattern appeared to be patchy and influenced primarily by localized sources both in the inner and outer creek areas. In the outer creek area, there is an area near the mole pier where a single high concentration was observed, however the remainder of the outer creek area was more uniform. In the inner creek, two isolated areas of elevated concentrations were observed off along the northern shore. PCBs at the Paleta stations were not significantly correlated with TOC or fines (Table 7-10). However, PCBs were significantly correlated with LMWPAH, HMWPAH, and PPPAH.

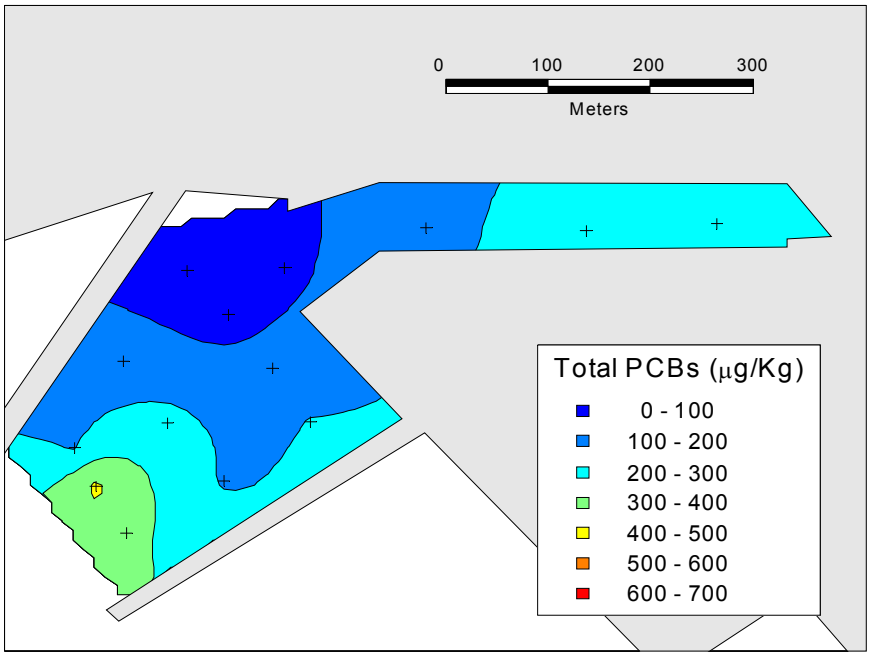


Figure 7-21. Spatial distribution of PCBs at the Chollas site.

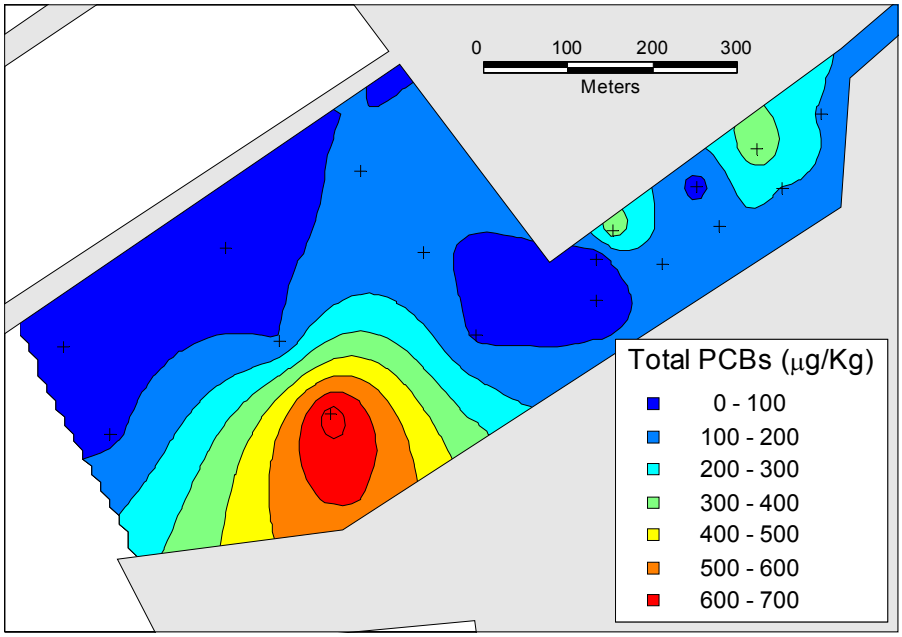


Figure 7-22. Spatial distribution of PCBs at the Paleta site.

7.5 PESTICIDES

Concentrations of pesticides were characterized for γ-Chlordane, α-Chlordane, 2,4'-DDE, 4,4'-DDE, 2,4'-DDD, 4,4'-DDD, 2,4'-DDT, and 4,4'-DDT. Total Chlordane (TCHLOR) was determined as the sum of γ-Chlordane and α-Chlordane. Total DDT (TDDT) was determined as the sum of all DDE, DDD, and DDT isomers. Pesticide concentrations in sediment provide one indicator of potential contaminant exposure for aquatic organisms. Results for sediment pesticides at reference, Chollas, and Paleta stations are summarized below. The data displayed include only the results for total Chlordane and total DDT, however the complete set of data for all individual congeners can be found in Appendix A.

7.5.1 Reference

Pesticide results for the reference stations are shown in Table 7-3 and Table 7-4. TCHLOR concentrations at the reference stations were generally low, and showed minimal variation from station to station. TCHLOR at the reference stations ranged from 0.18 to 0.91 μg/kg. The mean TCHLOR concentration was 0.6 μg/kg and the low variability at the reference stations was reflected in the RSD (55%). TDDT concentrations at the reference stations were somewhat higher and more variable than TCHLOR. TDDT ranged from 1.3 to 11 μg/kg. Station CP2231 was somewhat higher than other reference stations for TDDT (11 μg/kg). No comparative ranges for pesticides were established for reference stations in the SAP, however, the range of TCHLOR and TDDT at the reference stations in this study was comparable to the range reported at BPTCP reference stations (1-4 μg/kg and 3-9 μg/kg, respectively). None of the reference stations had chlordane or DDT levels exceeding their respective SQG of 4.8 μg/kg and 100 μg/g OC, respectively.

7.5.2 Chollas Site

Pesticide results for the Chollas stations are shown in Table 7-7 and Table 7-8. Mean concentrations for pesticides at the Chollas stations were significantly higher than the reference mean for both TCHLOR (59X) and TDDT (9X). Variability of TCHLOR and TDDT concentrations at the Chollas stations was lower than seen at the reference stations including CP2441, but comparable to the reference stations excluding CP2441. Among the Chollas stations, C14 had the highest concentration of both TCHLOR and TDDT, while the lowest concentration was found at station C07. The low concentrations at station C07 are consistent with the low fines and TOC present in this region. All but one Chollas station (C07) exceeded the chlordane SQG. None of the stations had TDDT levels that exceeded its SQG.

The spatial distributions of TCHLOR and TDDT at the Chollas site are shown in Figure 7-23 and Figure 7-24 respectively. The spatial pattern appeared to be strongly influenced by proximity to the Creek mouth, with additional influence from the distribution of fines and TOC. The distribution tends to follow the same pattern as for fines and TOC, with higher levels in the inner creek, and lower levels at the inner/outer creek boundary. Both TCHLOR and TDDT PCBs had significant positive correlations with fines and TOC at the Chollas stations (Table 7-9). In addition, TCHLOR and TDDT were highly correlated to each other in the Creek, suggesting common origin, transport and partitioning processes in the region (Figure 7-27).

7.5.3 Paleta Site

Pesticide results for the Paleta stations are shown in Table 7-7 and Table 7-8. Mean concentrations for pesticides at the Paleta stations were significantly higher than the reference mean for both TCHLOR (14X) and TDDT (5.2X). Variability of TCHLOR and TDDT concentrations at the Paleta stations was lower than seen at the reference stations including CP2441, but comparable to the reference stations excluding CP2441. Among the Paleta stations, P15 had the highest concentration of TCHLOR, and P17 had the highest concentration of TDDT. The lowest concentration of both TCHLOR and TDDT was found at station P09, consistent with the low fines and TOC measured there. Compared to Chollas stations, mean concentrations at the Paleta stations were generally lower for both TCHLOR (3.9X) and TDDT (1.7X). Seven of 17 Paleta stations exceeded the chlordane SQG though none of the stations exceeded the DDT SQG.

The spatial distributions of TCHLOR and TDDT at the Paleta site are shown in Figure 7-25 and Figure 7-26 respectively. As with the Chollas site, the spatial pattern appeared to be strongly influenced by proximity to the Creek mouth, with additional influence from the distribution of TOC. Both TCHLOR and TDDT had significant positive correlations with TOC at the Paleta stations (Table 7-10). In addition, TCHLOR and TDDT were highly correlated to each other (Figure 7-27). The TCHLOR-TDDT relationship at the Paleta site indicates a higher ratio of TDDT than at the Chollas site, suggesting that the upstream sources of these pesticides may be different in the two watersheds.

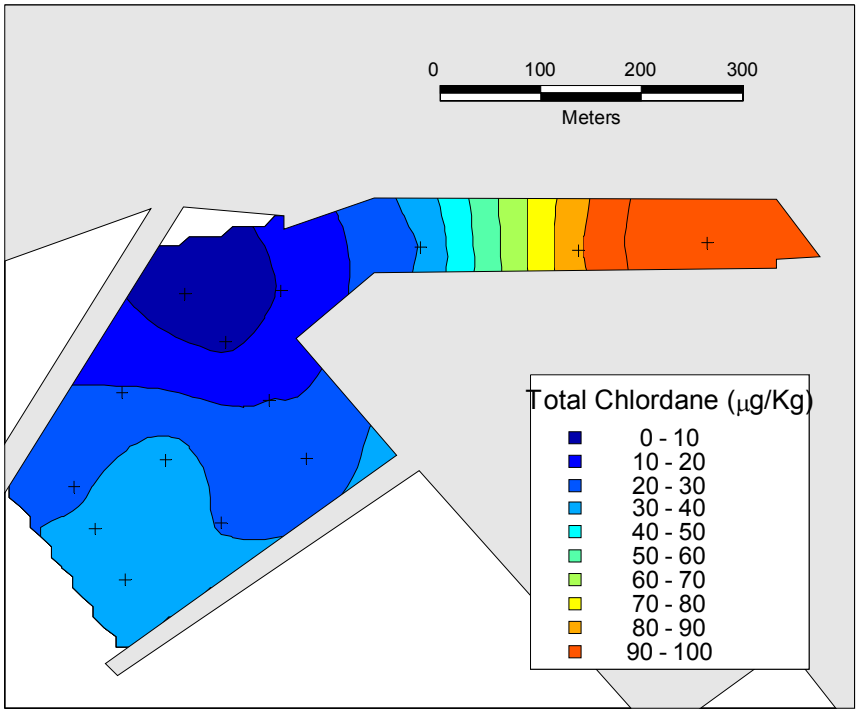


Figure 7-23. Spatial distribution of total chlordane in μg/kg at the Chollas site.

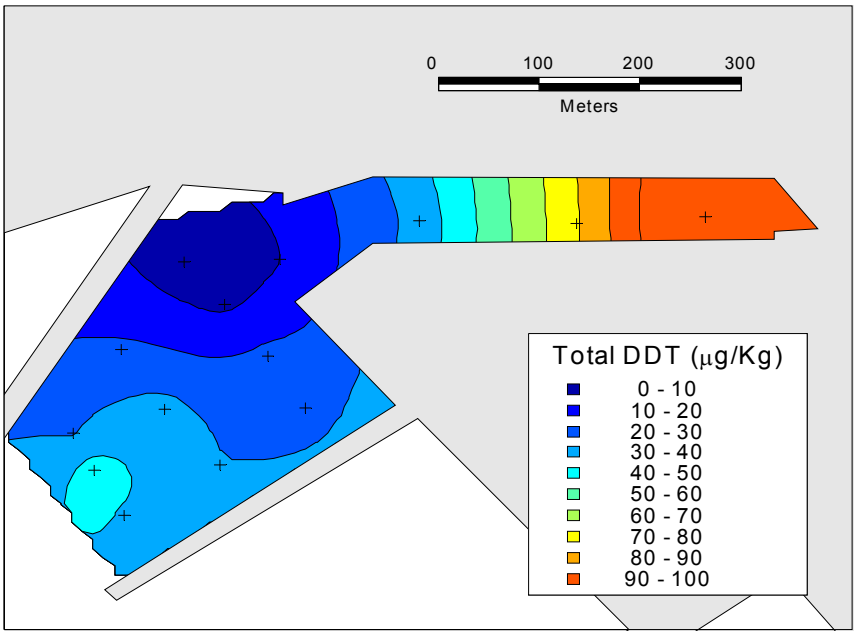


Figure 7-24. Spatial distribution of total DDT in μg/kg at the Chollas site.

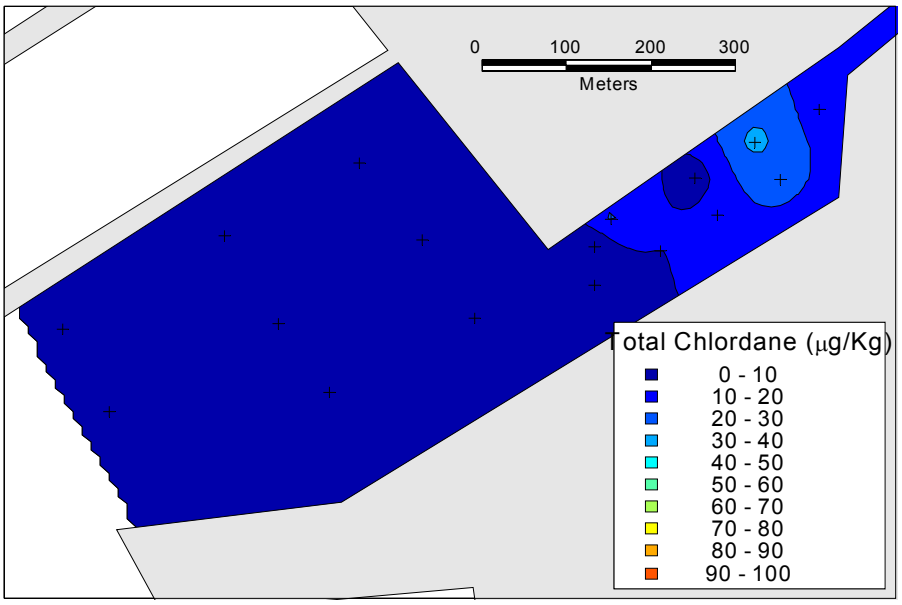


Figure 7-25. Spatial distribution of total chlordane in μg/kg at the Paleta site.

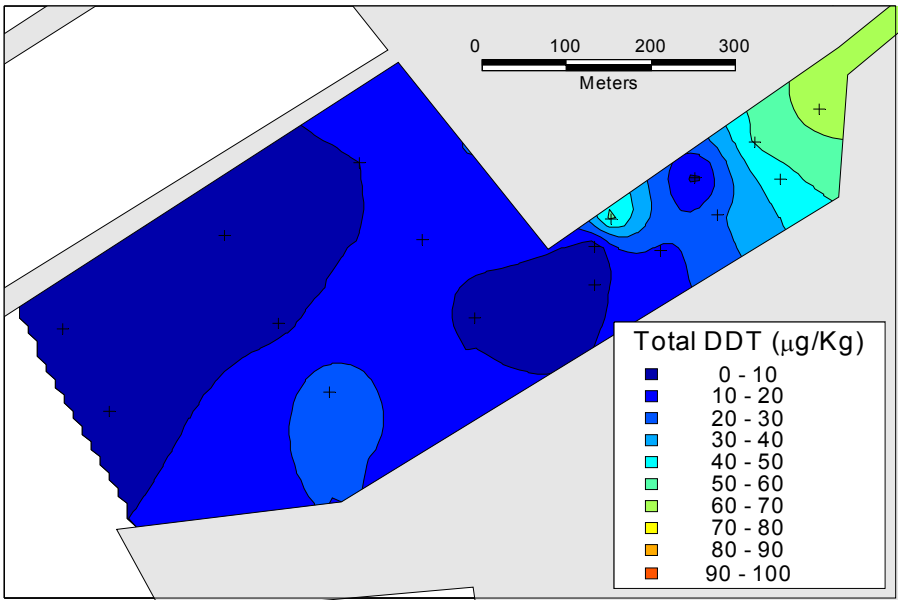


Figure 7-26. Spatial distribution of total DDT in μg/kg at the Paleta site.

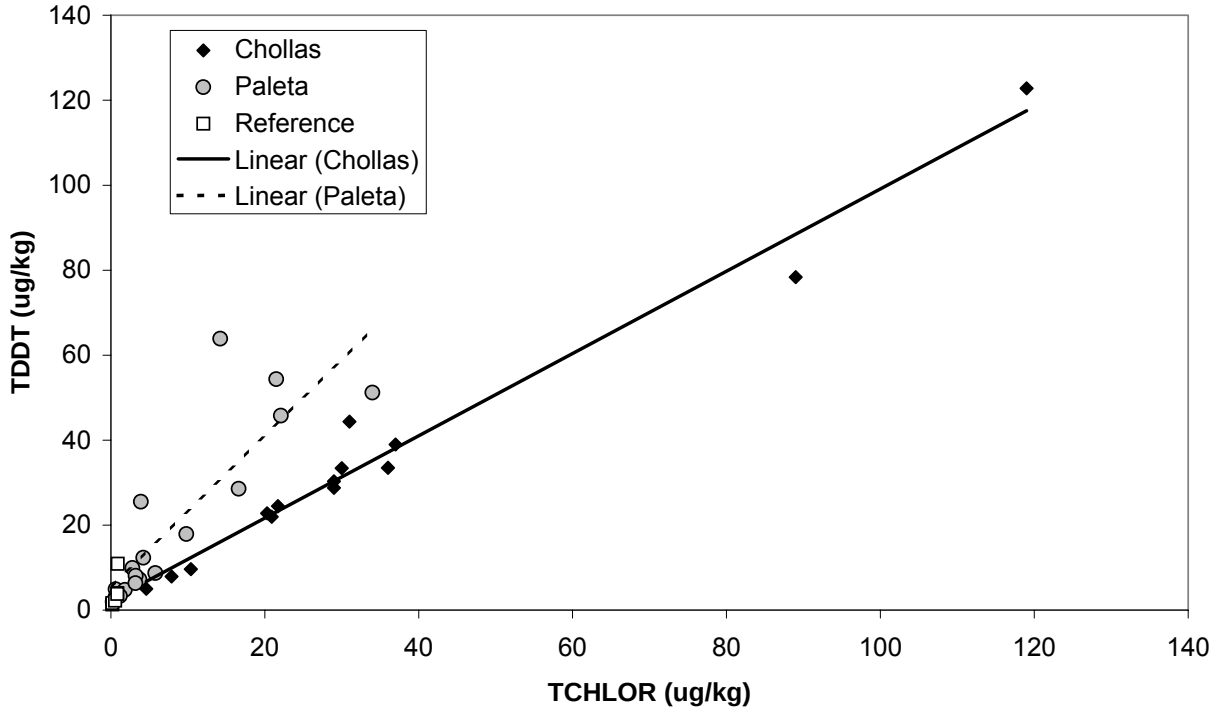


Figure 7-27. Relationship between TCHLOR and TDDT at the Chollas, Paleta, and reference stations.

8.0 BIOACCUMULATION

8.1 TISSUE SOLIDS AND LIPID CONTENT

The fraction of solids and lipid present in the tissues of clams exposed to site sediments were characterized at all reference and a subset of the Chollas and Paleta study stations. Tissue solids and lipid content were also characterized for clams prior to the sediment exposure (T_0) and for clams exposed to control (home) sediment. Study stations that were characterized included Chollas stations C02, C05, C08, C11, C12, C13, and C14 (Figure 5-1) and Paleta stations P02, P04, P08, P11, P13, P15, and P17 (Figure 5-2). Tissue solids content reflects the ratio of dry tissue to wet tissue in the clams and is a required parameter for conversion from dry weight units to wet weight units. Tissue lipid content indicates the fat fraction of the tissue. Many bioaccumulative compounds exhibit low water solubility and tend to concentrate in the lipid fractions of biological tissues. Results for tissue solids and lipid content in T_0, control, reference, Chollas, and Paleta samples are summarized below. The complete results are shown in Appendix B.

8.1.1 Control and T_0

Solids and lipid results for the control and T_0 samples are shown in Table 8-1 and Table 8-2. Three composite control samples were analyzed, and one T_0 sample. Each control sample was composited from clams in five separate exposure chambers containing home sediment. Solids content in the control tissues was consistently in the 10-12% range and comparable to the T_0 sample (12%), indicating that no significant changes occurred following exposure to the control sediments. Lipid content in the control tissues ranged from 5.9-7.6%, which was also comparable to the T_0 sample (7.0%). Variation among the control replicates was low indicating consistency among the exposures and analytical procedures.

8.1.2 Reference

Solids and lipid content results for the reference stations are shown in Table 8-1 and Table 8-2. The result for each reference station represents the composite of five replicate laboratory exposures. In addition, for station CP2433, three field replicates were collected and a composite sample was analyzed from five replicate laboratory exposures for each field replicate. The reported values for station CP2433 are thus the means of these three field replicates. The range of solids and lipid content across the reference stations was generally low. For example, solids content ranged from 10.4 to 12.1 %, with an RSD of only 5%, and lipid content had a range from 4.8 to 8.1 % with an RSD of 16%. Reference station mean tissue solids and lipid content were comparable to concentrations in the control samples. These results indicate that clams exposed to reference sediments had no major differences in general tissue properties compared to the clams exposed to control sediments.

8.1.3 Chollas Site

Solids and lipid content results for the Chollas stations are shown in Table 8-1 and Table 8-2. The result for each station represents the composite of five replicate laboratory exposures. In addition, for station C08, three field replicates were collected and a composite sample was analyzed from five replicate laboratory exposures for each field replicate. The reported values for station C08 are thus the means of these three field replicates. The range of solids and lipid content across the Chollas stations was comparable to those of the reference stations and the control samples. For example, solids content ranged from 11.0 to 11.6 %, with an RSD of 2%, and lipid content had a range from 4.7 to 7.5 % with an RSD of 14%. Among the Chollas

stations, C05 had the lowest lipid content, while station C08 had the highest level. These results indicate that clams exposed to Chollas sediments had no major differences in general tissue properties compared to the clams exposed to reference and control sediments.

8.1.4 Paleta Site

Solids and lipid content results for the Paleta stations are shown in Table 8-1 and Table 8-2. The result for each station represents the composite of five replicate laboratory exposures. In addition, for station P11, three field replicates were collected and a composite sample was analyzed from five replicate laboratory exposures for each field replicate. The reported values for station P11 are thus the means of these three field replicates. The range of solids and lipid content across the Paleta stations was comparable to those of the reference stations and the control samples. For example, solids content ranged from 10.9 to 11.9 %, with an RSD of 4%, and lipid content had a range from 6.3 to 8.0 % with an RSD of 9%. Among the Paleta stations, P11 had the lowest lipid content, while station P04 had the highest level. These results indicate that clams exposed to Paleta sediments had no major differences in general tissue properties compared to the clams exposed to reference and control home sediments.

Table 8-1. Tissue solids (%) and lipid content (%) data for the control, T_0, reference, Chollas, and Paleta.

Area	Station	Solids	Lipid
Control and T_0	**T0**	12.0	7.0
	Control 1	10.8	5.9
	Control 2	12.0	5.7
	Control 3	11.2	7.6
Reference	**2231**	11.5	7.2
	2243	10.4	8.1
	2433	12.1	6.7
	2440	12.1	6.7
	2441	11.7	6.8
	2238	11.8	4.8
Chollas	**C02**	11.3	6.4
	C05	11.3	4.7
	C08	11.6	7.5
	C11	11.0	6.0
	C12	11.2	7.2
	C13	11.4	6.6
	C14	11.1	6.4
Paleta	**P02**	10.9	6.7
	P04	11.0	8.0
	P08	11.8	7.2
	P11	11.9	6.3
	P13	11.9	7.8
	P15	11.0	6.6
	P17	11.1	7.5

Table 8-2. Summary statistics for solids (%) and lipid content (%) in clams exposed to control, reference, Chollas and Paleta sediments.

Area	Station	Solids	Lipid
Control	**Minimum**	10.8	5.7
	Maximum	12.0	7.6
	Mean	11.3	6.4
	Std Dev	0.6	1.1
	RSD (%)	5%	16%
Reference	**Minimum**	10.4	4.8
	Maximum	12.1	8.1
	Mean	11.6	6.7
	Std Dev	0.6	1.1
	RSD (%)	5%	16%
Chollas	**Minimum**	11.0	4.7
	Maximum	11.6	7.5
	Mean	11.3	6.4
	Std Dev	0.2	0.9
	RSD (%)	2%	14%
Paleta	**Minimum**	10.9	6.3
	Maximum	11.9	8.0
	Mean	11.4	7.2
	Std Dev	0.5	0.6
	RSD (%)	4%	9%

8.2 METALS

Concentrations of metals in the tissues of clams exposed to site sediments were characterized at all reference and a subset of the Chollas and Paleta study stations. Tissue concentrations were also characterized for clams prior to the sediment exposure (T_0) and for clams exposed to control (home) sediment. Tissues were analyzed for a range of metals including silver, arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc. Results for chromium and nickel could not be used due to inadvertent contamination of these samples by use of a stainless steel mixing blade during the homogenization process at the analytical laboratory. Study stations that were characterized included Chollas stations C02, C05, C08, C11, C12, C13, and C14 (Figure 5-2). Tissue concentrations reflect the uptake of metals from site sediments as regulated by their concentration and bioavailability in the sediment. Results for tissue metals at reference, Chollas, and Paleta stations are summarized below. The data displayed include only those metals that were identified as CoPCs in the historical review. The complete set of data can be found in Appendix B.

8.2.1 Control and T_0

Metals results for the control and T_0 samples are shown in Table 8-3 and Table 8-4. Three composite control samples were analyzed, and one T_0 sample. Each control sample was composited from clams in five separate exposure chambers containing home sediment. Metal concentrations in the control tissues were generally low, and comparable to the T_0 concentrations, indicating that no significant accumulation occurred for clams exposed to the control sediments. Variation among the control replicates was low indicating consistency among the exposures and analytical procedures. For example, copper in the control sample tissues ranged from 7 to 11 μg/g, with an RSD of only 22%, and arsenic ranged from 17.9 to 21.7 μg/g

with an RSD of only 10%. The remaining metals had similar ranges of variability. The ratio of the mean control tissue concentration to the T_0 concentration ranged from about 0.8 for arsenic, to about 1.4 for mercury. Thus results from the control samples provide a useful initial baseline for comparison of tissue concentrations from the reference and site stations.

8.2.2 Reference

Metals results for the reference stations are shown in Table 8-3 and Table 8-4. The tissue concentration for each reference station represents the composite of five replicate laboratory exposures. In addition, for station CP2433, three field replicates were collected and a composite sample was analyzed from five replicate laboratory exposures for each field replicate. The reported metals values for station CP2433 are thus the means of these three field replicates. The range of concentrations across the reference stations was generally low. For example, copper concentrations ranged from 11.3 to 14.1 μg/g, with an RSD of only 8%, and arsenic had a range from 18.7 to 22.2 μg/g with an RSD of 7%. Exceptions included mercury and lead, which had somewhat higher variability across stations. Reference station mean tissue concentrations of silver, arsenic, cadmium and zinc were comparable to concentrations in the control samples. Mean tissue concentrations of other metals were generally somewhat higher in the reference stations than control including copper (1.4X), lead (2.5X) and mercury (1.4X). These results indicate that reference areas of San Diego Bay have somewhat higher bioaccumulation potential for copper, lead and mercury compared to the control sediments.

8.2.3 Chollas Site

Metals results for the Chollas stations are shown in Table 8-3 and Table 8-4. The tissue concentration for each station represents the composite of five replicate laboratory exposures. In addition, for station C08, three field replicates were collected and a composite sample was analyzed from five replicate laboratory exposures for each field replicate. The reported metals values for station C08 are thus the means of these three field replicates. The range of concentrations across the Chollas stations was somewhat higher than that for the control samples. For example, copper concentrations ranged from 12.3 to 31 μg/g, with an RSD of 41%, and lead had a range from 3.8 to 9.3 μg/g with an RSD of 34%. However, Chollas station mean tissue concentrations of silver, arsenic, cadmium, mercury and zinc were comparable to concentrations in the control samples. Mean tissue concentrations of other metals were generally somewhat higher in Chollas stations than control including copper (1.7X) and lead (4.4X). Results compared to reference were similar, with arsenic, cadmium, mercury and zinc having similar mean tissue concentrations, and silver (1.2X), copper (1.3X) and lead (1.7X) having somewhat higher means at the Chollas stations. Among the Chollas stations, C11 had the highest concentrations of cadmium, copper, mercury, lead, and zinc, while station C2 had the highest levels of silver and arsenic. Lowest metal levels were not consistently found at any particular station, but were predominantly in the inner creek stations C12-C14 with the exception of zinc at station C05. These results indicate that Chollas stations have somewhat higher bioaccumulation potential for silver, copper and lead compared to the reference and/or control sediments.

The spatial distributions of metals at the Chollas site are shown in Figure 8-1 and Figure 8-2. The stations follow a transect that runs from the outer pier area to the inner creek (Figure 5-1). Spatial patterns of most metals showed similar patterns with a mid-transect maximum at station C11 (cadmium, copper, mercury, lead and zinc). This does not generally correspond with the highest concentrations in the sediment, but does correspond with the area of low TOC and fines. Some metals showed a general decreasing trend from the outer creek to inner creek (silver, arsenic and mercury), but these metals also showed some localized increase around

station C11. These results indicate that Chollas stations have somewhat higher bioaccumulation potential for silver, copper and lead compared to the reference and/or control sediments, and that bioaccumulation may be more strongly influenced by sediment physical properties (TOC and fines) than by sediment metals concentrations. Correlations (r) between metals in tissue and metals in sediment were examined for the Chollas stations alone (Table 8-5), and for the overall data set including Chollas, Paleta, and reference stations (Table 8-6). For the Chollas stations, there were no significant ($p<0.05$) metal-metal correlations (i.e. copper in tissue to copper in sediment), although silver, arsenic and cadmium had relatively high r-values ranging from 0.56-0.66. For the overall data set, cadmium, lead and zinc had statistically significant correlations with r-values ranging from 0.47-0.83.

8.2.4 Paleta Site

Metals results for the Paleta stations are shown in Table 8-3 and Table 8-4. The tissue concentration for each station represents the composite of five replicate laboratory exposures. In addition, for station P11, three field replicates were collected and a composite sample was analyzed from five replicate laboratory exposures for each field replicate. The reported metals values for station P11 are thus the means of these three field replicates. Tissue metal concentrations at the Paleta stations were somewhat higher than that for the control samples, although the variation across stations was generally low with the exception of lead. For example, copper concentrations ranged from 13.1 to 18.7 μg/g, with an RSD of only 13%, while lead had a range from 2.9 to 10.6 μg/g with an RSD of 47%. Paleta station mean tissue concentrations of silver, arsenic, cadmium, and zinc were comparable to concentrations in the control samples. Mean tissue concentrations of other metals were generally somewhat higher in Paleta stations than control including copper (1.7X), mercury (1.3X) and lead (4.6X). Results compared to reference were similar, with silver, arsenic, cadmium, mercury and zinc having similar mean tissue concentrations, and copper (1.2X) and lead (1.8X) having somewhat higher means at the Paleta stations. Among the Paleta stations, the inner creek area (stations P15 and P17) generally had the highest concentrations of cadmium, copper, mercury, lead, and zinc, while the outer creek (station P2) had the highest levels of silver, and arsenic concentrations were fairly uniform across the entire area. Lowest levels for a number of metals were found in the outer creek at station P2 (cadmium, copper, lead and zinc).

The spatial distribution of metals at the Paleta site are shown in Figure 8-3 and Figure 8-4. The stations follow a transect that runs from the outer pier area to the inner creek (Figure 5-2). Spatial patterns of cadmium, copper, lead and zinc showed similar patterns with a slightly increasing gradient of tissue concentrations going from the outer to inner creek areas. Mercury showed the opposite trend, with a slightly decreasing trend from outer to inner creek, and arsenic showed no obvious spatial trend along the transect. These results indicate that Paleta stations have somewhat higher bioaccumulation potential for copper, mercury and lead compared to the reference and/or control home sediments, and that bioaccumulation tends to increase toward the inner creek area for most metals. Correlations (r) between metals in tissue and metals in sediment were examined for the Paleta stations alone (Table 8-5), and for the overall data set including Chollas, Paleta, and reference stations (Table 8-7). For the Paleta stations, cadmium and lead had statistically significant metal-metal correlations (i.e. copper in tissue to copper in sediment) with r-values ranging of 0.83 and 0.91 respectively. For the overall data set, cadmium, lead and zinc had statistically significant correlations with r-values ranging from 0.47-0.83.

Table 8-3. Tissue metals data (mg/kg) for the control, T_0, reference, Chollas, and Paleta.

Area	Station	Ag	As	Cd	Cu	Hg	Pb	Zn
Control and T_0	**T0**	0.42	23.5	0.21	9.7	0.035	1.14	61.5
	Control 1	0.54	21.7	0.27	11.0	0.051	1.39	77.5
	Control 2	0.58	19.0	0.26	10.0	0.048	1.36	74.5
	Control 3	0.34	17.9	0.22	7.0	0.049	0.89	76.3
Reference	**2231**	0.24	21.8	0.20	14.1	0.109	3.16	82.5
	2243	0.39	22.2	0.28	14	0.080	2.81	73.1
	2433	0.37	20.7	0.24	12.1	0.064	2.59	73.9
	2440	0.33	19.5	0.23	11.3	0.067	5.71	82.5
	2441	0.41	18.7	0.27	12.8	0.048	2.14	77.9
	2238	0.48	19.3	0.22	12.6	0.046	1.89	77.5
Chollas	**C02**	0.73	25.3	0.23	16.5	0.059	4.90	76.2
	C05	0.37	22.0	0.23	13.5	0.060	4.83	73.2
	C08	0.40	23.5	0.24	13.7	0.052	4.38	85.3
	C11	0.49	23.6	0.31	31.0	0.066	9.27	99.9
	C12	0.35	18.2	0.22	14.2	0.054	5.60	83.9
	C13	0.37	19.7	0.21	12.6	0.042	3.77	74.8
	C14	0.46	19.1	0.29	12.3	0.041	4.50	86.7
Paleta	**P02**	0.41	22.5	0.18	13.1	0.065	2.89	70.2
	P04	0.40	21.9	0.25	15.8	0.066	3.85	81.1
	P08	0.44	20.3	0.22	15.3	0.064	3.84	66.3
	P11	0.38	21.6	0.28	13.3	0.062	6.79	78.2
	P13	0.33	21.9	0.20	16.2	0.068	5.08	79.2
	P15	0.39	22.2	0.29	17.3	0.070	10.6	84.7
	P17	0.32	21.8	0.28	18.7	0.055	5.91	99.4

Table 8-4. Summary statistics for metal concentrations (mg/kg) in clams exposed to control, reference, Chollas and Paleta sediments.

Area	Station	Ag	As	Cd	Cu	Hg	Pb	Zn
Control	**Minimum**	0.34	17.9	0.22	7.0	0.048	0.89	74.5
	Maximum	0.58	21.7	0.27	11.0	0.051	1.39	77.5
	Mean	0.49	19.5	0.25	9.3	0.049	1.21	76.1
	Std Dev	0.12	2.0	0.02	2.1	0.001	0.28	1.5
	RSD (%)	25%	10%	10%	22%	2%	23%	2%
Reference	**Minimum**	0.24	18.7	0.20	11.3	0.046	1.89	73.1
	Maximum	0.48	22.2	0.28	14.1	0.109	5.71	82.5
	Mean	0.37	20.4	0.24	12.8	0.069	3.05	77.9
	Std Dev	0.08	1.4	0.03	1.1	0.023	1.38	4.0
	RSD (%)	21%	7%	12%	8%	34%	45%	5%
Chollas	**Minimum**	0.35	18.2	0.21	12.3	0.041	3.77	73.2
	Maximum	0.73	25.3	0.31	31.0	0.066	9.27	99.9
	Mean	0.45	21.6	0.25	16.3	0.053	5.32	82.9
	Std Dev	0.13	2.7	0.04	6.6	0.009	1.83	9.3
	RSD (%)	30%	12%	15%	41%	18%	34%	11%
Paleta	**Minimum**	0.32	20.3	0.18	13.1	0.055	2.89	66.3
	Maximum	0.44	22.5	0.29	18.7	0.070	10.60	99.4
	Mean	0.38	21.7	0.24	15.7	0.064	5.57	79.9
	Std Dev	0.04	0.7	0.04	2.0	0.005	2.59	10.7
	RSD (%)	11%	3%	18%	13%	8%	47%	13%

Table 8-5. Correlation (r) between metals concentrations in tissue and sediment for Chollas bioaccumulation stations. Gray cells indicate statistically significant correlations (p<0.05).

		Tissue						
		Ag	**As**	**Cd**	**Cu**	**Hg**	**Pb**	**Zn**
Sediment	**Ag**	0.60	0.30	-0.16	0.07	0.33	0.03	-0.44
	As	0.33	0.56	0.73	0.85	0.47	0.73	0.67
	Cd	-0.08	-0.40	0.66	0.23	-0.41	0.24	0.43
	Cu	0.71	0.44	-0.04	0.22	0.28	0.10	-0.31
	Hg	0.71	0.47	-0.27	-0.05	0.35	-0.11	-0.52
	Pb	0.19	-0.18	0.56	0.33	-0.17	0.29	0.24
	Zn	0.12	-0.16	0.72	0.15	-0.40	0.11	0.38

Table 8-6. Correlation (r) between metals concentrations in tissue and sediment for Paleta bioaccumulation stations. Gray cells indicate statistically significant correlations (p<0.05).

		Tissue						
		Ag	**As**	**Cd**	**Cu**	**Hg**	**Pb**	**Zn**
Sediment	**Ag**	0.38	0.18	0.56	-0.01	-0.21	0.24	0.25
	As	-0.41	0.23	0.35	0.52	-0.75	-0.03	0.74
	Cd	-0.30	0.23	0.83	0.33	-0.24	0.86	0.61
	Cu	0.26	0.44	0.27	0.03	-0.06	-0.03	0.26
	Hg	0.21	0.14	0.51	-0.44	-0.26	0.23	0.08
	Pb	-0.12	0.32	0.84	0.31	0.01	0.91	0.53
	Zn	-0.22	0.45	0.78	0.41	-0.28	0.65	0.73

Table 8-7. Overall correlation (r) between metals concentrations in tissue and sediment for all bioaccumulation stations including reference, Chollas and Paleta. Gray cells indicate statistically significant correlations (p<0.05).

		Tissue						
		Ag	**As**	**Cd**	**Cu**	**Hg**	**Pb**	**Zn**
Sediment	**Ag**	0.24	0.31	0.22	0.15	0.01	0.30	-0.08
	As	0.10	0.28	0.35	0.49	-0.22	0.21	0.65
	Cd	0.05	0.01	0.67	0.31	-0.33	0.71	0.53
	Cu	0.21	0.36	0.11	0.27	-0.06	0.31	0.12
	Hg	0.07	0.31	0.14	0.00	0.19	0.27	-0.10
	Pb	0.09	0.19	0.52	0.34	-0.13	0.83	0.46
	Zn	0.16	0.19	0.47	0.34	-0.33	0.56	0.47

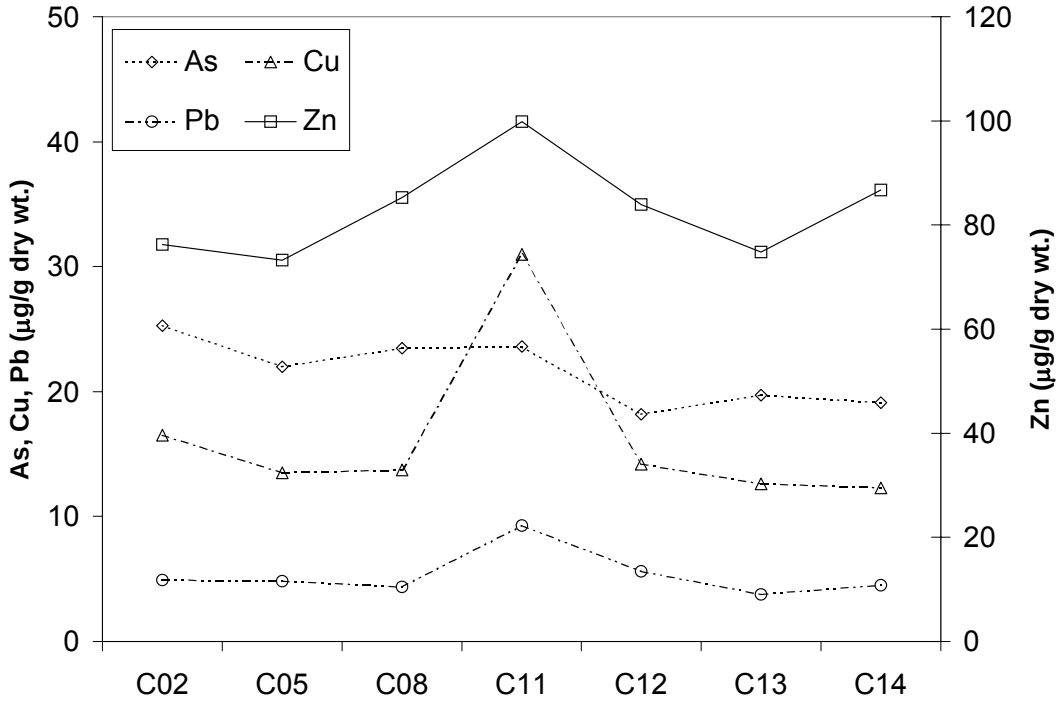


Figure 8-1. Spatial variation of tissue metals along the Chollas transect for arsenic, copper, lead and zinc.

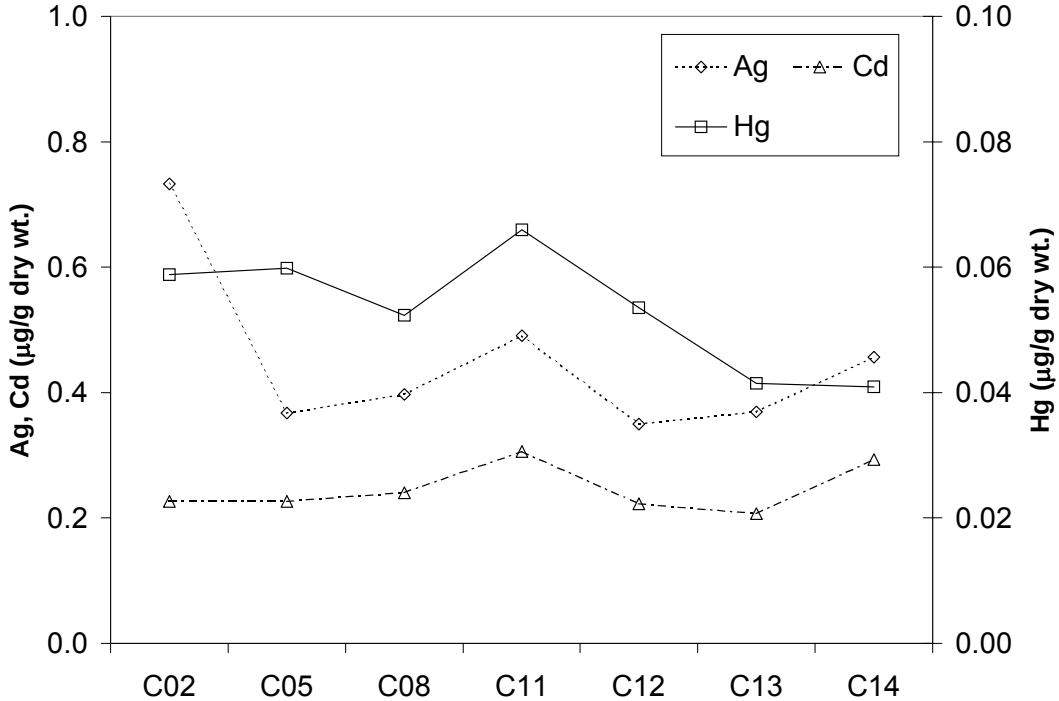


Figure 8-2. Spatial variation of tissue metals along the Chollas transect for silver, cadmium and mercury.

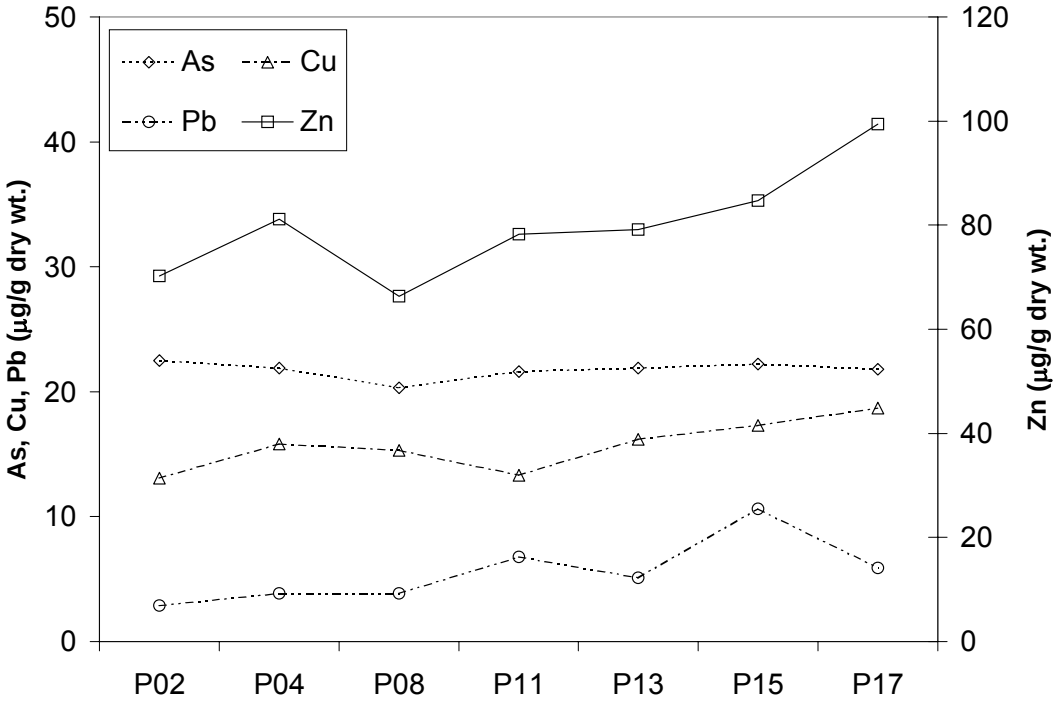


Figure 8-3. Spatial variation of tissue metals along the Paleta transect for arsenic, copper, lead and zinc.

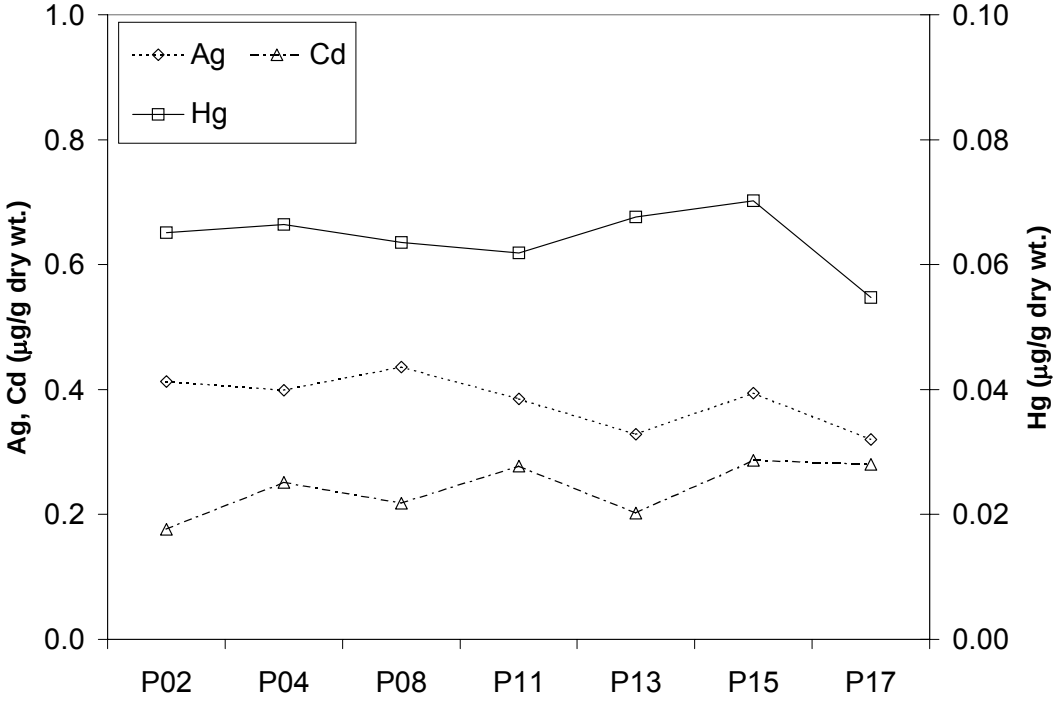


Figure 8-4. Spatial variation of tissue metals along the Paleta transect for silver, cadmium and mercury.

8.3 PAH

Concentrations of PAH in the tissues of clams exposed to site sediments were characterized at all reference and a subset of the Chollas and Paleta study stations. Tissue concentrations were also characterized for clams prior to the sediment exposure (T_0) and for clams exposed to control (home) sediment. Tissues were analyzed for the same range of PAHs as described previously for the sediment analysis. Study stations that were characterized included Chollas stations C02, C05, C08, C11, C12, C13, and C14 (Figure 5-1) and Paleta stations P02, P04, P08, P11, P13, P15, and P17 (Figure 5-2). Tissue concentrations reflect the uptake of PAHs from site sediments as regulated by their concentration and bioavailability in the sediment. Results for the PPPAH, LMWPAH, and HMWPAH summations at reference, Chollas, and Paleta stations are given below. The complete set of data can be found in Appendix B.

8.3.1 Control and T_0

PAH results for the control and T_0 samples are shown in Table 8-8 and Table 8-9. Three composite control samples were analyzed, and one T_0 sample. Each control sample was composited from clams in five separate exposure chambers containing home sediment. PAH concentrations in the control tissues were generally low, and comparable to or lower than the T_0 concentrations, indicating that no significant accumulation occurred for clams exposed to the control sediments. Variation among the control replicates was low indicating consistency among the exposures and analytical procedures. For example, PPPAH in the control sample tissues ranged from 103 to 156 μg/kg, with an RSD of only 21%. The other summations had similar ranges of variability. The ratio of the mean control tissue concentration to the T_0 concentration ranged from about 0.3 for HMWPAH, to about 0.8 for LMWPAH. Thus results from the control samples provide a useful initial baseline for comparison of tissue concentrations from the reference and site stations.

8.3.2 Reference

PAH results for the reference stations are shown in Table 8-8 and Table 8-9. The tissue concentration for each reference station represents the composite of five replicate laboratory exposures. In addition, for station CP2433, three field replicates were collected and a composite sample was analyzed from five replicate laboratory exposures for each field replicate. The reported PAH values for station CP2433 are thus the means of these three field replicates. PPPAH concentrations at the reference stations ranged from 199 to 5387 μg/kg, with an RSD of 120%. Most of the variability was associated with elevated accumulation at CP2440, corresponding to the elevated sediment levels previously described at that station. Reference station mean tissue concentrations of PAHs were generally higher than the control samples including LMWPAH (4.1X), HMWPAH (13.7X), and PPPAH (13.0X). These results indicate that reference areas of San Diego Bay have higher bioaccumulation potential for PAHs compared to the control sediments.

8.3.3 Chollas Site

PAH results for the Chollas stations are shown in Table 8-8 and Table 8-9. The tissue concentration for each station represents the composite of five replicate laboratory exposures. In addition, for station C08, three field replicates were collected and a composite sample was analyzed from five replicate laboratory exposures for each field replicate. The reported PAH values for station C08 are thus the means of these three field replicates. The range and variability of concentrations across the Chollas stations was higher than that for the control samples. For example, PPPAH concentrations ranged from 1442 to 17909 μg/kg, with an RSD of 114%. Results compared to reference showed comparable variability but higher levels for all

station-mean summations at Chollas including LMWPAH (2.1X), HMWPAH (4.5X), and PPPAH (3.3X). Among the Chollas stations, C12 had the highest concentrations of PAHs (all summations), while station C05 had the lowest HMWPAH and PPPAH levels, and station C02 had the lowest LMWPAH level. In general, the LMWPAH was a small fraction of the PPPAH concentration, indicating that the PAHs in the tissues are dominated by high molecular weight compounds. This is consistent with the fractionation observed in the sediments. Overall, the results indicate that Chollas stations generally have higher bioaccumulation potential for PAHs compared to the reference and/or control home sediments.

The spatial distribution of tissue PAHs at the Chollas site is shown in Figure 8-5. The stations follow a transect that runs from the outer pier area to the inner creek (Figure 5-1). Spatial patterns of HMWPAH and PPPAH showed similar patterns with a gradual increase from station C02 to station C11, followed by a rapid increase at station C12, and a subsequent decline toward the creek mouth at C14. This pattern corresponded closely with the concentrations in the sediment. Correlations (r) between PAH in tissue and PAH in sediment were examined for the Chollas stations alone (Table 8-10), and for the overall data set including Chollas, Paleta, and reference stations (Table 8-12). For this analysis, tissue concentrations were normalized to lipid content, and sediment concentrations were normalized to TOC. For the Chollas stations alone, statistically significant correlations were observed for all PAH summations with correlation coefficients ranging from 0.88 to 0.96. For the overall data set, statistically significant correlations were also found for all PAH summations.

8.3.4 Paleta Site

PAH results for the Paleta stations are shown in Table 8-8 and Table 8-9. The tissue concentration for each station represents the composite of five replicate laboratory exposures. In addition, for station P11, three field replicates were collected and a composite sample was analyzed from five replicate laboratory exposures for each field replicate. The reported PAH values for station P11 are thus the means of these three field replicates. The range of concentrations across the Paleta stations was generally higher than that for the control samples and reference stations, but lower than that for Chollas stations. For example, PPPAH concentrations ranged from 2447 to 9660 μg/kg, with an RSD of 50%. Results compared to reference showed higher levels for all station-mean summations at Paleta including LMWPAH (1.5X), HMWPAH (3.9X), and PPPAH (3.3X). Among the Paleta stations, P11 had the highest concentrations of PAHs (all summations), while station P02 had the lowest HMWPAH and PPPAH levels, and station P15 had the lowest LMWPAH level. In general, the LMWPAH was a small fraction of the PPPAH concentration, indicating that the PAHs in the tissues are dominated by high molecular weight compounds. This is consistent with the fractionation observed in the sediments. Overall, the results indicate that Paleta stations generally have higher bioaccumulation potential for PAHs compared to the reference and/or control home sediments.

The spatial distribution of tissue PAHs at the Paleta site is shown in Figure 8-5. The stations follow a transect that runs from the outer pier area to the inner creek (Figure 5-2). Spatial patterns of HMWPAH and PPPAH showed similar patterns with a gradual increase from station P02 to station P17, interrupted by an upward spike at station P11. This pattern varied from the pattern of PAH in the sediment, which increases steadily from station P02 to P17 interrupted by a downward spike at station P13. Correlations (r) between PAH in tissue and PAH in sediment were examined for the Paleta stations alone (Table 8-11), and for the overall data set including Paleta, Chollas, and reference stations (Table 8-12). For this analysis, tissue concentrations were normalized to lipid content, and sediment concentrations were normalized to TOC. For the

Paleta stations alone, statistically significant correlations were not observed for any PAH summations with correlation coefficients ranging from 0.21 to 0.66. For the overall data set, statistically significant correlations were found for all PAH summations.

Table 8-8. Tissue organic contaminant data from T_0, control, reference, Chollas, and Paleta stations (μg/kg).

Area	Station	LMWPAH	HMWPAH	PPPAH	TPCB	TCHLOR	TDDT
Control and T_0	**T0**	79	209	293	79	0.5	1.4
	Control 1	50	54	103	50	0.5	2.8
	Control 2	78	80	156	78	0.3	2.3
	Control 3	52	65	119	52	0.5	2.5
Reference	**CP 2231**	86	536	1063	164	2.2	8.9
	CP 2238	17	103	199	56	0.5	7.3
	CP 2243	20	118	267	159	1.5	11.1
	CP 2433	56	415	780	138	0.7	11.1
	CP 2440	1052	3049	5387	449	26.0	39.0
	CP 2441	236	1210	2143	77	0.2	10.1
Chollas	**C02**	162	839	1553	321	24.0	20.1
	C05	163	807	1442	168	25.0	18.3
	C08	239	1602	2390	174	22.3	17.0
	C11	185	2568	3322	219	35.0	24.4
	C12	1903	13597	17909	249	33.0	30.0
	C13	750	7241	8728	125	20.7	22.5
	C14	264	1608	2077	110	25.0	15.5
Paleta	**P02**	274	1050	2447	196	3.6	10.0
	P04	375	1054	2753	198	8.1	15.1
	P08	310	1682	3367	249	7.2	19.3
	P11	497	7486	9660	505	43.7	68.7
	P13	391	3523	5669	371	20.7	44.4
	P15	239	4494	6408	537	52.0	73.3
	P17	477	5489	7948	375	34.0	62.3

Table 8-9. Summary statistics for the tissue organic contaminant data (μg/kg).

Area	Station	LMWPAH	HMWPAH	PPPAH	TPCB	TCHLOR	TDDT
Control	**Minimum**	50	54	103	50	0.3	2.3
	Maximum	78	80	156	78	0.5	2.8
	Mean	60	66	126	60	0.4	2.5
	Std Dev	16	13	27	16	0.1	0.3
	RSD (%)	26%	20%	21%	26%	31%	10%
Reference	**Minimum**	17	103	199	56	0.2	7.3
	Maximum	1052	3049	5387	449	26.0	39.0
	Mean	245	905	1640	174	5.2	14.6
	Std Dev	404	1125	1966	142	10.2	12.0
	RSD (%)	165%	124%	120%	82%	197%	83%
Chollas	**Minimum**	162	807	1442	110	20.7	15.5
	Maximum	1903	13597	17909	321	35.0	30.0
	Mean	524	4037	5346	195	26.4	21.1
	Std Dev	643	4766	6088	74	5.4	5.0
	RSD (%)	123%	118%	114%	38%	21%	24%
Paleta	**Minimum**	239	1050	2447	196	3.6	10.0
	Maximum	497	7486	9660	537	52.0	73.3
	Mean	366	3540	5464	347	24.2	41.9
	Std Dev	98	2453	2755	140	19.3	27.0
	RSD (%)	27%	69%	50%	40%	80%	64%

Table 8-10. Correlation (r) between organic contaminant concentrations in tissue and sediment for Chollas bioaccumulation stations. Gray cells indicate statistically significant correlations ($p<0.05$).

		Tissue					
		LMWPAH	**HMWPAH**	**PPPAH**	**TPCB**	**TCHLOR**	**TDDT**
Sediment	**LMWPAH**	0.96	0.89	0.92	0.10	0.12	0.48
	HMWPAH	0.96	0.90	0.93	0.10	0.12	0.49
	PPPAH	0.96	0.89	0.92	0.12	0.11	0.49
	TPCB	-0.13	-0.21	-0.16	0.88	0.05	0.19
	TCHLOR	0.53	0.55	0.53	-0.38	-0.33	0.20
	TDDT	0.58	0.49	0.51	0.23	-0.44	0.11

Table 8-11. Correlation (r) between organic contaminant concentrations in tissue and sediment for Paleta bioaccumulation stations. Gray cells indicate statistically significant correlations ($p<0.05$).

		Tissue					
		LMWPAH	**HMWPAH**	**PPPAH**	**TPCB**	**TCHLOR**	**TDDT**
Sediment	**LMWPAH**	0.21	0.24	0.24	0.19	0.13	0.14
	HMWPAH	0.37	0.66	0.65	0.69	0.62	0.61
	PPPAH	0.28	0.55	0.54	0.60	0.53	0.51
	TPCB	0.46	0.84	0.82	0.91	0.86	0.83
	TCHLOR	0.25	0.78	0.77	0.97	0.96	0.91
	TDDT	0.65	0.96	0.96	0.91	0.92	0.94

Table 8-12. Overall correlation (r) between organic contaminant concentrations in tissue and sediment for all bioaccumulation stations including reference, Chollas and Paleta. Gray cells indicate statistically significant correlations (p<0.05).

		Tissue					
		LMWPAH	HMWPAH	PPPAH	TPCB	TCHLOR	TDDT
Sediment	LMWPAH	0.86	0.77	0.78	0.03	0.20	0.06
	HMWPAH	0.85	0.82	0.82	0.11	0.28	0.16
	PPPAH	0.84	0.81	0.83	0.12	0.29	0.17
	TPCB	0.23	0.42	0.43	0.84	0.79	0.74
	TCHLOR	0.35	0.55	0.50	0.17	0.67	0.33
	TDDT	0.26	0.62	0.60	0.51	0.75	0.70

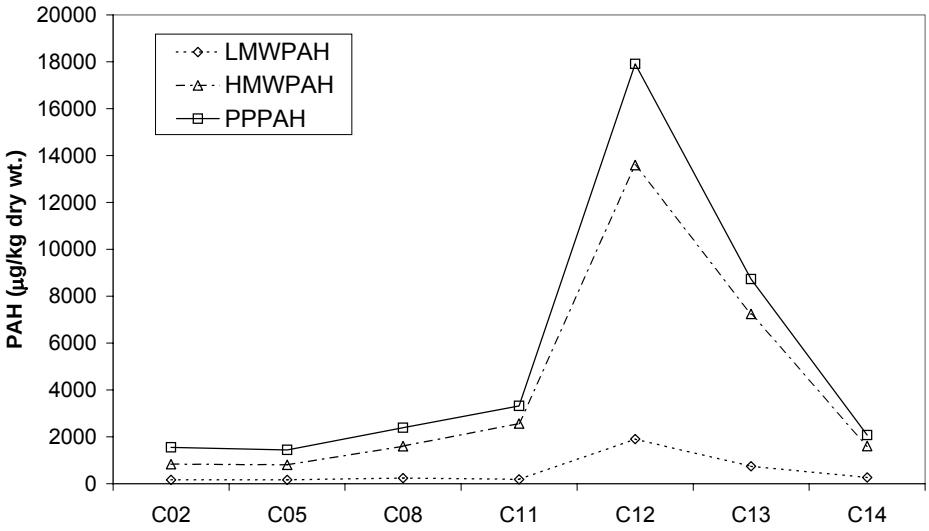


Figure 8-5. Spatial variation of tissue PAHs along the Chollas transect.

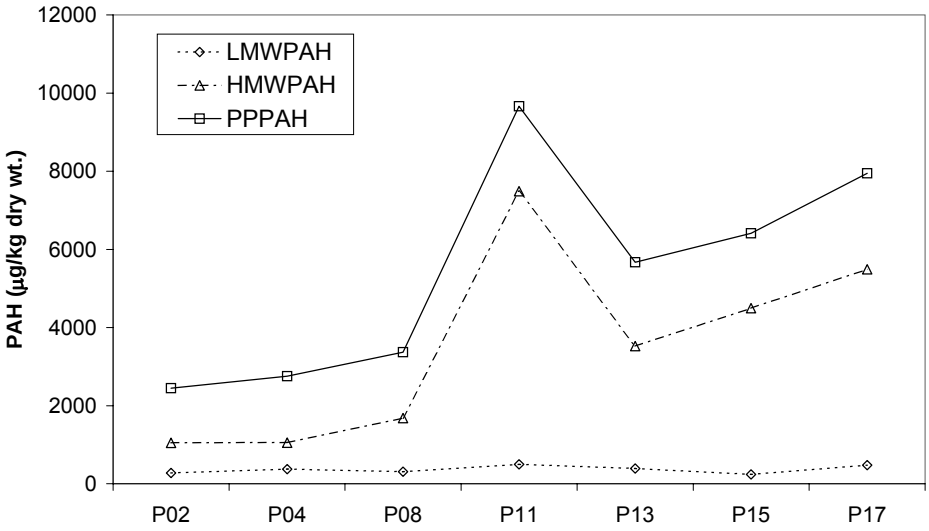


Figure 8-6. Spatial variation of tissue PAHs along the Paleta transect.

8.4 PCB

Concentrations of PCB in the tissues of clams exposed to site sediments were characterized at all reference and a subset of the Chollas and Paleta study stations. Tissue concentrations were also characterized for clams prior to the sediment exposure (T_0) and for clams exposed to control (home) sediment. Tissues were analyzed for the same range of PCBs as described previously for the sediment analysis. Study stations that were characterized included Chollas stations C02, C05, C08, C11, C12, C13, and C14 (Figure 5-1) and Paleta stations P02, P04, P08, P11, P13, P15, and P17 (Figure 5-2). Tissue concentrations reflect the uptake of PCBs from site sediments as regulated by their concentration and bioavailability in the sediment. Results for the TPCB summation at reference, Chollas, and Paleta stations are given below. The complete set of data can be found in Appendix B.

8.4.1 Control and T_0

PCB results for the control and T_0 samples are shown in Table 8-8 and Table 8-9. Three composite control samples were analyzed, and one T_0 sample. Each control sample was composited from clams in five separate exposure chambers containing home sediment. PCB concentrations in the control tissues were generally low, and comparable to or lower than the T_0 concentrations, indicating that no significant accumulation occurred for clams exposed to the control sediments. Variation among the control replicates was low indicating consistency among the exposures and analytical procedures. For example, TPCB in the control sample tissues ranged from 50 to 78 μg/kg, with an RSD of only 26%. The ratio of the mean control tissue concentration to the T_0 concentration was about 0.8. Thus results from the control samples provide a useful initial baseline for comparison of tissue concentrations from the reference and site stations.

8.4.2 Reference

PCB results for the reference stations are shown in Table 8-8 and Table 8-9. The tissue concentration for each reference station represents the composite of five replicate laboratory exposures. In addition, for station CP2433, three field replicates were collected and a composite sample was analyzed from five replicate laboratory exposures for each field replicate. The reported PCB values for station CP2433 are thus the means of these three field replicates. TPCB concentrations at the reference stations ranged from 56 to 449 μg/kg, with an RSD of 82%. Most of the variability was associated with elevated accumulation at CP2440, corresponding to the elevated sediment levels previously described at that station. Reference station-mean tissue concentrations of PCBs were generally higher than the control samples (2.9X). These results indicate that reference areas of San Diego Bay have higher bioaccumulation potential for PCBs compared to the control sediments.

8.4.3 Chollas Site

PCB results for the Chollas stations are shown in Table 8-8 and Table 8-9. The tissue concentration for each station represents the composite of five replicate laboratory exposures. In addition, for station C08, three field replicates were collected and a composite sample was analyzed from five replicate laboratory exposures for each field replicate. The reported PCB values for station C08 are thus the means of these three field replicates. The range of concentrations across the Chollas stations was comparable to the reference stations, but higher than control samples. For example, TPCB concentrations ranged from 110 to 321 μg/kg, with an

RSD of 38%. The station-mean concentration at Chollas (195 μg/kg) was only slightly higher than the reference mean (174 μg/kg). Among the Chollas stations, C02 had the highest concentration of TPCB, while station C14 had the lowest level. Overall, the results indicate that Chollas stations generally have similar bioaccumulation potential for PCBs compared to the reference stations, but higher bioaccumulation potential than the control sediments.

The spatial distribution of tissue PCBs at the Chollas Creek site is shown in Figure 8-7. The stations follow a transect that runs from the outer pier area to the inner creek (Figure 5-1). Spatial patterns of TPCB showed a general decrease from station C02 to station C14, with a secondary peak centered at station C12. This pattern varies from the concentrations in the sediment in that no secondary peak is present in the sediment concentrations at C12. The correlation (r) between TPCB in tissue and TPCB in sediment was examined for the Chollas stations alone (Table 8-10), and for the overall data set including Chollas, Paleta, and reference stations (Table 8-12). For this analysis, tissue concentrations were normalized to lipid content, and sediment concentrations were normalized to TOC. For the Chollas stations alone, a statistically significant correlation was observed for TPCB with a correlation coefficient of 0.88. For the overall data set, a statistically significant correlation was also found for TPCB (r=0.84).

8.4.4 Paleta Site

PCB results for the Paleta stations are shown in Table 8-8 and Table 8-9. The tissue concentration for each station represents the composite of five replicate laboratory exposures. In addition, for station P11, three field replicates were collected and a composite sample was analyzed from five replicate laboratory exposures for each field replicate. The reported PCB values for station P11 are thus the means of these three field replicates. The range of concentrations across the Paleta stations was higher than the reference stations and control samples. For example, TPCB concentrations ranged from 196 to 537 μg/kg, with an RSD of 40%. The station-mean concentration at Paleta (347 μg/kg) was higher than the reference mean (174 μg/kg) and the control sample mean (60 μg/kg). Among the Paleta stations, P15 had the highest concentration of TPCB, while station P02 had the lowest level. Overall, the results indicate that Paleta stations generally have higher bioaccumulation potential than the reference stations and control sediments.

The spatial distribution of tissue PCBs at the Paleta site is shown in Figure 8-8. The stations follow a transect that runs from the outer pier area to the inner creek (Figure 5-2). Spatial patterns of TPCB showed a general increase from station P02 to station P17, with secondary peaks centered at stations P11 and P15. This pattern corresponds closely to the pattern observed for concentrations in the sediment. The correlation (r) between TPCB in tissue and TPCB in sediment was examined for the Paleta stations alone (Table 8-11), and for the overall data set including Chollas, Paleta, and reference stations (Table 8-12). For this analysis, tissue concentrations were normalized to lipid content, and sediment concentrations were normalized to TOC. For the Paleta stations alone, a statistically significant correlation was observed for TPCB with a correlation coefficient of 0.91. For the overall data set, a statistically significant correlation was also found for TPCB (r=0.84).

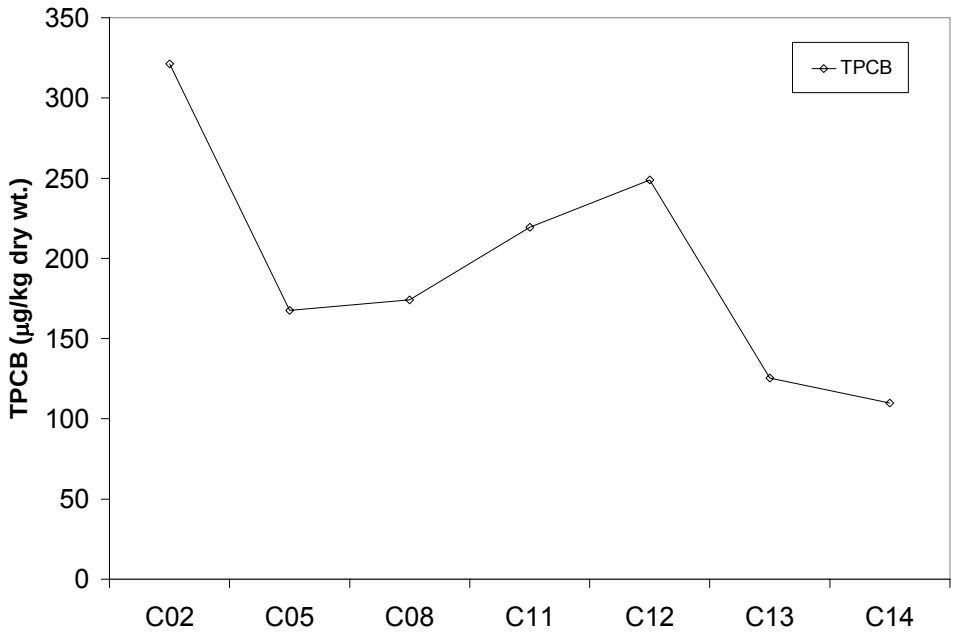


Figure 8-7. Spatial variation of tissue PCBs along the Chollas transect.

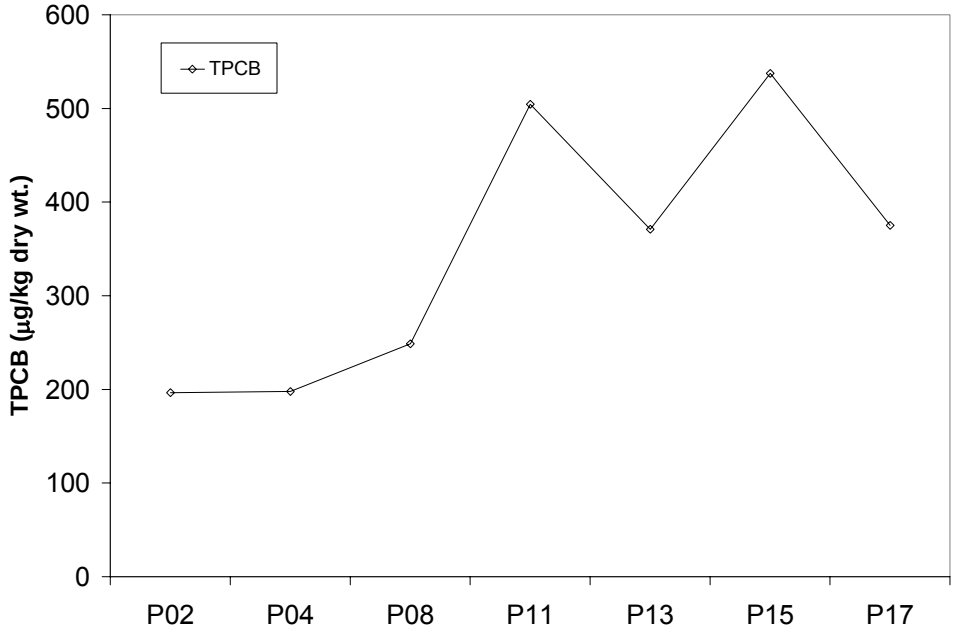


Figure 8-8. Spatial variation of tissue PCBs along the Paleta transect.

8.5 PESTICIDES

Concentrations of pesticides in the tissues of clams exposed to site sediments were characterized at all reference and a subset of the Chollas and Paleta study stations. Tissue concentrations were also characterized for clams prior to the sediment exposure (T_0) and for clams exposed to control (home) sediment. Tissues were analyzed for the same range of pesticides as described previously for the sediment analysis. Study stations that were characterized included Chollas stations C02, C05, C08, C11, C12, C13, and C14 (Figure 5-1) and Paleta stations P02, P04, P08, P11, P13, P15, and P17 (Figure 5-2). Tissue concentrations reflect the uptake of pesticides from site sediments as regulated by their concentration and bioavailability in the sediment. Results for the TCHLOR and TDDT summations at reference, Chollas, and Paleta stations are given below. The complete set of data can be found in Appendix B.

8.5.1 Control and T_0

Pesticide results for the control and T_0 samples are shown in Table 8-8 and Table 8-9. Three composite control samples were analyzed, and one T_0 sample. Each control sample was composited from clams in five separate exposure chambers containing home sediment. Pesticide concentrations in the control tissues were generally low, and comparable to or lower than the T_0 concentrations, indicating that no significant accumulation occurred for clams exposed to the control sediments. Variation among the control replicates was low indicating consistency among the exposures and analytical procedures. For example, TCHLOR in the control sample tissues ranged from 0.3 to 0.5 μg/kg, with an RSD of only 31%, and TDDT ranged from 2.3 to 2.8 μg/kg, with an RSD of only 10%. The ratio of the mean control tissue concentration to the T_0 concentration ranged from about 0.8 for TCHLOR, to about 1.8 for TDDT. Thus results from the control samples provide a useful initial baseline for comparison of tissue concentrations from the reference and site stations.

8.5.2 Reference

Pesticide results for the reference stations are shown in Table 8-8 and Table 8-9. The tissue concentration for each reference station represents the composite of five replicate laboratory exposures. In addition, for station CP2433, three field replicates were collected and a composite sample was analyzed from five replicate laboratory exposures for each field replicate. The reported pesticide values for station CP2433 are thus the means of these three field replicates. TCHLOR concentrations at the reference stations ranged from 0.2 to 26 μg/kg, with an RSD of 197%. TDDT had a similar range of variation at the reference sites (7.3 to 39 μg/kg) with an RSD of 83%. Most of the variability was associated with elevated accumulation at CP2440, corresponding to the elevated sediment levels previously described at that station. Reference station mean tissue concentrations of pesticides were generally higher than the control samples including TCHLOR (13X) and TDDT (5.8X). These results indicate that reference areas of San Diego Bay have higher bioaccumulation potential for pesticides compared to the control sediments.

8.5.3 Chollas Site

Pesticide results for the Chollas stations are shown in Table 8-8 and Table 8-9. The tissue concentration for each station represents the composite of five replicate laboratory exposures. In addition, for station C08, three field replicates were collected and a composite sample was analyzed from five replicate laboratory exposures for each field replicate. The reported pesticide values for station C08 are thus the means of these three field replicates. The range of TCHLOR

concentrations across the Chollas stations was higher than that for the control samples and reference stations, while the range of concentrations for TDDT was comparable to the reference stations, but higher than the control samples. For example, TCHLOR concentrations ranged from 20.7 to 35 μg/kg, with an RSD of 21%, and TDDT concentrations ranged from 15.5 to 30 μg/kg, with an RSD of 24%. Chollas results compared to reference showed higher levels for station-mean TCHLOR (5.1X) and TDDT (1.4X). Among the Chollas stations, C11 had the highest concentration of TCHLOR and C12 had the highest concentration of TDDT, while station C13 had the lowest TCHLOR level and station C14 had the lowest TDDT level. Overall, the results indicate that Chollas stations generally have higher bioaccumulation potential for TCHLOR compared to the reference or control sediments, whereas TDDT showed comparable bioaccumulation potential to the reference stations, but higher than the control samples.

The spatial distribution of tissue pesticides at the Chollas site is shown in Figure 8-9. The stations follow a transect that runs from the outer pier area to the inner creek (Figure 5-1). Spatial patterns of TCHLOR and TDDT showed similar patterns with relatively constant levels from C02 to C08 followed by a peak in the area of stations C11-C12, and a subsequent decrease in concentration toward the creek mouth at C14. This pattern varies from the pattern of concentrations in the sediment which consistently showed highest pesticide levels at C14 near the creek mouth. Correlations (r) between pesticides in tissue and pesticides in sediment were examined for the Chollas stations alone (Table 8-10), and for the overall data set including Chollas, Paleta, and reference stations (Table 8-12). For this analysis, tissue concentrations were normalized to lipid content, and sediment concentrations were normalized to TOC. For the Chollas stations alone, no statistically significant correlations were observed for TCHLOR or TDDT. For the overall data set, statistically significant correlations were found for both TCHLOR and TDDT with correlation coefficients of 0.67 and 0.70 respectively.

8.5.4 Paleta Site

Pesticide results for the Paleta stations are shown in Table 8-8 and Table 8-9. The tissue concentration for each station represents the composite of five replicate laboratory exposures. In addition, for station P11, three field replicates were collected and a composite sample was analyzed from five replicate laboratory exposures for each field replicate. The reported pesticide values for station P11 are thus the means of these three field replicates. The range of TCHLOR and TDDT concentrations across the Paleta stations was higher than that for the control samples and reference stations. For example, TCHLOR concentrations ranged from 3.6 to 52 μg/kg, with an RSD of 80%, and TDDT concentrations ranged from 10 to 73.3 μg/kg, with an RSD of 64%. Paleta results compared to reference showed higher levels for station-mean TCHLOR (4.7X) and TDDT (2.9X). Among the Paleta stations, P15 had the highest concentration of TCHLOR and TDDT, while station P02 had the lowest TCHLOR and TDDT level. Overall, the results indicate that Paleta stations generally have higher bioaccumulation potential for TCHLOR and TDDT compared to the reference or control sediments.

The spatial distribution of tissue pesticides at the Paleta site is shown in Figure 8-10. The stations follow a transect that runs from the outer pier area to the inner creek (Figure 5-2). Spatial patterns of TCHLOR and TDDT showed similar patterns with a general increasing trend from P02 near the pier head to P17 near the creek mouth. This pattern is similar to the pattern of concentrations in the sediment. Correlations (r) between pesticides in tissue and pesticides in sediment were examined for the Paleta stations alone (Table 8-11), and for the overall data set including Chollas, Paleta, and reference stations (Table 8-12). For this analysis, tissue concentrations were normalized to lipid content, and sediment concentrations were normalized

to TOC. For the Paleta stations alone, statistically significant correlations were observed for both TCHLOR and TDDT with correlation coefficients of 0.96 and 0.94 respectively. For the overall data set, statistically significant correlations were also found for both TCHLOR and TDDT with correlation coefficients of 0.67 and 0.70 respectively.

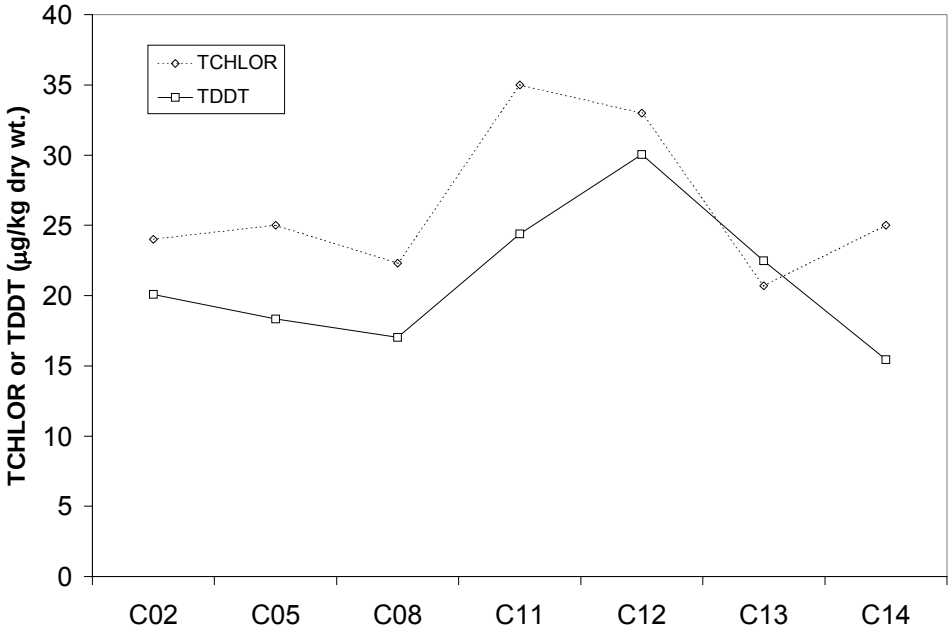


Figure 8-9. Spatial variation of tissue pesticides along the Chollas transect.

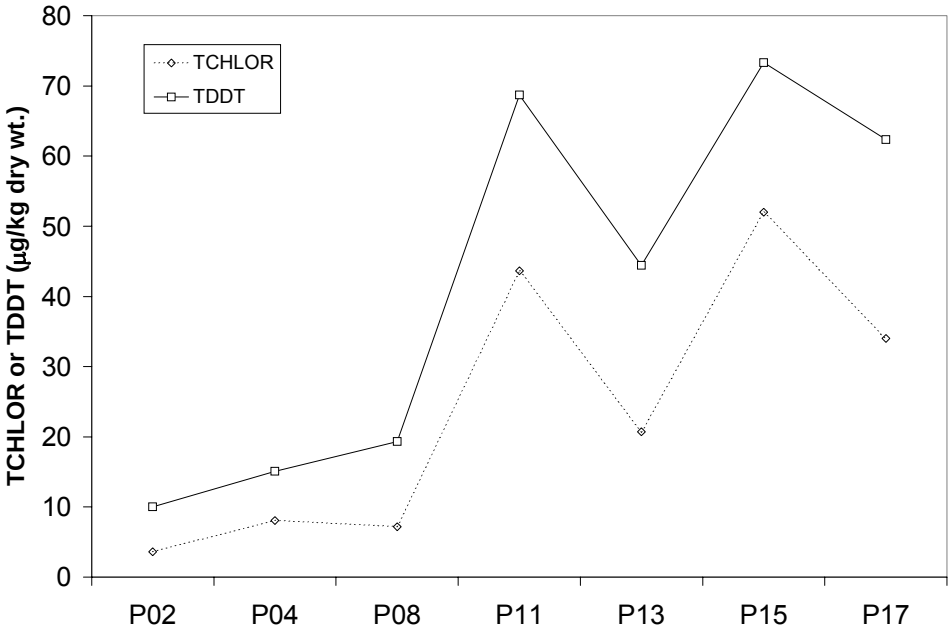


Figure 8-10. Spatial variation of tissue pesticides along the Paleta transect.

9.0 TOXICITY RESULTS

9.1 BULK SEDIMENT TOXICITY

Test samples were classified as toxic if the mean amphipod survival was significantly less than the control ($p \leq 0.05$, t-test) and was also less than the MSD (minimum significant difference) value of 75% of the control. The MSD value was based on analyses conducted by the UC Davis Marine Pollution Studies Laboratory.

9.1.1 Reference Sites

Amphipod survival in the reference site sediments ranged from 76 - 95% of the control mean, after removing outliers (Table 9-1, Table 9-2). Of the six reference site stations, three stations (CP2241, CP2238 and CP2243) had sediments that were marginally toxic (significantly different, but ≥75% of control survival). The remaining three sites were not toxic to amphipods.

The concentration of unionized ammonia among the six reference sites ranged from 0.011 - 0.653 mg/L NH_3 in the overlying water, and from 0.008 - 0.159 mg/L NH_3 in the porewater (Table 9-3). These concentrations are below the toxic effects threshold for *Eohaustorius estuarius* survival (1.15 mg/L NH_3). Therefore ammonia did not cause the toxicity to the amphipods.

9.1.2 Chollas Site

Amphipod survival in Chollas site sediments ranged from 52 - 96% of the control mean, after removing outliers (Table 9-1). Of the 14 Chollas stations, seven had sediments that were marginally toxic to the amphipods (significantly different, but ≥ 75% of control survival), while six sites were toxic (significantly different and <75% of control survival). The concentration of unionized ammonia ranged from 0.004 - 0.324 mg/L NH_3 in the overlying water, and from 0.006 - 0.041 mg/L NH_3 in the porewater (Table 9-3). These concentrations are below the toxic effects threshold for *Eohaustorius estuarius* survival (1.15 mg/L NH_3). Therefore ammonia did not cause the toxicity to the amphipods.

The greatest toxic effects among Chollas stations were associated with sediments from the inner channel, and along the sides of the outer channel (Figure 9-1). Amphipod survival for stations C13 and C14 (located within the inner channel) was 78 and 53% of the control survival, respectively. Survival at stations C01 and C06 (located on the sides of the outer channel area) were 59 and 62% of the control, respectively.

9.1.3 Paleta Site

Amphipod survival in Paleta site sediments ranged from 50 - 98% of the control mean, after removing outliers (Table 9-2). Sediment from station P11 was toxic to amphipods (50% of control survival). Eight other stations were marginally toxic (significantly different from the control, all of these were ≥75% control survival). The concentrations of unionized ammonia in the overlying water (<0.001 - 0.173 mg/L NH_3, Table 9-3) and porewater (<0.001 - 0.055 mg/L NH_3) were below the toxic effects threshold for *E. estuarius* survival.

The Paleta site station that was toxic to amphipods was located in the inner channel area (Figure 9-2). The eight sites with marginal toxicity were evenly divided among the inner and outer channel areas.

9.2 PORE WATER TOXICITY

Test samples were classified as toxic if the mean sea urchin fertilization was significantly less than the control ($p \leq 0.05$, t-test) and was also less than the MSD (minimum significant difference) value of 88% of the control. The MSD value was based on analyses conducted by the UC Davis Marine Pollution Studies Laboratory.

9.2.1 Reference

Sea urchin fertilization in 100% porewater ranged from 36 – 102% of the control mean (Table 9-1). The porewater from stations CP2231, CP2440, and CP2238 was toxic (significantly different and <88% control) to sea urchin gametes (36, 85, and 66% of control fertilization, respectively). Pore water from the remaining three sites was not toxic.

The concentrations of unionized ammonia in the porewater samples ranged from 0.001 - 0.005 mg/L NH_3, which is below the toxic effects threshold for *S. purpuratus* gametes (0.44 mg/L NH_3). Therefore ammonia did not cause the toxicity (Table 9-3).

9.2.2 Chollas Site

Sea urchin fertilization in 100% porewater ranged from 0 - 106% of the control mean (Table 9-1). Stations C12, and C13 were the only sites with porewater that was toxic to sea urchin gametes (80%, and 0% of control fertilization, respectively). One site (C10) had marginal toxicity (significantly different, but $\geq$88% of control fertilization; C10 = 88%), while the remaining 11 sites were not toxic. The concentrations of unionized ammonia in the porewater samples ranged from <0.001 - 0.007 mg/L NH_3, which is below the toxic effects threshold for *S. purpuratus* gametes (0.44 mg/L NH_3) (Table 9-3). Therefore ammonia did not cause the toxicity.

Toxic stations C13 and C12 were both located in the inner channel of the Chollas site (Figure 9-3). The marginally toxic station (C10) was located in the outer channel area.

9.2.3 Paleta Site

Sea urchin fertilization in 100% porewater ranged from 71 - 120% of the control mean (Table 9-2). Pore water from two of the stations were toxic to sea urchin gametes (P01 = 71%, P02 = 78% control fertilization). The remaining Paleta site stations were not toxic. The concentrations of ammonia were not measured in any of the Paleta site porewater samples for the sea urchin fertilization test. However, ammonia concentrations were measured in porewater from the accompanying amphipod test that used these same sediments. The concentration of porewater unionized ammonia in the amphipod test ranged from (<0.001 - 0.055 mg/L NH_3), which is below the toxic effects threshold for *S. purpuratus* gametes (Table 9-3).

The two stations that were toxic to sea urchin gametes were both located in the outer channel area, closest to San Diego Bay (Figure 9-4).

9.3 SEDIMENT-WATER INTERFACE TOXICITY

Test samples were classified as toxic if the mean sea urchin embryo development was significantly less than the control ($p \leq 0.05$, t-test) and was also less than the MSD (minimum significant difference) value of 59% of the control. The MSD value was based on analyses conducted by the UC Davis Marine Pollution Studies Laboratory.

9.3.1 Reference

Embryo development in the sediment-water interface tests ranged from 88-116% of the control mean, after removing outliers and correcting for NH_3 influence (Table 9-1). None of the sediments were toxic to sea urchin embryos after removing outliers and correcting for NH_3 influence.

Ammonia outliers were identified in at least one replicate from five of the six reference stations. Stations CP2440 and CP2433 each had one outlier, station CP2441 had two outliers, and stations CP2231 and CP2243 each had three outliers. All replicates from station CP2231 were determined to be outliers, and no usable data were obtained from this station.

Two stations had data that were corrected for ammonia influence. Stations CP2238 and CP2440 each had one replicate that was influenced by ammonia. The percent normal embryo development for the replicate from station CP2238 increased from 69 to 100% of the control after correcting for ammonia, while the replicate from station CP2440 increased from 11 to 100% of the control.

9.3.2 Chollas Site

Embryo development in the sediment-water interface tests with Chollas site sediments ranged from 24 - 90% of the control mean, after removing outliers and correcting for ammonia influence (Table 9-1). Six of the stations inhibited embryo development relative to the seawater control, but only three stations had results below the MSD value and were classified as toxic to sea urchin embryos. The other eight stations were not toxic.

Concentrations of unionized ammonia ranged from <0.001 - 0.099 mg/L NH_3 Table 9-3). One replicate from station C09 was removed due to ammonia. Four other stations had data that were corrected for ammonia-influence. Stations C08 and C12 had one replicate that was influenced by ammonia, while station C03 had two replicates with NH_3-influence. All four replicates from station C04 were influenced by ammonia.

Toxic sediments were found in both the inner and outer channel areas (Figure 9-5). The center and southern portions of the outer channel area were toxic, as were some areas of the inner channel. Sediment from the middle portion of the inner channel was not toxic.

9.3.3 Paleta Site

Embryo normal development in the sediment-water interface tests ranged from 10 - 110% of the control mean, after removing outliers and correcting for ammonia influence (Table 9-2). Four of the stations had sediments that were toxic to sea urchin embryos (stations P11, P15, P16 and P17). All of the toxic stations were located in the inner channel area, where four of the seven inner channel stations were toxic (Table 9-2, Figure 9-6). Two of the three inner channel stations that were not toxic had relatively low normal development (station P12 = 54%, station P14 = 66% control). However, station P12 only had one replicate after removing outliers, and could not be statistically evaluated against the control, and station P14 had a high variability (coefficient of variation = 40%).

Concentrations of unionized ammonia ranged from <0.001 - 0.495 mg/L NH_3 Table 9-3). Five stations had at least one replicate that was removed as an outlier due to ammonia. Stations P08, P11 and P14 each had one outlier replicate, while stations P12 and P13 had three outlier replicates. All four replicates from stations P03 and P10 were removed as outliers. Nine other

stations had data that were corrected for ammonia influence: stations P07, P08, P12, P13, P15 and P17 each had one replicate that was influenced by ammonia, while station P05 had two replicates with NH_3-influence and stations P11 and P14 had three replicates influenced by ammonia.

Table 9-1. Toxicity of reference site sediments collected in July 2001, and the Chollas site sediments using whole sediment, sediment-water interface, or porewater toxicity tests. * = Marginal toxicity (significantly different, but ≥ threshold based on MSD from control; ** = Toxic (significantly different and <MSD threshold). MSD thresholds were 75% for amphipod survival , 59% for sea urchin embryo development, and 88% for sea urchin fertilization. † = The seawater control from the reference toxicant test was used for statistical comparison in the sea urchin fertilization test with the porewater samples. The reference samples from July were collected and tested concurrently with the Chollas site sediments.

Sample	Amphipod 10 day survival Whole Sediment					Sea urchin development Sediment-water interface				Sea urchin fertilization 100% Pore water			
	Mean	Mean, Outliers Removed	Std Dev	% Control	Sig. Diff. from Control	Mean	Mean, Outliers Removed, NH_3 Corrected	Std Dev	Sig. Diff. from Control	Mean	Std Dev	% Control	Sig. Diff. from Control
July 2001													
Home Sediment	91	99	2.5	100									
Core Tube Blank						84	100	6.6					
Seawater control										36	32	38	
Reference Toxicant Seawater Control										93	8.8	100†	
CP2231	35	75	14.1	76		0	All Outliers			61	13	66	**
CP2243	50	83	16.1	84		44	106	6.7		91	2.1	97	
CP2433	83	83	13	84	*	77	116	4.3		93	2.6	100	
CP2440	81	94	4.8	95		63	99	1.9		79	3.8	85	**
CP2441	71	81	13.8	82	*	27	89	-		96	1.7	102	
C01	38	58	12.6	59	**	61	72	46.3		84	4.8	90	
C02	71	71	8.9	72	**	65	77	22.7		93	3.3	100	
C03	75	75	6.1	76	*	36	62	21.8	*	99	0.5	106	
C04	61	70	10.8	71	**	30	79	21.9		87	4.6	93	
C05	79	79	10.8	80	*	59	70	61.3		92	2.4	98	
C06	61	61	23.3	62	**	50	60	35.5		88	6.1	94	
C07	93	93	4.5	94	*	76	90	12.7		94	4.5	101	
C08	95	95	3.5	96	*	62	82	18.9		96	1	103	
C09	69	79	11.1	80	*	20	32	24.1	**	88	4.2	95	
C10	43	68	15.3	69	**	53	63	23.6	*	82	3.3	88	*
C11	90	90	9.4	91	*	65	77	5.4	*	92	6.7	99	
C12	91	91	8.9	92		15	24	7.9	**	75	5.6	80	**
C13	38	78	3.5	78	*	74	88	9.8		0	0	0	**
C14	21	53	3.5	53	**	28	33	42.6	**	86	5.6	92	

Table 9-2. Toxicity of the reference station collected in August 2001, and the Paleta site sediments using whole sediment, sediment-water interface, or porewater toxicity tests. * = Marginal toxicity (significantly different, but ≥ threshold based on MSD from control; ** = Toxic (significantly different and <MSD threshold). MSD thresholds were 75% for amphipod survival , 59% for sea urchin embryo development, and 88% for sea urchin fertilization.

Sample	Amphipod 10 day survival Whole Sediment					Sea urchin development Sediment-water interface				Sea urchin fertilization 100% Pore water			
	Mean	Mean, Outlier Removed	Std Dev	% Control	Sig. Diff. from Control	Mean	Mean, Outliers Removed, NH_3 Corrected	Std Dev	Sig. Diff. from Control	Mean	Std Dev	% Control	Sig. Diff. from Control
August 2001													
Home Sediment	94	94	6.5	100									
Screen Tube Blank						75	100	6.1					
Seawater Control										82	13	100	
Reference Toxicant Seawater Control										34	27.1	41	
CP2238	85	85	7.9	90	*	50	88	50.9		29	8.8	36	**
P01	90	90	10	96		60	80	52.1		58	5	71	**
P02	82	82	12	87	*	79	104	16.6		64	5.7	78	**
P03	92	92	7.6	98		1	All outliers			93	2	113	
P04	83	83	9.1	88	*	83	110	13.1		83	8.3	101	
P05	78	88	9	93		52	80	18.3		85	3.6	104	
P06	88	88	9.7	94		73	97	19.5		70	6.4	85	
P07	91	91	6.5	97		68	96	47.4		94	3.5	115	
P08	82	82	7.6	87	*	54	106	9.5		72	1.7	88	
P09	92	92	6.7	98		67	88	22.6		83	2.4	101	
P10	73	84	4.8	89	*	10	All outliers			91	1.3	111	
P11	47	47	11	50	**	7	47	21.2	**	88	4.2	107	
P12	78	88	6.5	93		0	54	-		95	3.6	116	
P13	70	79	4.8	84	*	25	100	-		82	1.5	100	
P14	76	86	7.5	92		19	66	26.8		96	1.5	117	
P15	80	80	7.1	85	*	16	27	8.8	**	97	1.7	118	
P16	79	79	10.1	84	*	7	10	10.7	**	97	1.6	118	
P17	84	84	6.5	89	*	32	47	46.1	**	98	0.8	120	

Table 9-3. Concentrations of unionized ammonia (mg/L). Water quality measurements were made on the individual replicates for the sediment-water interface test, whereas a single replicate was used for water quality measurements in the amphipod survival test. For the sea urchin fertilization test, water quality measurements were made on the porewater before it was distributed to the individual replicate containers. Bolded values indicate exceedance of the toxic effects threshold for the species being tested (threshold for *E. estuarius* survival = 1.15 mg/L NH_3, *S. purpuratus* embryo development = 0.033 mg/L NH_3, *S. purpuratus* fertilization = 0.44 mg/L NH_3). NA = not measured.

	Bulk Sediment Amphipod Survival				Sediment-Water Interface Sea Urchin Development			Pore Water Sea Urchin Fertilization
	Overlying Water		Pore Water					
Station	Initial	Final	Initial	Final	Replicate	Initial	Final	
CP2231	0.059	0.653	0.107	0.087	1	**0.061**	**0.185**	0.002
					3	**0.072**	**0.170**	
					4	**0.074**	**0.235**	
CP2243	0.012	0.105	0.033	0.159	1	0.016	**0.066**	0.001
					2	0.015	**0.058**	
					3	**0.062**	**0.114**	
					4	**0.190**	**0.792**	
CP2433	0.011	0.023	0.008	0.009	1	**0.039**	**0.098**	0.002
					2	**0.047**	**0.085**	
					3	0.031	0.019	
					4	0.023	**0.035**	
CP2440	0.013	0.119	0.017	0.023	1	0.033	**0.088**	0.001
					2	**0.054**	**0.092**	
					3	**0.078**	**0.043**	
					4	0.030	**0.114**	
CP2441	0.022	0.322	0.018	0.052	1	**0.045**	**0.155**	0.005
					2	0.014	**0.068**	
					3	**0.108**	**0.163**	
					4	**0.056**	**0.261**	
CP2338	0.023	0.131	0.029	0.048	1	NA	0.015	NA
					2	NA	**0.052**	
					3	NA	0.010	
					4	NA	**0.102**	
C01	0.008	0.191	0.009	0.013	1	0.020	**0.046**	0.003
					3	0.022	**0.059**	
C02	0.009	0.102	0.012	0.022	1	0.022	0.024	0.002
					2	0.032	0.031	
					3	0.021	**0.035**	
					4	0.029	0.022	

	Bulk Sediment				Sediment-Water Interface			Pore Water
	Amphipod Survival				Sea Urchin Development			Sea Urchin Fertilization
	Overlying Water		Pore Water					
Station	Initial	Final	Initial	Final	Replicate	Initial	Final	
C03	0.004	0.012	0.008	0.009	1	0.023	0.023	<0.001
					3	**0.039**	0.033	
					4	**0.039**	**0.057**	
C04	0.013	0.089	0.009	0.009	1	**0.044**	**0.059**	0.002
					2	**0.048**	**0.064**	
					3	0.031	**0.065**	
					4	**0.044**	**0.052**	
C05	0.007	0.035	0.008	0.008	1	**0.035**	0.023	0.001
					2	0.024	0.009	
					4	0.018	0.015	
C06	0.006	0.013	0.010	0.008	1	0.016	**0.041**	<0.001
					2	0.023	0.006	
					3	0.022	0.030	
					4	0.024	0.020	
C07	0.010	0.040	NA	NA	1	0.026	0.013	0.007
					2	0.013	<0.001	
					3	0.002	**0.040**	
					4	0.025	**0.063**	
C08	0.005	0.011	0.014	0.015	1	0.014	NA	<0.001
					2	0.012	<0.001	
					3	0.012	0.008	
					4	**0.038**	**0.068**	
C09	0.009	0.005	0.014	0.008	1	0.020	0.002	0.003
					2	0.014	0.010	
					3	**0.099**	**0.044**	
					4	0.008	0.025	
C10	0.008	0.083	0.008	0.034	1	0.023	0.031	0.002
					2	0.011	<0.001	
					3	0.025	0.008	
					4	0.012	**0.035**	
C11	0.004	0.008	NA	0.023	1	0.014	<0.001	NA
					2	0.021	<0.001	
					3	0.021	<0.001	
					4	0.016	<0.001	
C12	0.011	0.156	0.006	0.041	1	0.008	0.022	0.002
					2	0.021	**0.045**	
					3	0.028	**0.054**	
					4	0.009	NA	

Station	Bulk Sediment Amphipod Survival				Sediment-Water Interface Sea Urchin Development			Pore Water Sea Urchin Fertilization
	Overlying Water		Pore Water					
	Initial	Final	Initial	Final	Replicate	Initial	Final	
C13	0.015	0.324	0.034	0.009	1	0.019	0.032	<0.001
					2	0.015	**0.037**	
					3	**0.035**	0.026	
					4	0.019	<0.001	
C14	0.016	0.121	0.012	0.031	1	0.019	**0.044**	0.003
					2	0.020	0.020	
					3	0.020	**0.035**	
					4	0.029	0.016	
P01	0.098	0.009	0.015	0.020	1	NA	0.022	NA
					2	NA	**0.040**	
					3	NA	**0.048**	
					4	NA	**0.037**	
P02	0.011	0.007	0.015	0.016	1	NA	0.027	NA
					2	NA	0.019	
					3	NA	0.014	
					4	NA	0.030	
P03	<0.001	0.006	0.019	0.025	1	NA	**0.154**	NA
					2	NA	**0.263**	
					3	NA	**0.495**	
					4	NA	**0.218**	
P04	0.007	0.008	0.008	0.015	1	NA	0.013	NA
					2	NA	0.032	
					3	NA	**0.041**	
					4	NA	0.003	
P05	0.007	0.004	0.012	0.019	1	NA	**0.072**	NA
					2	NA	0.015	
					3	NA	**0.039**	
					4	NA	**0.056**	
P06	<0.001	0.007	0.009	0.015	1	NA	0.007	NA
					2	NA	**0.055**	
					3	NA	**0.039**	
					4	NA	0.006	
P07	<0.001	0.005	0.006	0.011	1	NA	0.022	NA
					2	NA	0.020	
					3	NA	**0.065**	
					4	NA	0.022	
P08	0.016	0.031	0.025	0.038	1	NA	**0.078**	NA
					2	NA	**0.142**	

Station	Bulk Sediment Amphipod Survival				Sediment-Water Interface Sea Urchin Development			Pore Water Sea Urchin Fertilization
	Overlying Water		Pore Water					
	Initial	Final	Initial	Final	Replicate	Initial	Final	
					3	NA	**0.050**	
					4	NA	**0.059**	
P09	0.119	0.026	0.023	0.034	1	NA	0.031	NA
					2	NA	0.022	
					3	NA	0.028	
					4	NA	0.022	
P10	0.025	0.091	0.036	0.049	1	NA	**0.105**	NA
					2	NA	**0.135**	
					3	NA	**0.212**	
					4	NA	**0.134**	
P11	0.079	0.011	0.028	0.028	1	NA	**0.064**	NA
					2	NA	**0.096**	
					3	NA	**0.198**	
					4	NA	**0.074**	
P12	0.014	0.021	0.019	0.032	1	NA	**0.162**	NA
					2	NA	**0.095**	
					3	NA	**0.143**	
					4	NA	**0.155**	
P13	0.034	0.119	0.033	0.055	1	NA	**0.148**	NA
					2	NA	**0.079**	
					3	NA	**0.175**	
					4	NA	**0.148**	
P14	0.014	0.072	0.016	0.030	1	NA	**0.065**	NA
					2	NA	**0.087**	
					3	NA	**0.082**	
					4	NA	**0.107**	
P15	0.019	0.043	0.014	0.023	1	NA	<0.001	NA
					2	NA	**0.060**	
					3	NA	**0.048**	
					4	NA	0.012	
P16	0.000	0.071	0.017	0.019	1	NA	**0.052**	NA
					2	NA	**0.044**	
					3	NA	0.028	
P17	0.009	0.173	0.017	0.013	1	NA	0.031	NA
					2	NA	0.029	
					3	NA	**0.056**	
					4	NA	**0.072**	

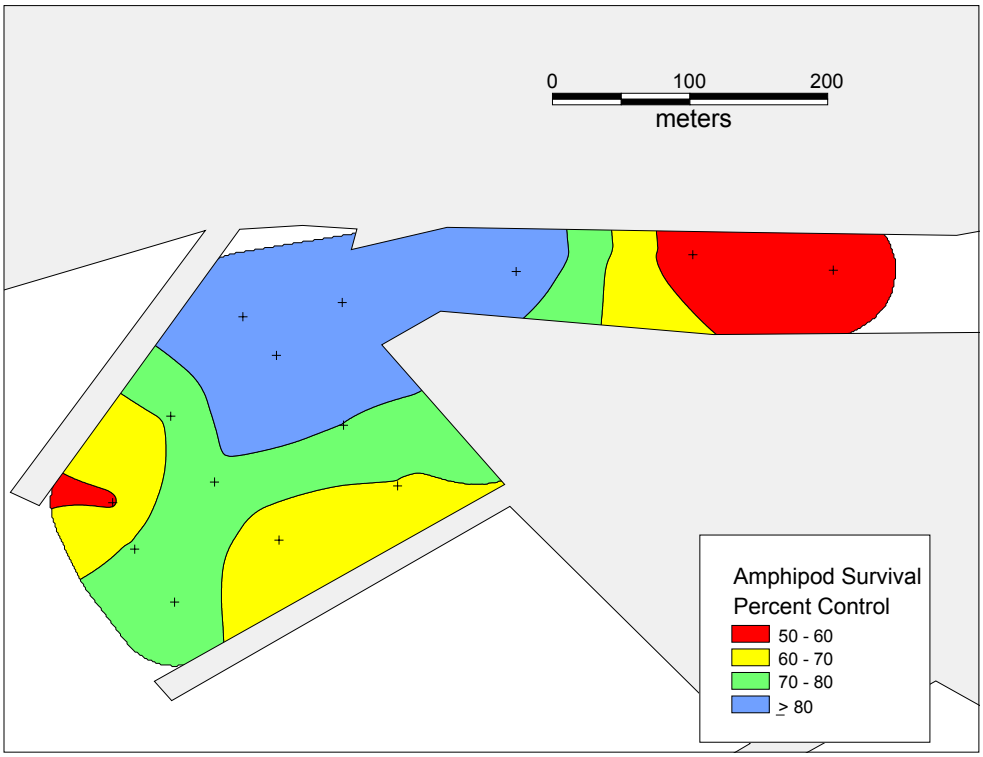


Figure 9-1. Spatial distribution of amphipod survival in Chollas site sediments.

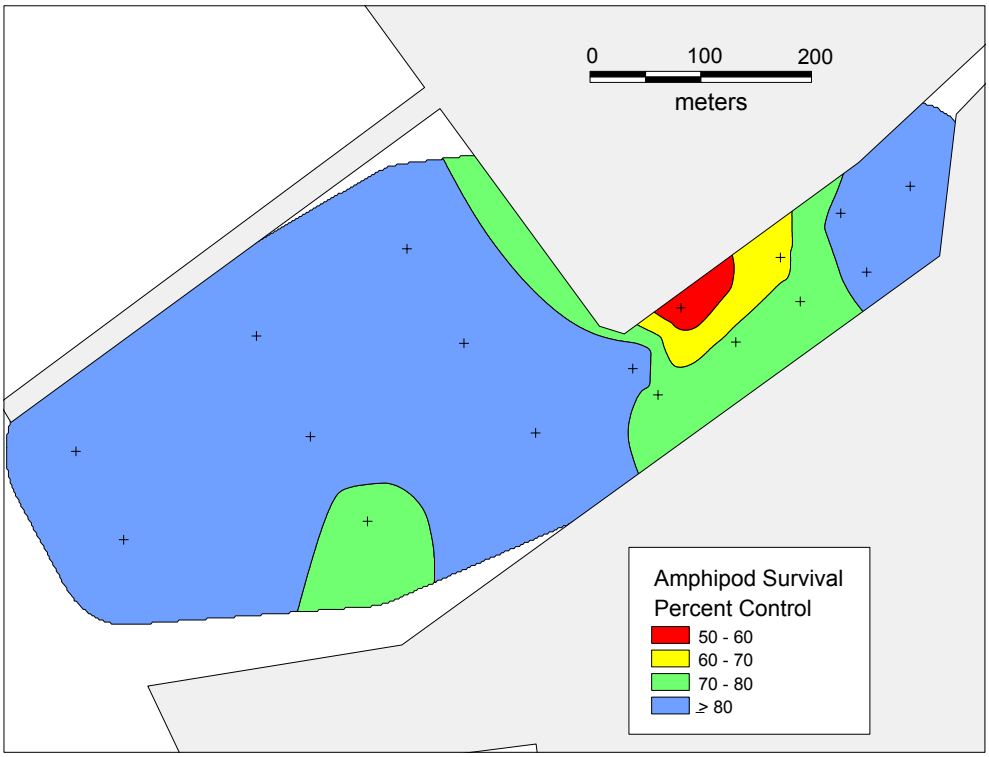


Figure 9-2. Spatial distribution of amphipod survival in Paleta site sediments.

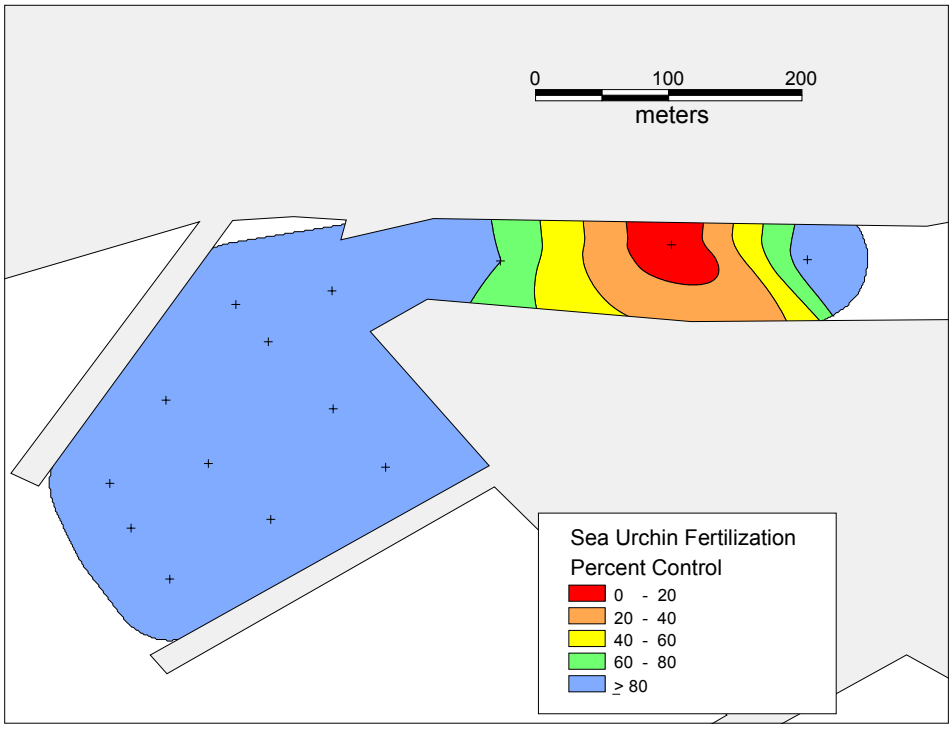


Figure 9-3. Spatial distribution of sea urchin fertilization in Chollas site sediment porewater.

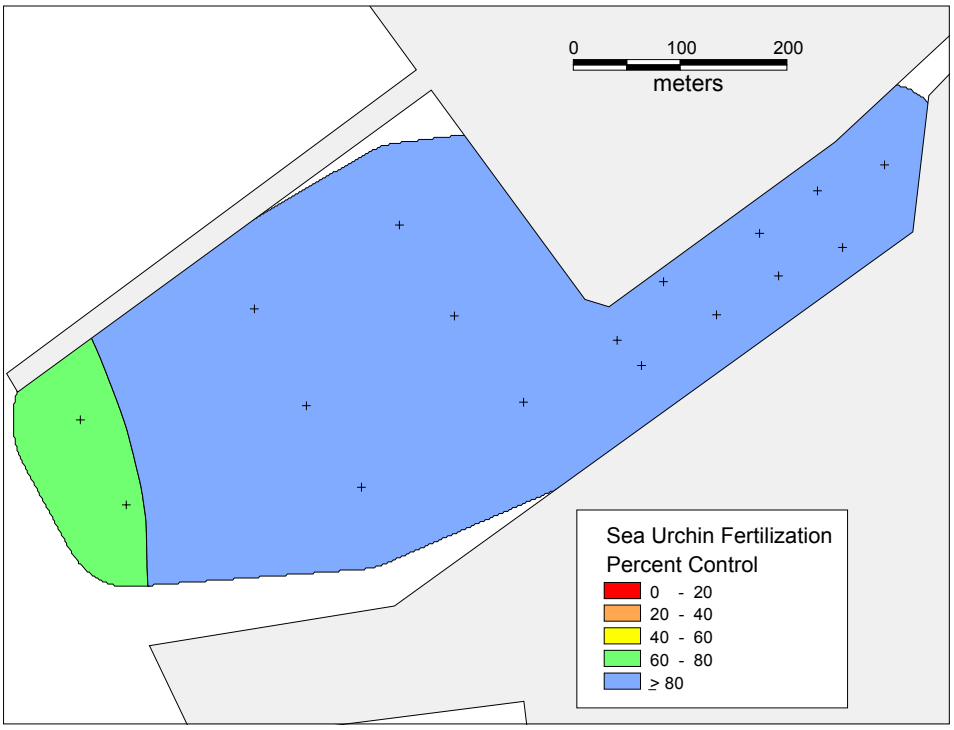


Figure 9-4. Spatial distribution of sea urchin fertilization in Paleta site sediment porewater.

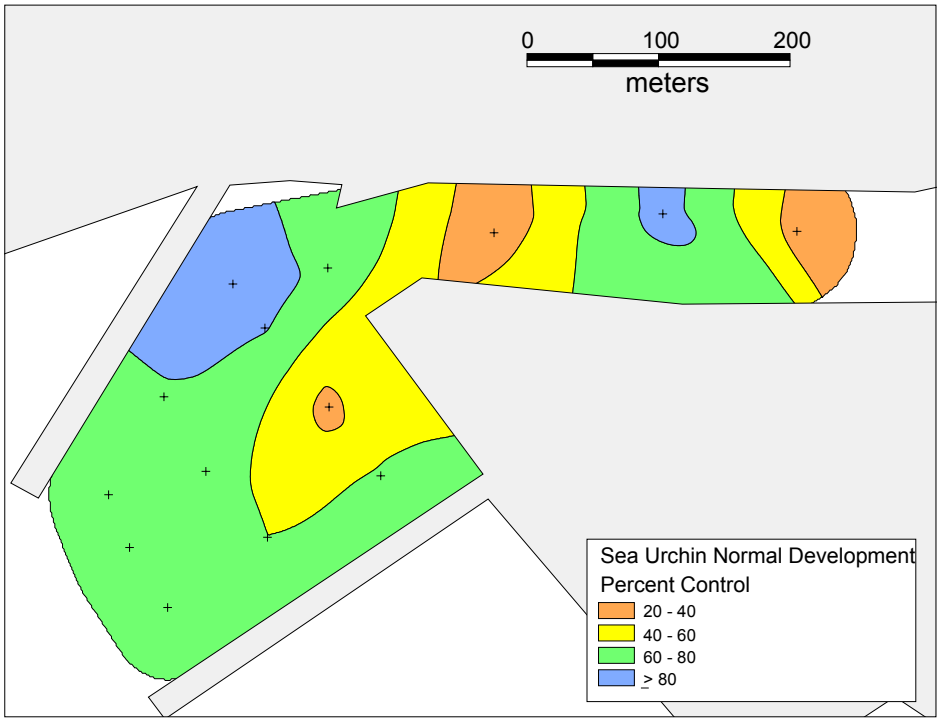


Figure 9-5. Spatial distribution of sea urchin embryo normal development in Chollas site sediment-water interface samples.

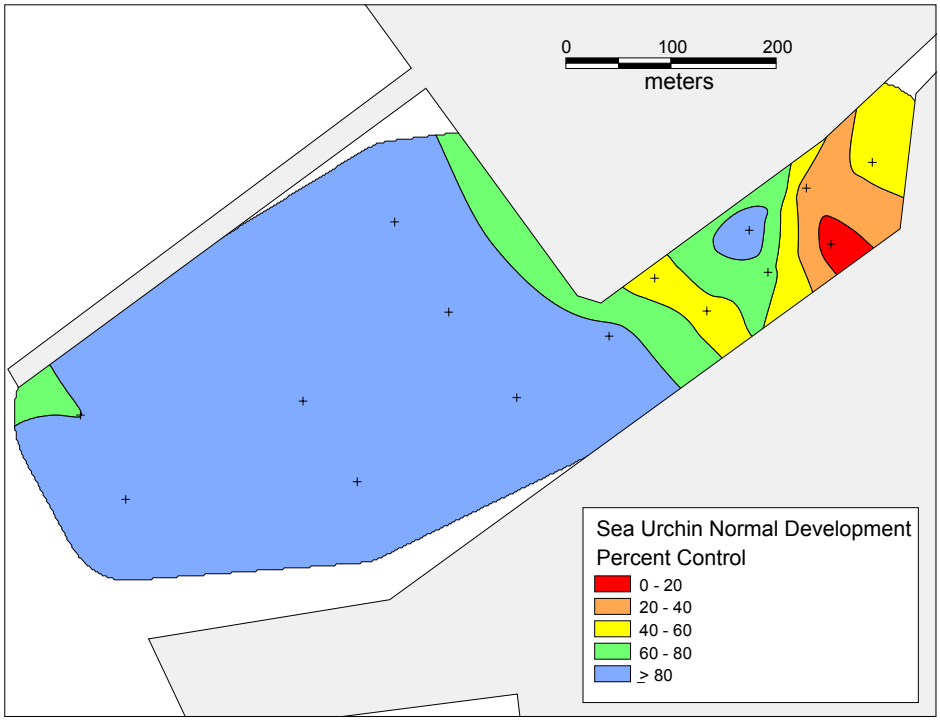


Figure 9-6. Spatial distribution of sea urchin embryo normal development in Paleta site sediment-water interface samples.

9.4 TOXICITY-CHEMISTRY RELATIONSHIPS

Two approaches were used to identify relationships between the toxicity results and sediment contamination. First, spearman nonparametric correlations were calculated using the amphipod survival, sea urchin development, and chemistry data. The analyses were conducted separately for the Chollas and Paleta sites and each set of correlations also included data from the reference stations. The sea urchin fertilization results were not used in this analysis because this test did not detect toxicity at enough stations to indicate relationships. Scatter plots of the toxicity and chemistry results for each station were also used to examine the magnitude of change between the parameters having significant correlations and to help distinguish between spurious and biologically significant patterns.

9.4.1 Chollas Site

Toxicity to amphipods showed a negative correlation with 5 sediment parameters: percent fines, organic carbon, PCBs, chlordane, and DDTs (Table 9-4). No significant negative correlations between amphipod survival and the concentration of metals were found when the concentration data were normalized to sediment fines content. A positive correlation between normalized chromium concentration and survival was present, indicating that the amphipods tended to survive better in sediments containing elevated concentrations of chromium. The positive correlation with chromium may have been related to the presence of paint chips at some of the Chollas stations. Several stations (C07, C08, and C11) had relatively high concentrations of cadmium, chromium, copper, nickel, lead, and zinc with no toxic impact on the test organisms.

The significant correlations between amphipod survival and percent fines or TOC appeared to be largely the result of the presence of high toxicity at station C14 (nearest the mouth of Chollas Creek), which also contained the highest concentrations of fine sediment and organic carbon at the Chollas site. A similar range of percent fines was also present at the reference and Paleta stations with no apparent effect on amphipod survival (Figure 9-7), suggesting that the negative correlation present among the Chollas data represented the influence of other constituents associated with the fine sediments, rather than a direct toxic effect of the fine sediments.

The scatter plots for PCBs, chlordane, and DDTs indicate that higher concentrations of these contaminants were usually associated with substantial toxicity to amphipods and that these constituents may be directly associated with the causes of toxicity to amphipods at the inner portion of the Chollas site (Figure 9-8). The patterns for chlordane and DDT are dominated by high concentrations at stations C13 and C14, reflecting the influence of runoff discharge on sediment contamination and toxicity in the inner portion of the Chollas site.

The toxicity correlation results differ from the bioaccumulation data for Chollas, where no significant correlation between sediment and clam tissue was detected for chlordane and DDTs. The differences in the two sets of correlation results may be due to the use of different species and exposure durations in the toxicity and bioaccumulation tests. The toxicity data differ from bioaccumulation data in that the survival results are not chemical specific. Thus, some of the toxicity correlations may be driven by cross correlations among chemicals, rather than cause and effect relationships. Fewer stations were investigated in the bioaccumulation portion of the study, which also may have contributed to differences in the correlation results. The chlordane bioaccumulation data

for the Chollas site indicate that benthic organisms are likely to be exposed to increased concentrations of chlordane relative to the baseline condition and thus support the inference from the toxicity results that chlordane is a potential cause of sediment toxicity.

Correlation analysis of the sea urchin development results also indicated that toxicity in the water column was most strongly associated with the concentrations of trace organic contaminants. Sea urchin development was negatively correlated with PAHs, PCBs, chlordane, and DDTs (Table 9-4). A plausible relationship between overlying water toxicity and trace organic contamination was indicated by the scatter plots; toxicity was usually present at elevated concentrations of PAHs, PCBs, Chlordane, and DDT (Figure 9-9).

9.4.2 Paleta Site

Amphipod survival among the Paleta stations was negatively correlated with only cadmium (Table 1 4). The correlation with cadmium appeared to be a spurious result that was related to a trend among the nontoxic samples for slightly lower survival at higher normalized cadmium concentrations (Figure 1 8). The only station with significant amphipod toxicity, P11, was notable in having the highest normalized mercury concentration relative to all other stations in the study. No significant correlations with percent fines or sediment organic carbon were indicated, despite the presence of a similar range in values for most of the stations compared to the Chollas site (Figure 1 7). The lack of significant correlations between amphipod toxicity and chemistry is not unexpected, considering that toxicity was present at only one of the Paleta stations.

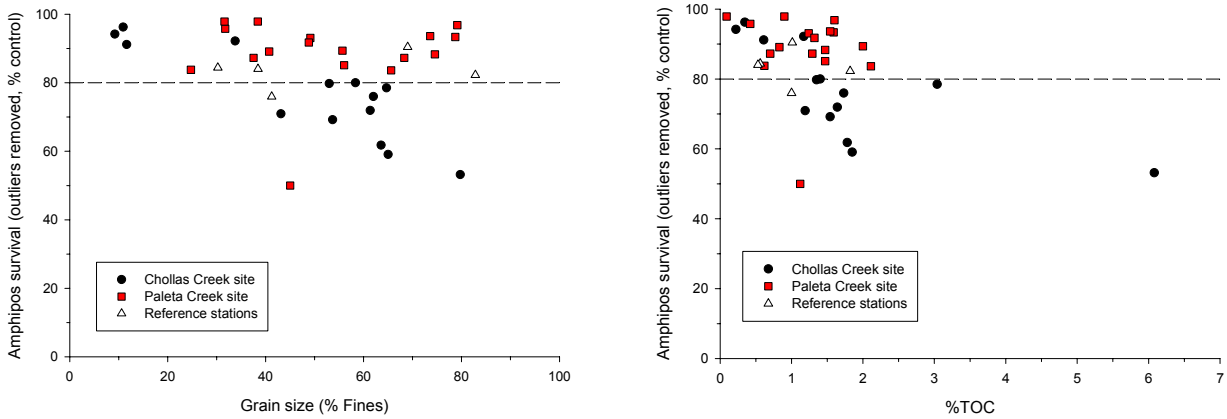
The toxicity to sea urchin embryos from the Paleta stations was negatively correlated with cadmium, lead, PAHs, PCBs, chlordane, and DDTs (Table 9-4). Examination of the scatter plots shows that the correlation results appear to represent patterns in the data that may be directly related to toxic effects. For example, the percentage of normal sea urchin embryos shows a strong and consistent decline with increased concentrations of HMWPAHs, chlordane, and cadmium (Figure 9-9). Furthermore, the patterns of change in toxicity with increased concentration of PAHs, PCBs, chlordane and DDTs is similar between the Paleta and Chollas stations, indicating that the relationship is more likely to be associated with these chemicals as opposed to unmeasured factors.

The toxicity correlation results differ from the bioaccumulation data for Paleta, where significant correlations between sediment and clam tissue were detected for PCBs, chlordane and DDTs. The differences in the two sets of correlation results may be due to the use of different species and exposure durations in the toxicity and bioaccumulation tests. Correlations between toxicity and contaminants were not expected for the Paleta data since the incidence of amphipod toxicity was very low.

Table 9-4. Spearman nonparametric correlation between toxicity and chemistry results. The chemistry data for metals were normalized to the %fines content and the trace organics data were not normalized. Data for the reference stations were included in each correlation analysis.

	Chollas		Paleta	
	Amphipod Survival	Sea Urchin Development	Amphipod Survival	Sea Urchin Development
Fines	-0.62	-0.20	0.04	-0.08
TOC	-0.76	-0.43	-0.07	-0.37
Ag (fn)	0.40	-0.06	-0.07	-0.10
As (fn)	0.35	-0.04	-0.05	0.20
Cd (fn)	0.28	-0.16	-0.51	-0.50
Cr (fn)	0.55	0.11	-0.04	0.04
Cu (fn)	0.19	-0.31	0.14	-0.14
Hg (fn)	0.34	0.08	-0.09	-0.11
Ni (fn)	0.44	-0.05	0.01	-0.10
Pb (fn)	0.23	-0.26	-0.27	-0.56
Zn (fn)	0.24	-0.18	-0.15	-0.38
LMWPAH	-0.43	-0.77	0.07	-0.57
HMWPAH	-0.44	-0.77	-0.15	-0.61
TPCB	-0.56	-0.59	-0.03	-0.60
TCHLOR	-0.53	-0.64	-0.13	-0.64
TDDT	-0.59	-0.65	-0.14	-0.67
Mean SQGQ1	-0.48	-0.71	-0.04	-0.68

Amphipod Survival



Sea Urchin Development

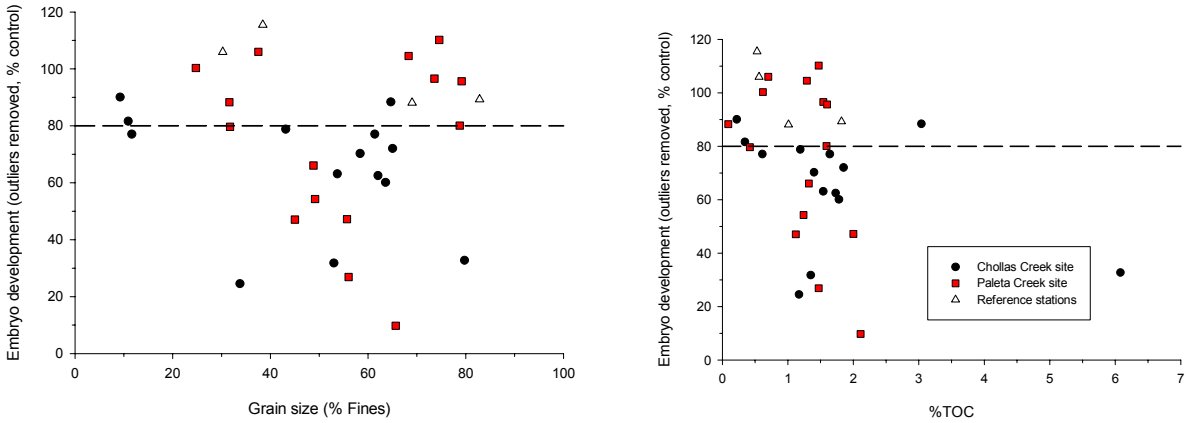


Figure 9-7. Relationship between toxicity test response and sediment grain size or organic carbon. Upper graphs show the results for the amphipod survival test and the lower graphs show the results for the sea urchin development test.

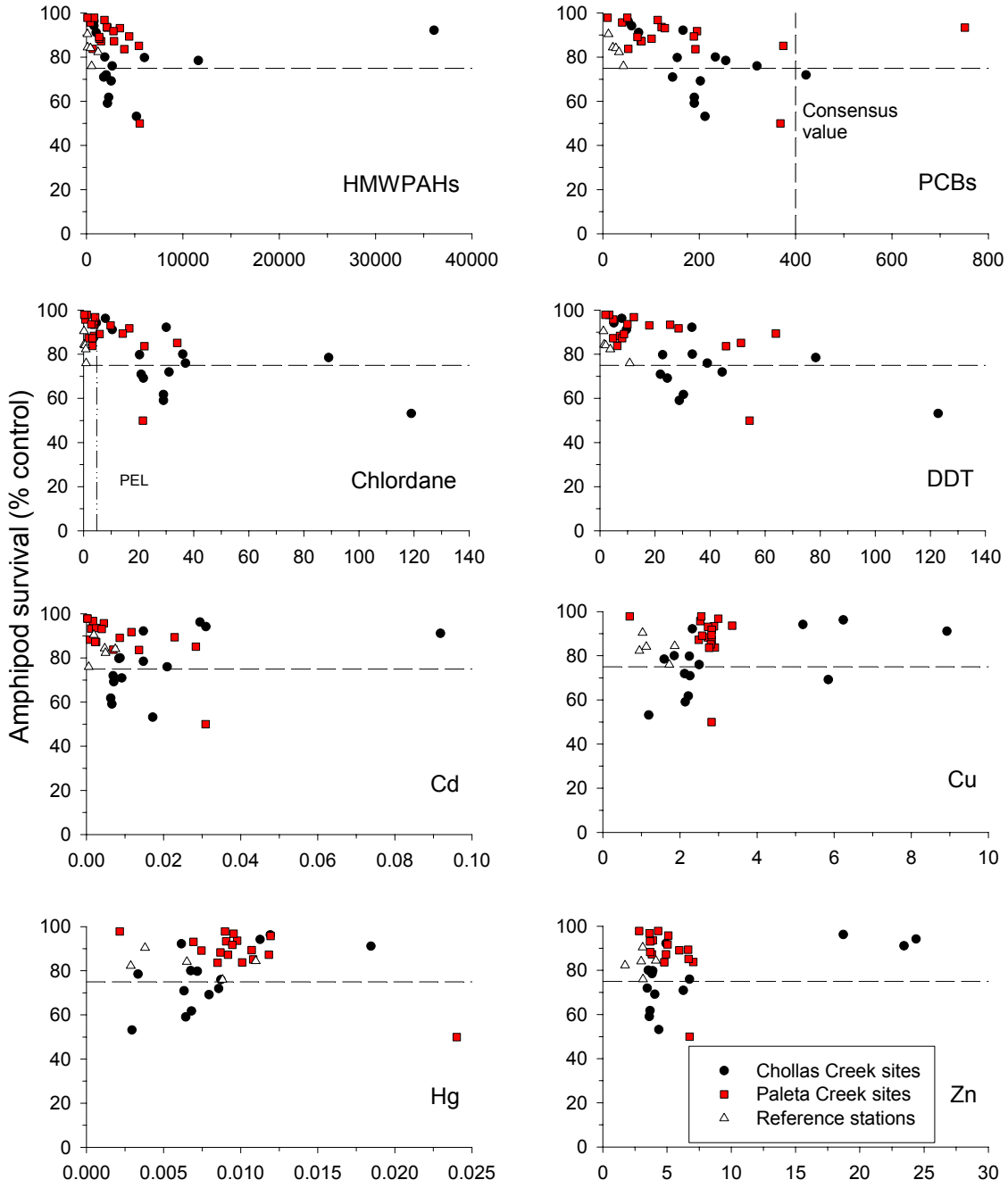


Figure 9-8. Relationship between amphipod toxicity test response and concentration of sediment contaminants. The metals data are normalized to % fines (mg/kg/%fines) and the organics data are expressed as µg/kg.

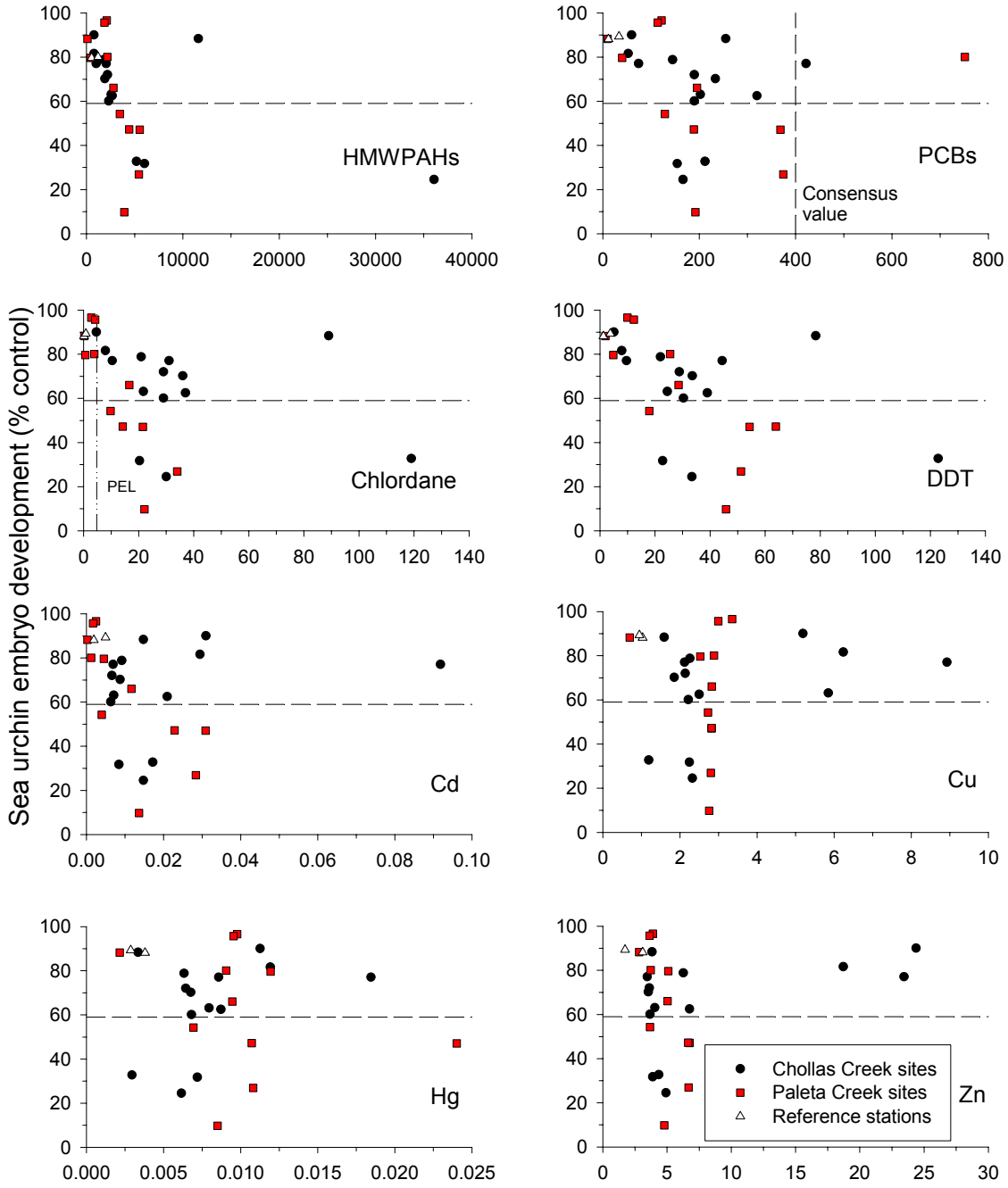


Figure 9-9. Relationship between sea urchin toxicity test response and concentration of sediment contaminants. The metals data are normalized to % fines (mg/kg/%fines) and the organics data are expressed as µg/kg.

10.0 BENTHIC COMMUNITY ANALYSIS

10.1 SPECIES ABUNDANCE

A list of all benthic macrofauna species present at each site and their abundance is included in Appendix D. The common species, defined as those with a total abundance ranked in the top 30 within each study site, are summarized below along with data for several species that are indicators of disturbance associated with pollution gradients.

10.1.1 Reference

The macrofauna community at the reference sites was dominated by polychaetes typical of soft-bottom environments. Twenty polychaete taxa were included in the species ranked in the top 30 based on total abundance at the reference sites (Table 10-1). Eight crustacean taxa and two bivalve taxa were also among the most abundant macrofauna species present. The tanaid crustacean *Kalliapsuedes crassus* was ranked most abundant overall due to the presence of extremely high numbers at station CP2231 (5,128/0.1m^2 grab). *K. crassus* was in low abundance (7) at only one other reference site, yet it was ranked first overall because the high abundance at CP2231 was greater than the total abundance for any other species. *Mediomastus sp* was the next most abundant species observed at any single reference station, with an abundance of 348 at CP2433. Since the high abundance of *K. crassus* at CP2231 was not observed at any other station in the study and the high abundance of K. crassus was likely to influence the occurrence of other species at this station, it was decided to exclude the macrofauna data for CP2231 from the analyses used to determine impacts relative to the reference sites (Section 11).

Six of the top-ranked polychaete species were common in samples from at least five of six reference sites. These included *Scoletoma sp C*, *Mediomastus sp*, *Leitoscoloplos pugettensis*, *Pista agassizi*, *Prionospio heterobranchia*, and *Theora lubrica* (Table 10-1). The bivalve *Musculista senhousia* was also common among the reference sites. Several of the abundant species showed patterns of occurrence that appeared to relate to location in the bay. For example, the polychaete *Chaetozone corona* and the clam *Tagelus subteres* were common only at the three stations located in the upper bay (i.e., CP2433, CP2440, and CP2441). Species that tended to be relatively more abundant at the lower bay stations included the polychaetes *Scyphoproctus oculatus*, and *Harmothoe imbricata* complex.

Three indicators of disturbance or pollution were measured: *Capitella capitata*, *Streblospio benedicti*, and *Euphilomedes carcharodonta*. *Capitella* was present in low abundance only at CP2440 (Table 10-2) This was also the only station where *Euphilomedes* was found. *Streblospio* was not found at any of the reference sites. Amphiurid brittlestars (indicators of relatively undisturbed conditions) were found at five of the six reference sites (Table 10-2). The numbers ranged from 1 specimen at Station CP2440 to 11 specimens at CP2441. Station CP2443 was the only site where no amphiurids were found.

10.1.2 Chollas Site

The common macrofauna present at the Chollas site showed some overlap with the reference stations. Eighteen of the top 30 reference taxa ranks were also among the top 30 at the Chollas stations (Table 10-3). Six of the top ten reference taxa were also ranked in the top ten at Chollas; these taxa included 5 polychaetes (*Scoletoma sp C*, *Exogone lourei*, *Mediomastus sp*, *Leitoscoloplos pugettensis*, *Pista agassizi*) and the infaunal mussel *Musculista senhousia*.

Thirteen of the top 30 Chollas taxa were not common at the reference sites. These taxa included the polychaete *Capitella capitata* (rank 2), which was present in high numbers at the two innermost stations (C13 and C14). Three other polychaetes, *Cossura candida* (rank 8), *Psuedopolydara paucibranciata* (rank 11), and *Scolanthus sp A* (rank 12) were common at most of the outer Chollas sites but were not common at the reference sites. Two additional taxa, Oligochaeta (21 individuals at 5 stations) and the ostracod *Euphilomedes carcharodonta* (41 individuals at 10 sites) were common overall at the Chollas stations but were not among the top 30 at the reference sites.

The species composition of the outer (stations C01-C10) and inner (C11-C14) regions of the Chollas site showed differences in species composition. Only seven of the top 30 taxa were prevalent throughout the entire study site (i.e., present in at least 7 of 10 outer stations and at least two of the inner stations). Eleven of the common taxa were present only at the outer Chollas stations). Three taxa had distributions almost exclusively in the inner portion of the Chollas site: these included two polychaetes (*Capitella capitata* and *Streblospio benedicti*) and one mollusc (*Bulla gouldiana*).

The three indicator species for disturbance and pollution: *Capitella*, *Streblospio*, and *Euphilomedes were* present at some of the Chollas stations. *Capitella* was present at three of the 14 Chollas site stations (Table 10-2). The inner Chollas area had a higher proportion of stations with *Capitella*; two out of four sites in the inner area had *Capitella*, compared to 1 out of 10 sites in the outer area. The inner area also had a greater number of *Capitella* at each site. Seventy five specimens were found at Station C13 and 501 *Capitella* were found at Station C14, while 3 specimens were found at Station C07 in the outer area of the site. Stations C13 and C14 were also the only Chollas site stations with *Streblospio* present. Station C13 had 7 specimens, and Station C14 had 1 present. *Euphilomedes* was found at most Chollas stations (10 out of 13 stations), with numbers of specimens ranging from 1 at Stations C06 and C11 to 8 at Station C02. The proportion of stations with *Euphilomedes* present was similar between inner (75%) and outer (70%) channel areas.

Amphiurids (indicators of relatively undisturbed conditions) were found at only two of the 14 Chollas stations. One specimen was found at Station C07, while three were found at Station C09. Both of these sites are in the outer area.

10.1.3 Paleta Site

Fourteen of the most common reference site macrofauna were also common at the Paleta site (Table 10-4). These overlap species were also common at the Chollas site. Eight of the top 10 taxa at Paleta were also common at the reference and Chollas sites; these taxa included seven polychaetes (*Scoletoma sp C*, *Medioamastus sp*, *Leitoscoloplos pugettensis*, *Pista agassizi*, *Prionospio heterobranchia*, *Exogone lourei*,

and *Lumbrineris erecta*), one bivalve (*Musculista senhousia*), and one amphipod (*Amphideutopus oculatus*).

There were relatively few differences in species presence between the outer and inner areas of the Paleta site. The top twelve taxa were prevalent in both regions (i.e., present at 12 or more of the 17 stations). Only four of the common taxa had a distribution that was entirely or mostly restricted to the inner portion of the site. These taxa included three polychaetes (*Aphelochaeta sp*, *Scoletoma sp A*, and *Harmothoe imbricata*) and one mollusc (*Bulla gouldiana*). Scolelepis sp was the only common species with a distribution restricted to the outer area of the Paleta site; this polychaete was present only at station P07.

The indicator species *Capitella* and *Streblospio* were not found at any of the Paleta stations **(**Table 10-2). *Euphilomedes* was present at twelve of the stations, with counts ranging from 1 specimen at Stations P01, P05, P09, and P14 to 40 specimens at Station P12. The percentage of stations with *Euphilomedes* present was similar between inner (71%, 5 out of 7 sites) and outer (70%, 7 out of 10 sites) creek areas. Only one amphiurid was found at the Paleta site. This specimen was found at Station P01, which is located in the outer creek area.

Table 10-1. Species abundance at reference stations. Numbers indicate rank based on total abundance for all reference stations.

Species	All reference stations	CP2231	CP2238	CP2243	CP2433	CP2440	CP2441
Kalliapsuedes crassus	1	1	10				
Scoletoma sp C	2	8	1	1	2	5	1
Exogone lourei	3	2	22	3		7	
Mediomastus sp	4	5	4	4	5	4	5
Leitoscoloplos pugettensis	5	49	4	9	3	4	2
Pista agassizi	6	6	8	8	12	1	13
Diplocirrus sp SD1	7		22		1	2	11
Scyphoproctus oculatus	8	7	7	2			
Nicolea gracilibranchus	9	3					
Musculista senhousia	10	24	2	4		23	54
Prionospio (Prionospio) heterobranchia	11	11	14	14		6	4
Leptochelia dubia	12	4					
Paracerceis sculpta	13	71	3	14			
Scoletoma sp	14				6	12	3
Neanthes acuminata Cmplx	15	71	6	7			
Edwardsia californica	16		14	6			36
Harmothoe imbricata Cmplx	16	10	14	24			
Syllis (Typosyllis) nipponica	18	15			8	38	
Heterophoxus oculatus	19	14	18	33		20	
Marphysa sp HYP1	20	10					
Theora lubrica	20	49	22	33	12	9	26
Scleroplax granulata	22				4	55	
Pyromaia tuberculata	23	12				38	
Chaetozone corona	24				7	28	8
Dorvillea (Schistomeringos) longicornis	25	30		24		12	26
Euchone limnicola	26	71		33	43	8	
Amphideutopus oculatus	28	71		20	24	10	
Lophopanopeus bellus	28	14					
Lumbrineris erecta	30	18		10	43		
Scoletoma sp A	30				10	23	10
Tagelus subteres	30				16	14	13

Table 10-2. Abundance of indicator species at the study sites.

Station	Number per grab			
	Capitella capitata Complex	*Streblospio benedicti*	*Euphilomedes carcharodonta*	Amphiuridae
CP2231	0	0	0	6
CP2243	0	0	0	0
CP2433	0	0	0	2
CP2440	2	0	16	1
CP2441	0	0	0	11
CP2238	0	0	0	5
C01	0	0	5	0
C02	0	0	8	0
C03	0	0	2	0
C04	0	0	0	0
C05	0	0	0	0
C06	0	0	1	0
C07	3	0	7	1
C08	0	0	0	0
C09	0	0	4	3
C10	0	0	7	0
C11	0	0	1	0
C12	0	0	3	0
C13	75	7	3	0
C14	501	1	0	0
P01	0	0	1	1
P02	0	0	0	0
P03	0	0	0	0
P04	0	0	3	0
P05	0	0	1	0
P06	0	0	0	0
P07	0	0	3	0
P08	0	0	3	0
P09	0	0	1	0
P10	0	0	5	0
P11	0	0	6	0
P12	0	0	40	0
P13	0	0	4	0
P14	0	0	1	0
P15	0	0	0	0
P16	0	0	0	0
P17	0	0	21	0

Table 10-3. Species abundance at the Chollas site.

Species	All reference stations	All of Chollas Creek site	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14
Kalliapsuedes crassus	1															
Scoletoma sp C	2	1	1	1	2	2	1	2	1	1	1	1		2	10	
Exogone lourei	3	10	14	23	18	8	16	5	21		4	6			12	
Mediomastus sp	4	6	7	4	18	7	7	10	2		6	4				
Leitoscoloplos pugettensis	5	3	2	2	1	4	2	1	3	4	3	2		1	20	
Pista agassizi	6	7	9	12	10	3		7	12		6	7		10	20	
Diplocirrus sp SD1	7	16	14	23	12	16	16	11	32		18	9		6		
Scyphoproctus oculatus	8															
Nicolea gracilibranchus	9															
Musculista senhousia	10	4	4	6	7	1		4	32		2	3		3	5	
Prionospio (Prionospio) heterobranchia	11	5	3	23	12	5	6	4	4		6	5	4		4	
Leptochelia dubia	12	84													20	
Paracerceis sculpta	13															
Scoletoma sp	14	25		23		16			16		14					
Neanthes acuminata Cmplx	15	17				24			14		35			10	3	3
Edwardsia californica	16	14	8	8	18		8		6	2	25	16				
Harmothoe imbricata Cmplx	16	24	28			14					18	12				8
Syllis (Typosyllis) nipponica	18	84	28													
Heterophoxus oculatus	19	38	20								25	26				
Marphysa sp HYP1	20															
Theora lubrica	20	13	6	9	7	9	8	7	21		25					
Scleroplax granulata	22															
Pyromaia tuberculata	23	34	20	12				26				26				
Chaetozone corona	24	48							21					10		
Dorvillea (Schistomeringos) longicornis	25	9	12	23	7	24	16	14	5		14	16			2	2
Euchone limnicola	26	18	17		4	12		16	32		13	20				
Amphideutopus oculatus	28	22	20	23	18			10				16				
Lophopanopeus bellus	28	59		12												
Lumbrineris erecta	30	21		23	7	10	16	26	21						20	
Scoletoma sp A	30	19					6		14		11					
Tagelus subteres	30	59							21							

Table 10-4. Species abundance at the Paleta site.

Species	All reference stations	All of Paleta Creek site	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15	P16	P17
Kalliapsuedes crassus	1	42												14					
Scoletoma sp C	2	1	2	1	1	1	1	2	1	2	1	4	2	2	3	1	1	1	3
Exogone lourei	3	8		18	7	6	12	7	11	4		10		30	18	12	15		
Mediomastus sp	4	2	3	3	2	3	2	3	3	1	14	1	2	1	5	5	3	10	8
Leitoscoloplos pugettensis	5	3	4	2	4	2	4	1	2	5	5	2	1	7	4	4	2	2	4
Pista agassizi	6	5	4	10	5	12	5	7	8	6	14	7	8	6	1	3	15	4	10
Diplocirrus sp SD1	7	18	12	4	24			12	18	27		20	19	30		28	15		
Scyphoproctus oculatus	8	42			10														
Nicolea gracilibranchus	9	78			24														
Musculista senhousia	10	4	14	5	3	8	4	4	5	2	14	3	12	9	2	2		8	2
Prionospio (Prionospio) heterobranchia	11	7	12	8	9	6		12	6	8	2	10	6	9	7	8	8	6	10
Leptochelia dubia	12	56								27				30					
Paracerceis sculpta	13	56			16														
Scoletoma sp	14	19				20		7					10	14			5	10	12
Neanthes acuminata Cmplx	15	78												30					
Edwardsia californica	16	36								27				20	30	28			
Harmothoe imbricata Cmplx	16	28								13		20			18	28		14	
Syllis (Typosyllis) nipponica	18																		
Heterophoxus oculatus	19	32	24		12	20			18							28			
Marphysa sp HYP1	20																		
Theora lubrica	20	11	2	6		12	12		11			6	4	12	11	9		14	4
Scleroplax granulata	22																		
Pyromaia tuberculata	23	36				20						20	19	20					
Chaetozone corona	24																		
Dorvillea (Schistomeringos) longicornis	25	20			24				18	12		20	19	12	10				
Euchone limnicola	26	36			16	20		12										14	
Amphideutopus oculatus	28	6	8	7	24	5	12	12	11	9		5		4	6	6	9		
Lophopanopeus bellus	28																		
Lumbrineris erecta	30	10			12	20				10	2	8	8	20	8	7	6	6	13
Scoletoma sp A	30	22								20	14			9			6	14	18
Tagelus subteres	30	42												14					

10.2 SPECIES ASSEMBLAGES

Cluster analysis was used to determine if there were distinct assemblages of species among the stations. All of the stations were analyzed as single group in order to identify patterns both within and among the three major study areas (reference, Chollas, and Paleta).

The cluster analysis indicated six principal groups of stations (Figure 10-1). The first major separation of the stations occurred between 11 stations located primarily in the inner areas of Chollas and Paleta (group 2 clusters) and the remaining stations (group 1 clusters). The primary factors distinguishing groups 1 and 2 appeared to be related to proximity to the creek discharges and location within the narrow (inner) portion of each study area. All of the reference stations clustered into group 1. Three subgroups within group 1 were identified. Group 1A included the three upper bay reference sites and one station from outer Chollas (Figure 10-2). The three lower bay reference sites and one outer Paleta station (P03) clustered together into group 1C. The third subgroup (1B) was composed of 18 stations from both the Chollas and Paleta sites. Most of these stations were from the outer areas, but several of the inner Paleta stations were also included (Figure 10-1).

Within the second major group of the dendrogram, the two innermost Chollas stations (C13 and C14) showed the greatest differences in community composition relative to the other stations and were placed into group 2C (Figure 10-1). Station C11 was also relatively highly dissimilar to the others and was placed in a separate group (2B). Group 2A comprised the remaining stations, which were predominately from the inner area of the Paleta site (Figure 10-2).

Five of the six assemblage groups identified from the cluster analysis did not appear to be strongly influenced by depth or general sediment characteristics. The depths of the stations in each group were similar for the most part, and those stations with extreme values (e.g., shallow) were usually grouped with stations from depths more typical of the study sites (Figure 10-3). Group 2C was the only group to indicate a trend relative to depth; the two stations contained in this group were both shallow and located near the mouth of Chollas Creek. Sediment grain size did not appear to have a strong influence on most of the six assemblage groups either. Although a wide range of percent fines was present among the stations, most of the cluster groups contained a similar range of values (Figure 10-4). Again, group 2C was the only group to show a consistent trend relative to percent fines (relatively high). The concentration of sediment Total Organic Carbon (TOC) also had a similar range among five of the six cluster groups (Figure 10-5). Group 2C was again distinctive in containing the two highest TOC concentrations of all the stations. The presence of relatively high or low values for depth, grain size, and TOC at the group 2C stations indicates the distinct benthic assemblage at these stations may be due to extreme habitat characteristics in addition to chemical contamination.

Location with the bay appeared to be a secondary factor that influenced the species assemblages at the reference sites, as the three lower bay stations were grouped separately from the upper bay stations. There are several habitat factors that are likely to vary between the two regions of the bay, such as water temperature and currents; these factors may have been responsible for the variation in assemblages indicated by

the cluster analysis. Although the lower bay reference stations were located closer to the Chollas and Paleta sites than the upper bay stations, these reference stations were slightly less similar in species composition to the outer stations at Chollas and Paleta.

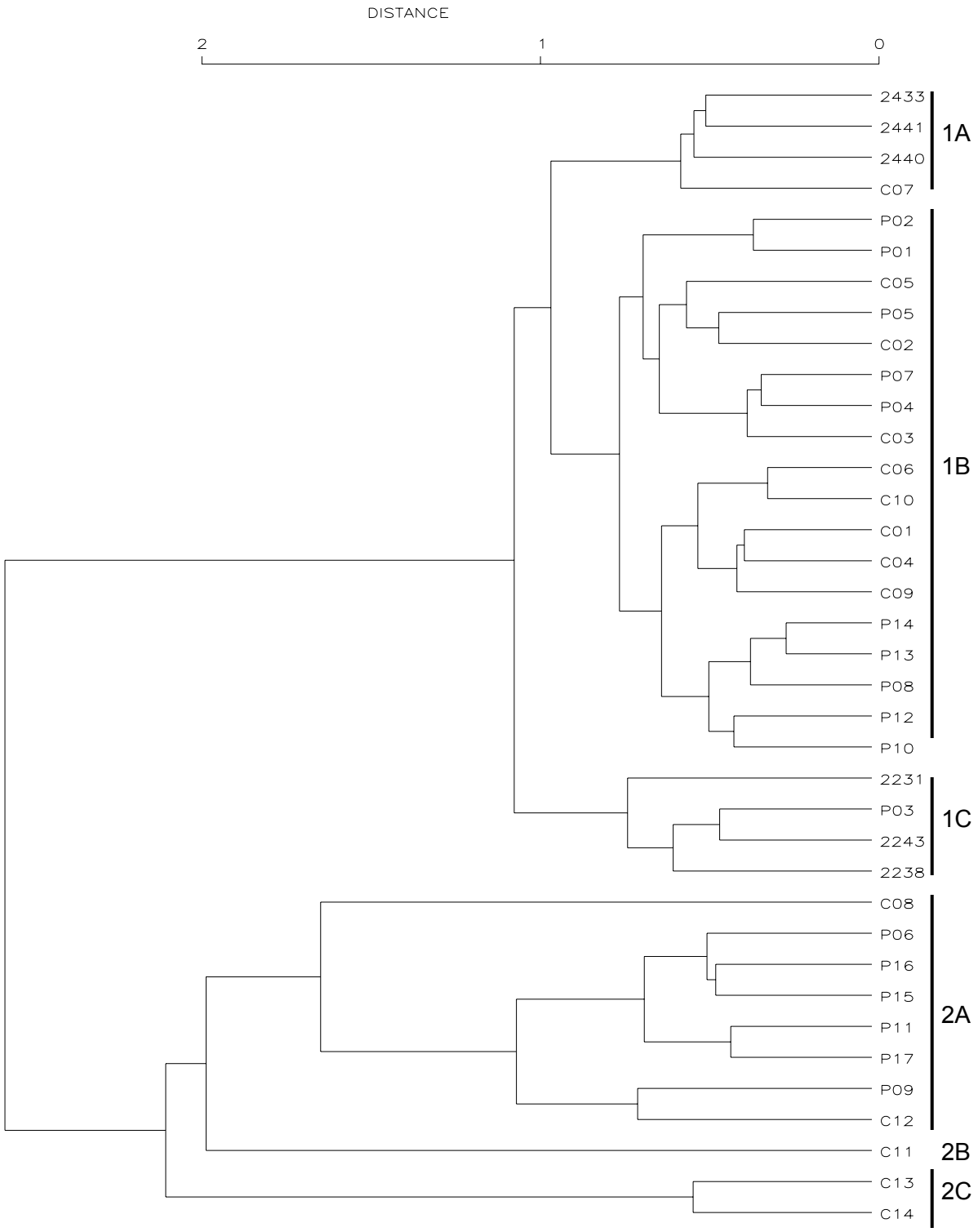


Figure 10-1. Station dendrogram based on similarity analysis of species abundances.

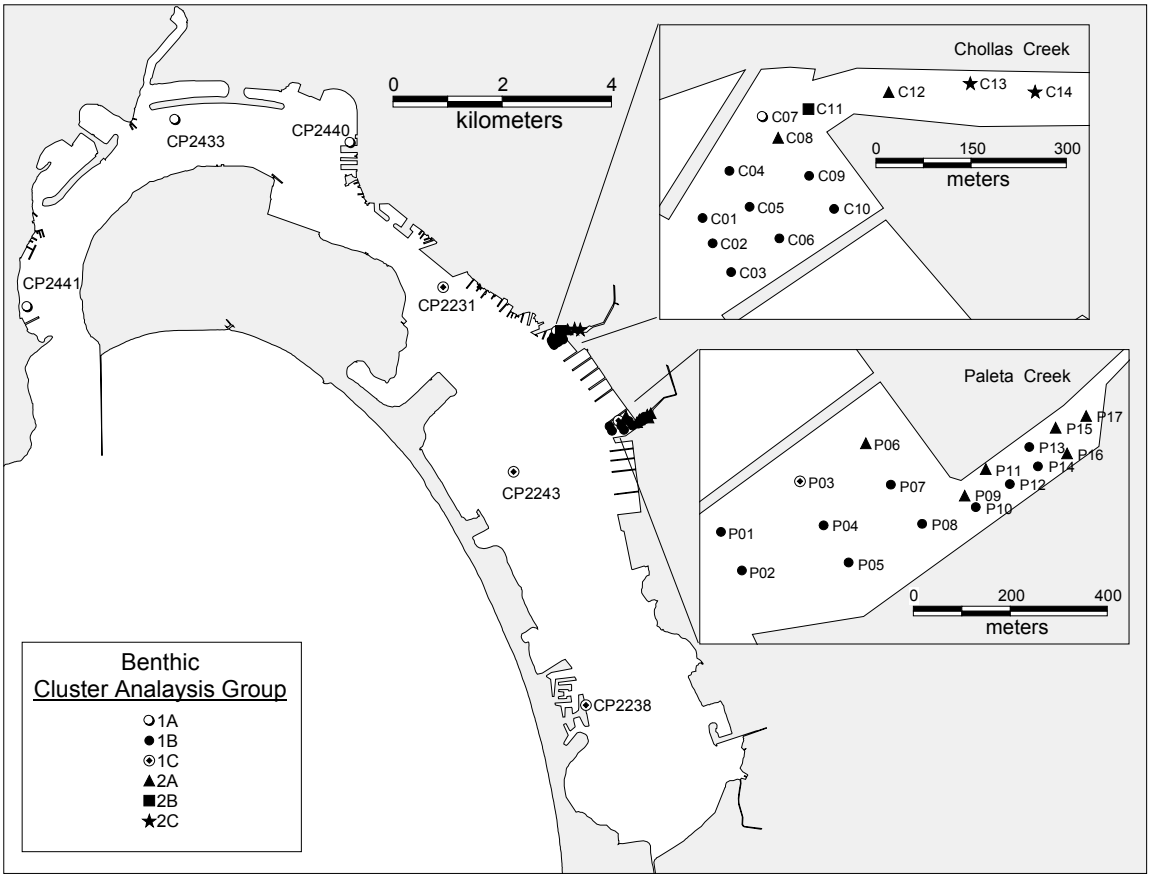


Figure 10-2. Location of stations in cluster analysis groups.

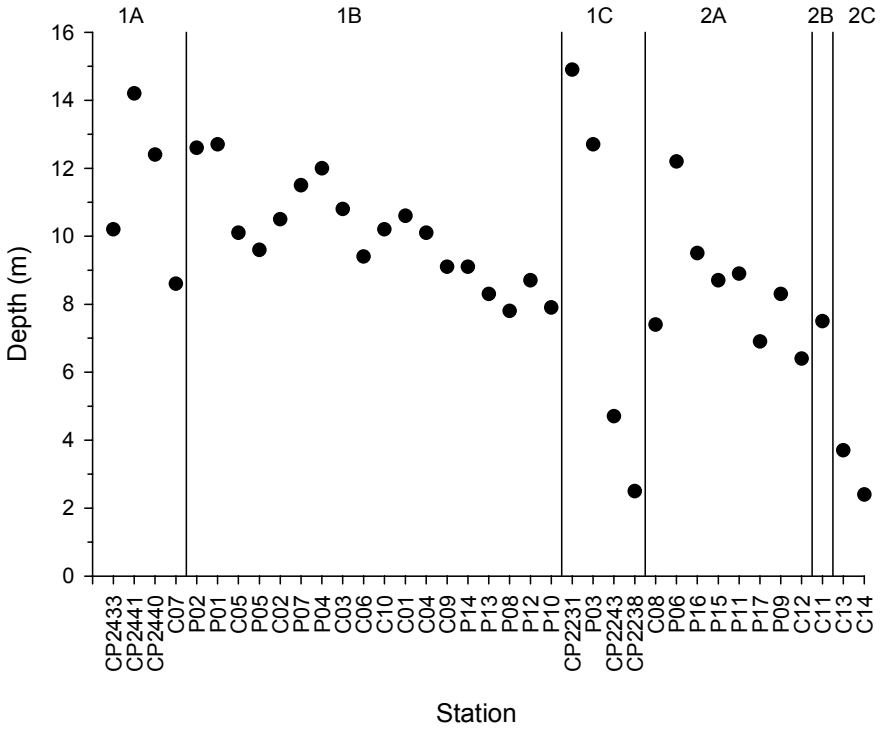


Figure 10-3. Depth of stations in each assemblage cluster. Station groups are indicated by the vertical reference lines.

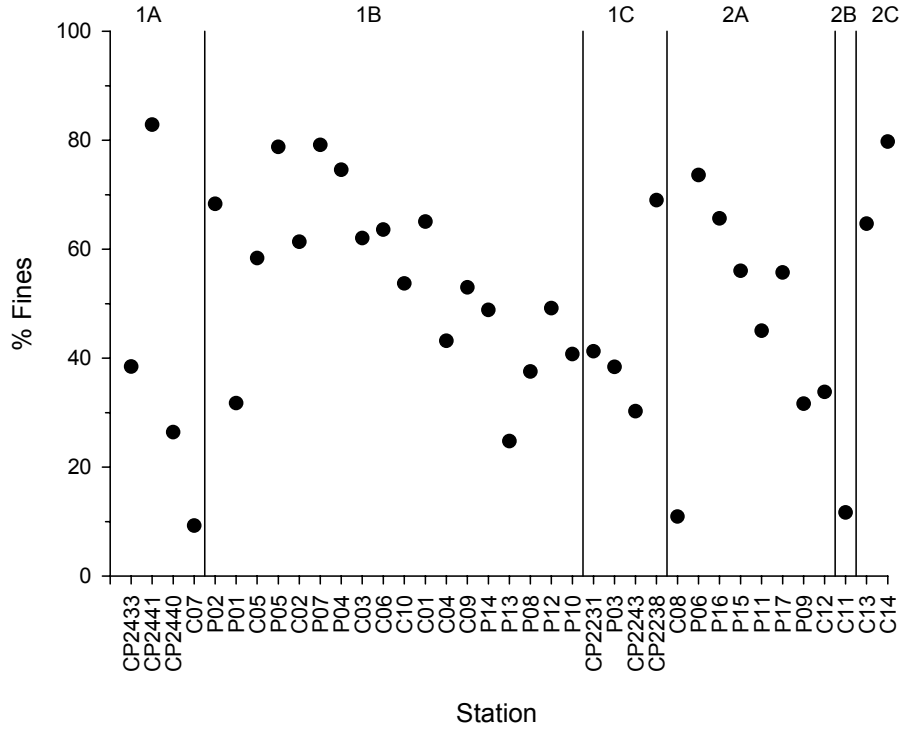


Figure 10-4. Grain size of stations in each assemblage cluster. Station groups are indicated by the vertical reference lines.

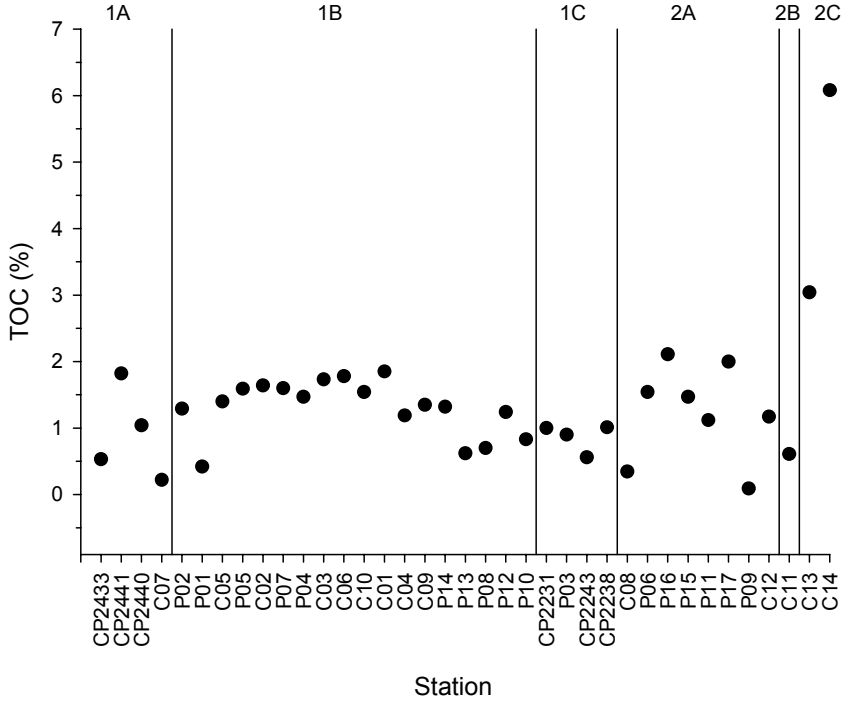


Figure 10-5. Total Organic Carbon content of stations in each assemblage cluster. Station groups are indicated by the vertical reference lines.

10.3 COMMUNITY MEASURES

Four measures of benthic macrofauna community structure or health were calculated for each station. The measures included three commonly used metrics (abundance, number of taxa, and Shannon-Wiener diversity) and the Benthic Response Index (BRI).

10.3.1 Reference

Benthic organism abundance (the number of organisms per sample) varied by a factor of 15, ranging from 419 organisms at Station CP2238 to 6343 animals at Station CP2231 (Table 10-5). The number of taxa per sample varied by a factor of three, ranging from 32 species at Station CP2238 to 88 at Station CP2231. Species diversity (Shannon-Weiner Index) ranged from 1.09 at Station CP2231 to 2.93 at Station CP2441.

Station CP2231 had characteristics that were atypical of the other reference stations. The abundance at this site was much greater than that of any other reference station. This station also had the highest number of taxa per grab and the lowest species diversity among the reference sites. The high abundance and low diversity was due to a very large population of the tanaid crustacean *Kalliapsuedes crassus*, which is not typical of soft-bottom reference conditions in San Diego Bay.

The BRI values for the reference stations ranged from 22.8 – 60.3 (Table 10-5). The BRI values were compared to five thresholds established as part of the Bight'98 regional survey (Ranasinghe et al., 2003). The threshold categories, arranged in increasing order of disturbance, are:

Reference	BRI <31 = reference
Response Level I	BRI 31-41 = marginal category, 5-25% loss of biodiversity
Response Level II	BRI 42-52 = 25-50% loss of biodiversity
Response Level III	BRI 53-72 = 50-80% loss of biodiversity
Response Level IV	BRI >73 = >80% loss of biodiversity

Three of the six reference stations (CP2231, CP2243 and CP2238) exceeded the lowest threshold, which represents an undisturbed reference community. Of these, Station CP2231 was in the marginal category (5-25% loss of biodiversity), while Stations CP2243 and CP2238 were both in response level III which is characterized by a 50-80% loss of biodiversity.

10.3.2 Chollas Site

Benthic macrofauna abundance varied by a factor of 92 among the Chollas stations, ranging from 7 at Station C11 to 642 animals at Station C09 (Table 10-5). Macrofauna abundance at seven of the 14 stations was less than half of the lowest value found among the San Diego Bay reference sites. Sites with low abundance were located in the inner channel area, and in the middle of the outer channel area of the Chollas site (Figure 10-6).

The number of taxa present per sample ranged from 6 species at Station C08 to 43 species at Station C09 (Table 10-5). Four of the stations had less than half the number of taxa found at the reference sites. Sites with the lowest number of species were

located in the inner channel area, and in the middle of the outer channel area (Figure 10-7).

Species diversity (Shannon-Weiner Index) ranged from 0.44 at Station C14 to 2.67 at Station C09 (Table 10-5). The lowest species diversity was found at the innermost station, located closest to the mouth of Chollas Creek (Figure 10-8).

Benthic Response Index (BRI) values for the Chollas site ranged from 30 to 83. Most stations (9 out of 14) were classified as BRI response level III, indicating at least a 50% loss of biodiversity (Table 10-5, Figure 10-9), and one station (C14) exceeded the threshold response level IV (>80% loss of biodiversity). Station C11, located at the transition between the inner and outer areas of the site, had a BRI value characteristic of a reference community.

10.3.3 Paleta Site

Macrofauna abundance within the Paleta site varied by a factor of 20, ranging from 39 organisms per sample at Station P09 to 773 organisms per sample at Station P08 (Table 10-5). Ten of the 17 Paleta site stations had less than half the abundance of the lowest reference site value. Two of the three sites with the highest abundance were in the inner channel area, while the third was located in the outer creek area (Figure 10-10).

The number of taxa among stations ranged from 15 species at Station P06 to 36 species at Stations P12 and P14. The number of taxa at 13 of the 17 Paleta site stations was less than half of the lowest value found among the San Diego Bay reference sites. The lowest numbers of taxa were found at stations in the outer channel area (Figure 10-11).

Relatively high species diversity values were found throughout the Paleta Site (Figure 10-12).Species diversity ranged from 1.81 at Station P05 to 2.82 at Station P11.

BRI values for the Paleta site ranged from 32 at Station P01 to 69 at Station P16 (Table 10-5). Most stations (9 out of 17) were classified as response level III (at least a 50% loss of biodiversity). No station was classified in the “reference” category and only two stations had a community composition that was characteristic of a marginal loss of diversity (response level I). The highest BRI values were found in the inner channel area, Figure 10-13).

Table 10-5. Benthic community measures for reference, Chollas, and Paleta stations. BRI category I – IV represent progressively greater losses in reference community species.

Station	Community Metrics			Benthic Response Index	
	Abundance	Number of Taxa	Shannon-Wiener Diversity	Value	Response Level
CP2231	6343	88	1.09	39	I
CP2243	691	41	2.34	55	III
CP2433	421	57	2.82	23	Reference
CP2440	918	66	2.88	30	Reference
CP2441	476	66	2.93	30	Reference
CP2238	419	32	2.56	60	III
C01	375	34	2.49	50	II
C02	154	32	2.47	48	II
C03	163	22	2.05	54	III
C04	471	29	2.44	55	III
C05	206	21	1.89	56	III
C06	301	32	2.63	50	II
C07	431	40	2.40	45	II
C08	20	6	1.16	65	III
C09	642	43	2.67	53	III
C10	314	30	2.46	53	III
C11	7	7	1.95	30	Reference
C12	34	14	2.27	55	III
C13	190	26	2.15	72	III
C14	553	10	0.44	83	IV
P01	155	31	2.76	32	I
P02	125	22	2.47	41	I
P03	254	31	2.42	54	III
P04	210	24	2.26	50	II
P05	127	16	1.81	51	II
P06	70	15	2.09	56	III
P07	196	22	2.25	53	III
P08	773	33	2.21	44	II
P09	39	18	2.67	48	II
P10	255	26	2.50	54	III
P11	88	24	2.82	55	III
P12	304	36	2.69	43	II
P13	768	35	2.35	51	II
P14	487	36	2.42	57	III
P15	114	21	2.24	59	III
P16	153	19	2.06	69	III
P17	151	20	2.63	65	III

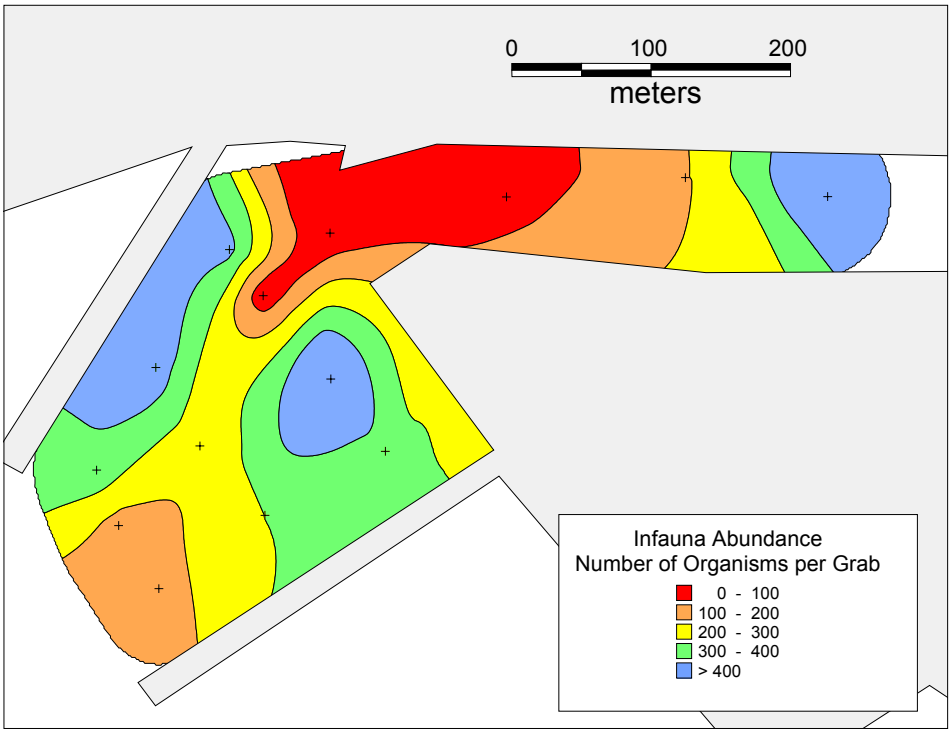


Figure 10-6. Spatial distribution of infauna abundance at the Chollas Site.

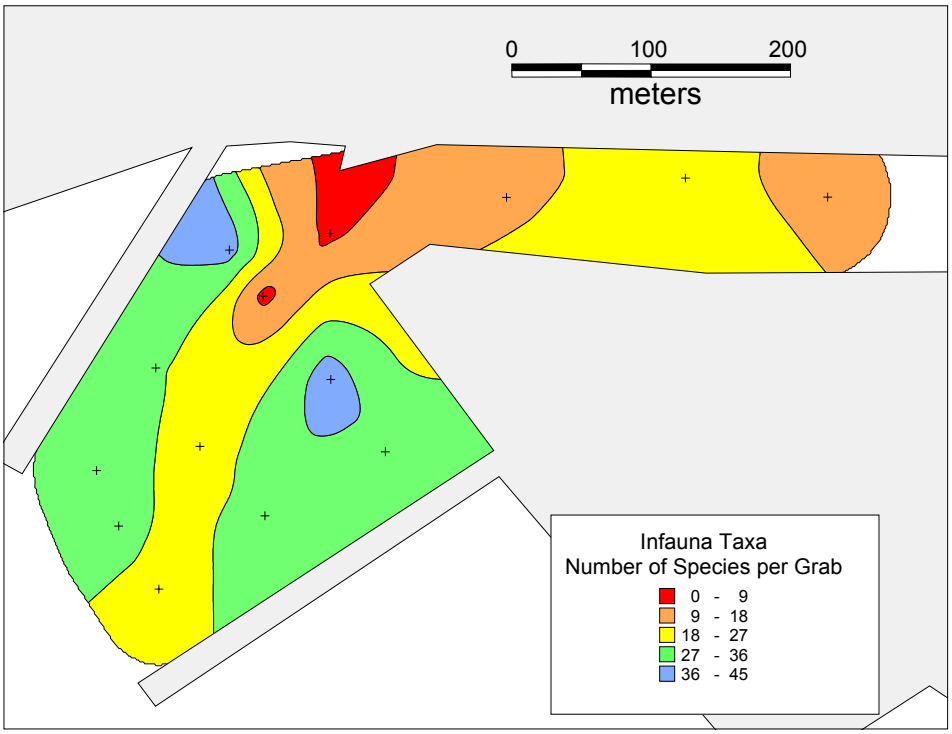


Figure 10-7. Spatial distribution of number of species per sample in sediments from the Chollas Site.

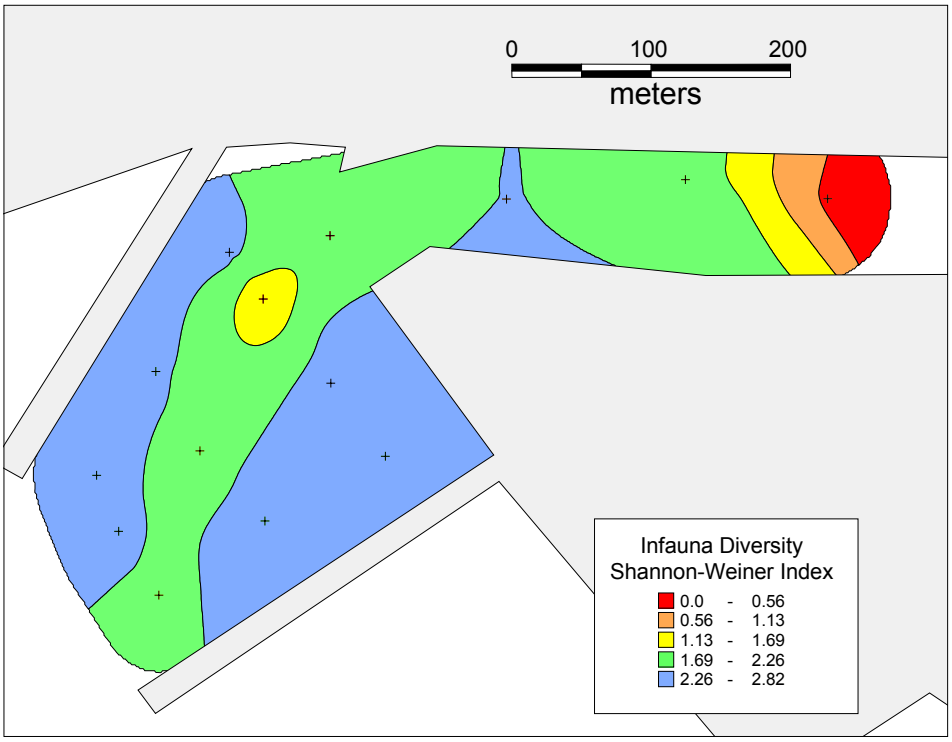


Figure 10-8. Spatial distribution of species diversity at the Chollas Site.

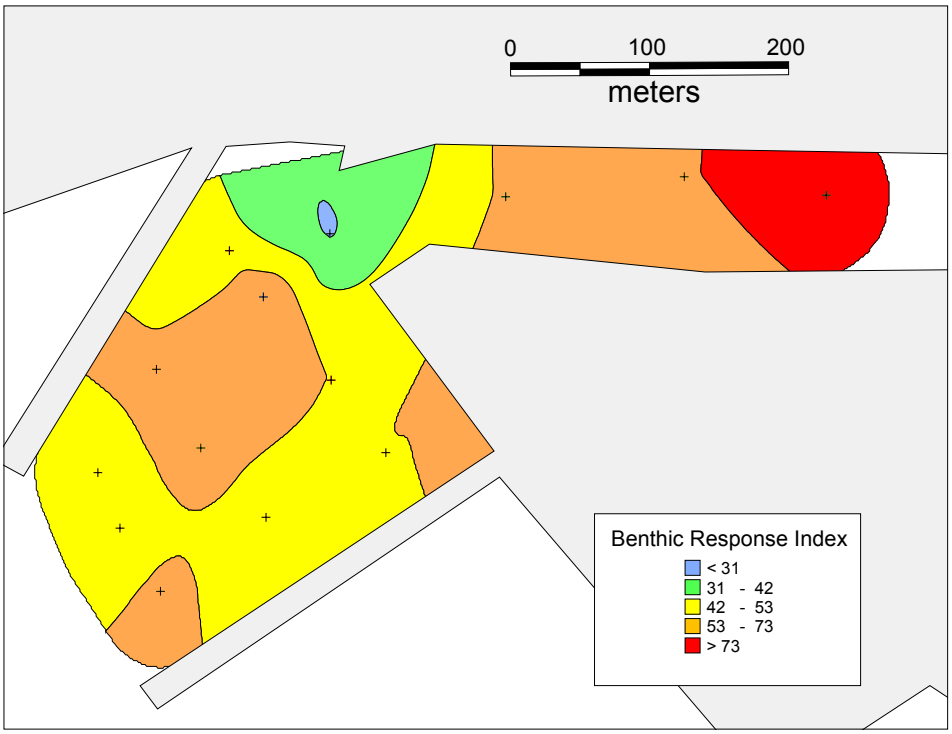


Figure 10-9. Spatial distribution of Benthic Response Index at the Chollas Site.

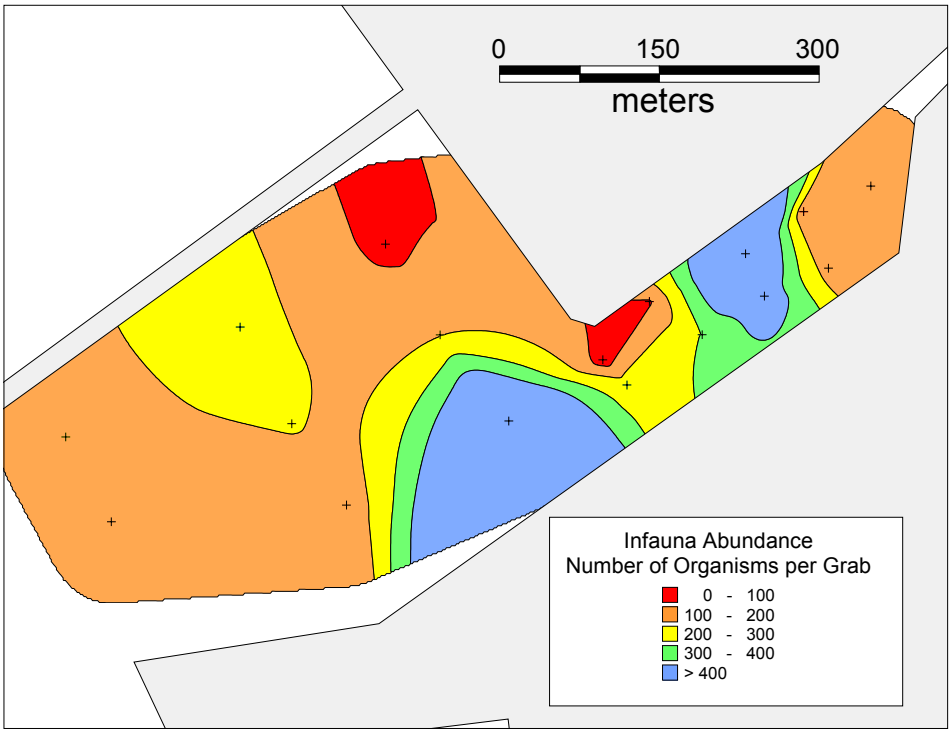


Figure 10-10. Spatial distribution of infauna abundance at Paleta Site.

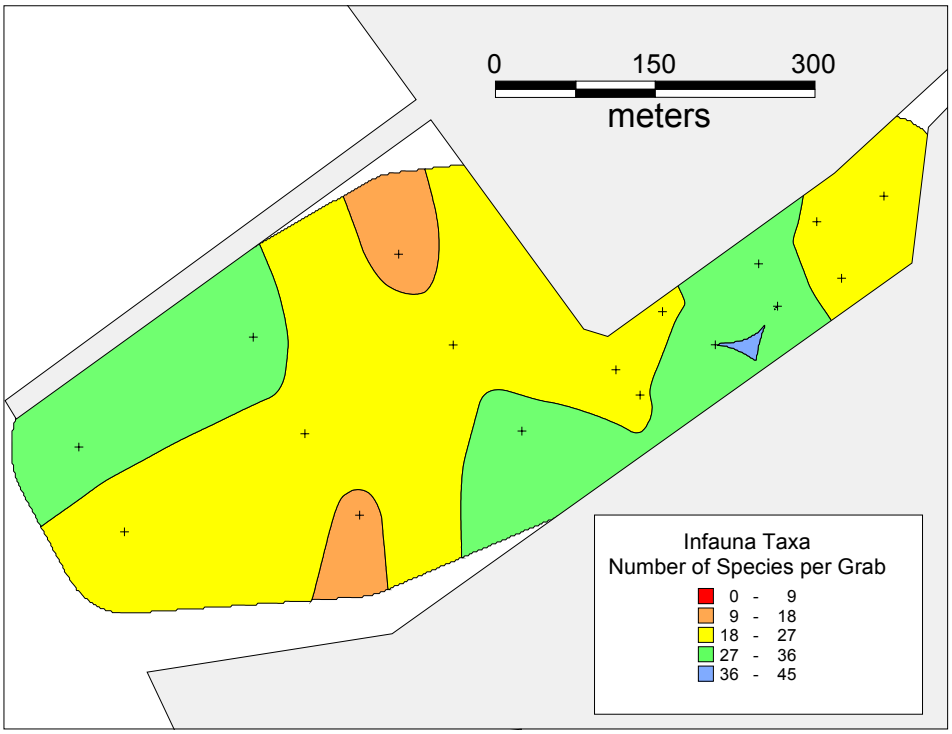


Figure 10-11. Spatial distribution of number of species per grab in sediments from the Paleta Site.

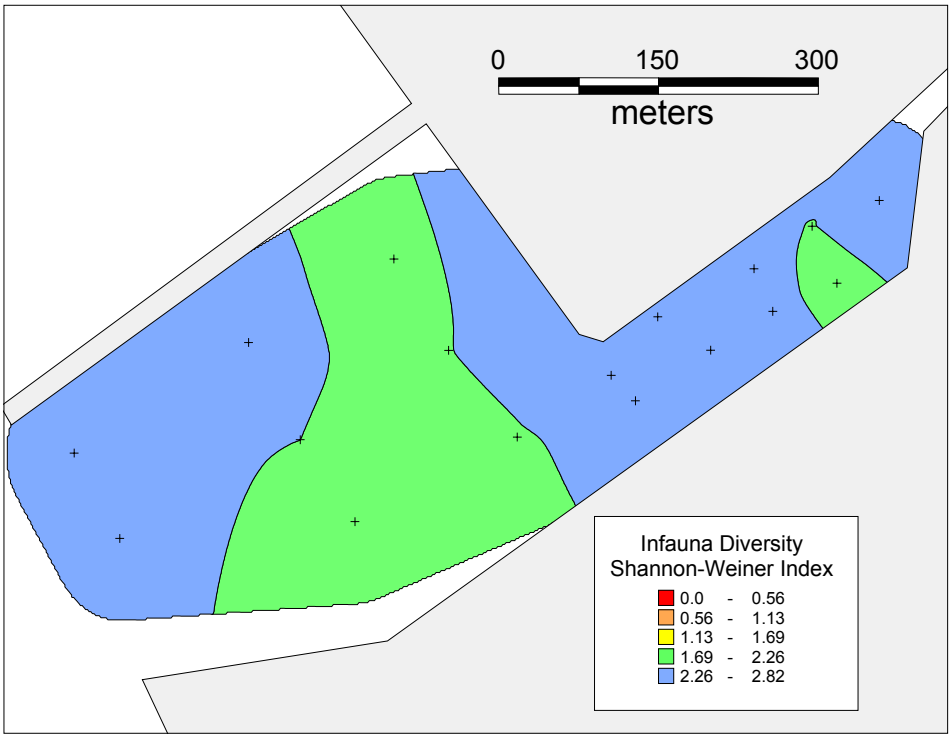


Figure 10-12. Spatial distribution of species diversity at the Paleta Site.

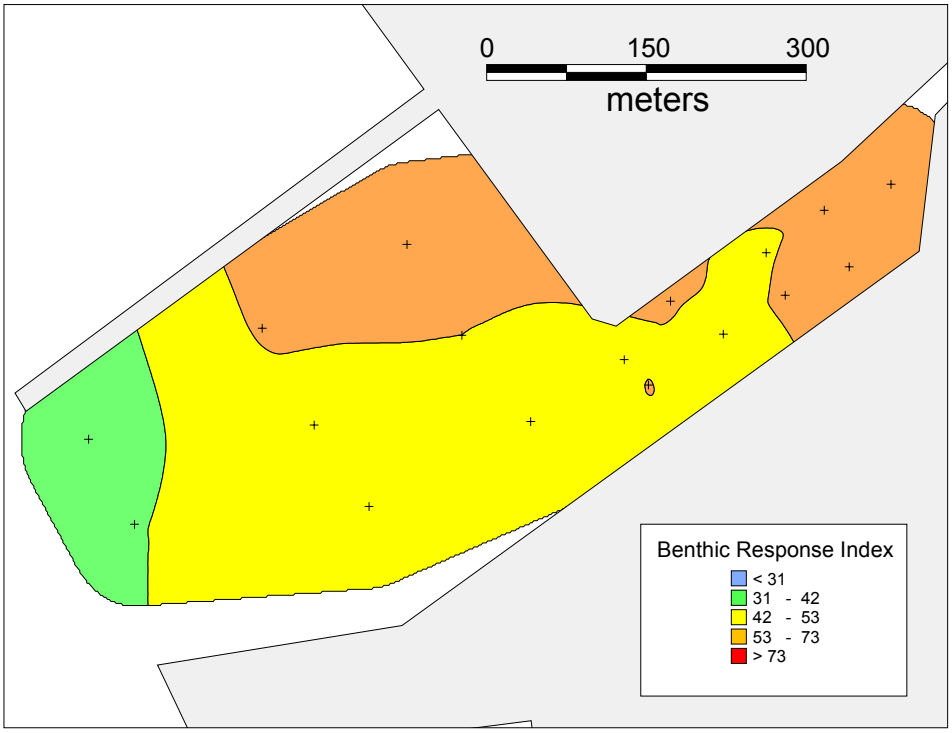


Figure 10-13. Spatial distribution of Benthic Response Index at the Paleta Site.

11.0 ASSESSMENT OF EFFECTS

11.1 BASELINE POOL CHARACTERISTICS

The Baseline Pool was used to represent the baseline condition that would be expected to exist at the Chollas and Paleta sites in the absence of direct influence from contaminant sources. As described in Section 4, the Baseline Pool of stations used for analysis in this study consisted of 18 stations: five of six stations from the Chollas/Paleta study (CP2440 removed), four of five stations from the Phase I Shipyard study (SY2440 removed), and nine of 22 stations from the Bight'98 study based on a distance from shore evaluation (see Appendix E). In addition to the results of individual parameters and summary statistics for those parameters, the upper (i.e. for concentration) or lower (i.e. for survival) 95th-percentile prediction limit was computed for each parameter from the Baseline Pool. The prediction limits were used as a threshold to determine if conditions at the study sites differed from the baseline condition. Although multiple comparisons were made to the Baseline Pool predictive limits, no correction for multiple comparisons was applied to the predictive limits so the comparisons would remain conservative and more protective.

Each parameter was evaluated for normality prior to its statistical evaluation using prediction limits. An exception to this was the fines-normalized metals data that were subject to a normalization process described in Appendix E4. The normality of each parameter was tested using both the Kolmogorov/Smirnov (KS) and Shapiro-Wilk tests. In the event a distribution was not normally distributed ($P<0.1$) the data were transformed using ln, square-root, arcsine, or cube transforms. In instances when multiple transforms could satisfy normality, the best transform was chosen based on best professional judgment after review of the resulting p and r statistics and review of a graphical representation of the data. The data transforms used for the Baseline Pool are shown in Table 11-1. The data transforms for the Reference Pool are included for comparison.

11.1.1 Physical Properties

The range of fines content and TOC for the Baseline Pool is consistent with the levels of fines and TOC at the Chollas and Paleta Sites (Table 11-2). The range of fines in the Baseline Pool and Chollas and Paleta study sites is 13% to 82.8% and 9.2% to 82.8% respectively. The full range of TOC represented by stations in the Baseline Pool (0.4% to.8%) is somewhat narrower than the range from Chollas and Paleta stations (0.1to 6.1%). However, 28 of the 31 stations from the Chollas and Paleta sites did have TOC levels that fell within the Baseline Pool's TOC range. TOC in the Baseline Pool stations generally increased with increasing % fines following a similar trend to that observed at the Chollas and Paleta stations.

11.1.2 Metals

Metals characteristics and summary statistics for the Baseline Pool are shown in Table 11-2. Metal concentrations in the Baseline Pool were generally low, and showed minimal variation from station to station. For example, arsenic in the Baseline Pool ranged from 2.5 to 9.1 mg/kg, with an RSD of only 33%, and zinc ranged from 18 to 43.2 mg/kg with an RSD of only 42%. Silver and cadmium had somewhat higher variation with RSDs of 58% and 62%, respectively. Among the Baseline Pool stations, 2257 had the highest occurrence of maximum metal concentrations including arsenic, chromium, copper, nickel, lead and zinc. Higher metals levels at this station are consistent with the high fines content (77%) observed at this station. Station 2265 had the highest occurrence of minimum metal concentrations including silver, arsenic, copper, mercury, nickel, lead and zinc. Lower metals levels at this station are consistent with the low fines content (13%) observed at this

station. Relative to SQGs, maximum metals concentrations in the Baseline Pool all fell below their respective ERM threshold. The 95% upper predictive limit for metals in the Baseline pool was based on a regression analysis with fines content to minimize the confounding influence of natural variations in background metal concentrations. Thus, the 95% upper predictive limit for metals was dependent on the fines content at each station (Table 11-3). In general, this means that stations with higher fines content will have a higher 95% upper predictive limit. For example, the 95% upper predictive limit for copper ranged from 85.9 mg/kg for a fines content of 25% to 159.5 mg/kg for a fines content of 75%. An example of the regression analysis is shown in Figure 11-1 and the method is described in Appendix E4.

11.1.3 Organic Contaminants

Sediment PPPAH concentrations in the Baseline Pool ranged from about 199 to 2143 μg/kg and averaged 388 μg/kg (Table 11-4). The concentrations of PPPAH found at the Baseline Pool stations correspond to changing TOC levels with the highest PPPAH (2143 μg/kg) and TOC found at CP 2441. None of the PAH levels measured at these stations exceeded the CBSQG value of 1800 μg/g OC. The PAH data were ln transformed to ensure normality when making statistical comparisons. The predictive limit for PPPAH was based on N of 18.

PCB concentrations in the Baseline Pool ranged from 10.5 to 77.1 μg/kg with a mean TPCB concentration of 29.6 μg/kg (Table 11-4). None of the PCB levels measured at these stations exceeded the CBSQG PCB value of 400 μg/kg. The PCB data were ln transformed to insure normality when making statistical comparisons. Because the PCB data for all Bight'98 stations had elevated method detection limits (MDL), these station data were not used in calculating the upper predictive limit. The predictive limit was therefore based on N of 9.

TCHLOR concentrations at the Baseline Pool stations were generally low, and ranged from 0.2 to 0.9 μg/kg with a mean concentration of 0.5 μg/kg (Table 11-4). TDDT concentrations were somewhat higher and more variable than TCHLOR. TDDT ranged from 1.3 to 10.8 μg/kg with a mean of 3.9 μg/kg. None of the TCHLOR levels measured at these stations exceeded the ERM value of 6 μg/kg. All TDDT values were also below their SQG value of 100 μg/g OC (Swartz, 1999).

TCHLOR data were normally distributed but TDDT data were ln transformed to make its distribution normal. The prediction limits for both TCHLOR and TDDT were based on an N of five instead of 18 because the station data obtained from the shipyard study did not contain measurements on pesticides and all station data from the Bight'98 stations yielded non-detect information only.-

11.1.4 SQGQ1 Calculation

As mentioned previously, CoPCs were evaluated against their individual benchmark SQGs, as well as a group against a mean SQGQ1 quotient benchmark (Fairey et al. 2001). The SQGQ1 quotient is an empirically derived guideline that was best predictive of acute toxicity to marine amphipods. The SQGQ1 is calculated as follows:

SQGQ1 = ((Σ ([cadmium]/4.21)([copper]/270)([lead]/112.18)([silver]/1.77)([zinc]/410)([total chlordane]/6)([dieldrin]/8)([total PAHOC]/1,800)([total PCB]/400))/9).

The denominators in each of the quotients are the SQG values that were most predictive in identifying threshold effects for the individual chemical. In the order of chemicals above, the SQGs used were: PEL, ERM, PEL, PEL, ERM, ERM, ERM, consensus, consensus. There were no dieldrin data for the current study and the SQGQ1 therefore was calculated without its quotient and the overall denominator was adjusted from 9 to 8. The SQGQ1 was calculated for all stations in the Baseline Pool as well as for each of the Chollas and Paleta stations (Table 11-5).

11.1.5 Toxicity

Control-adjusted amphipod survival in the Baseline Pool sediments ranged from 71 to 100%, with a mean of 88% (Table 11-6). Of the 18 stations, two stations (2235, 2260) had survival levels that were significantly different and <75% of control survival, and three stations (CP2241, CP2238 and CP2243) had survival levels that were significantly different, but >75% of control survival. The remaining stations had survival levels that were not significantly different and ≥75% of control survival.

Control-adjusted normal sea urchin embryo development in the sediment-water interface tests for the Baseline Pool ranged from 88 to 115% with a mean of 100% (Table 11-6). No stations in the Baseline Pool had embryo development was significantly different and/or <59% of control survival. The urchin embryo development lower 95% prediction limit was calculated using an N of four instead of 18 because no data were collected at the Bight'98 or shipyard stations and data from CP 2231 yielded only outlier values.

Control-adjusted sea urchin fertilization in 100% porewater for the Baseline Pool ranged from 36 to 102% with a mean of 85% (Table 11-6). Sea urchin fertilization at stations CP 2231, CP 2238, and SY 2433 was significantly different and <88% control (66, 36, and 79% of control fertilization, respectively). Sea urchin fertilization at the remaining stations was not significantly different and ≥88% relative to controls. The urchin fertilization lower 95% prediction limit was calculated using an N of nine instead of 18 because no data were available from the Bight'98 stations.

11.1.6 Benthic Community

Abundance measurements in the Baseline Pool sediments ranged from 237 to 2263 with a mean of 842. The number of Taxa ranged from 28 to 108 with a mean of 50. The Shannon-Wiener diversity index ranged from 1.8 to 2.9 with a mean of 2.4. The Benthic Response Index (BRI) yielded results ranging from 17 to 60 with a mean BRI of 36.5 (Table 11-7). Two stations (CP 2238 and CP 2243) were in BRI response level IV, three stations (SY 2243, 2235, and 2258) were in response level III, and the remaining stations were response level II or below. The prediction limits for the benthic community measurements were calculated using an N of 16 instead of 18 because the benthic data for CP 2231 and SY 2231 was considered anomalous and therefore no benthic community parameters were computed for those two stations.

11.1.7 Bioaccumulation

As described in section 4.2, statistical analysis for potential impacts to aquatic dependent wildlife and human health from CoPC in the sediment at the study sites necessitated that the Baseline Pool contain bioaccumulation data. However, because the Bight'98 study did not collect bioaccumulation data for the San Diego Bay stations, the Baseline Pool for bioaccumulation data is limited to only nine stations. The requisite calculations to analyze potential risks to wildlife and human health also required a slightly different list of organic chemical constituents than was needed for sediment chemistry analysis. Therefore, upper 95% predictive limits where created for the

following organic parameters: naphthalene, benzo-a-pyrene, TPCB, α-chlordane, γ-chlordane, sum of ortho and para DDE, sum of ortho and para DDD, and the sum of ortho and para DDT.

Tissue characteristics and metals data, summary statistics, and upper 95% predictive limits for the Baseline Pool are shown in Table 11-8. Tissue metal concentrations in the Baseline Pool were generally low, and showed minimal variation from station to station. For example, arsenic in the Baseline Pool ranged from 18.7 to 22.2 mg/kg, with an RSD of only 6%, and zinc ranged from 73.1 to 82.5 mg/kg with an RSD of only 5%. Other metals had somewhat higher variation with RSDs ranging from 22% and 38%. Among the Baseline Pool stations, SY2441 had the highest occurrence of maximum metal concentrations including silver, cadmium, chromium, copper, and nickel. Station SY2231 had the highest occurrence of minimum metal concentrations including silver, chromium, copper, nickel, and lead. The 95% predictive limit for Zn was calculated using an N of five instead of nine because of an apparent bias detected in the four shipyard station's bioaccumulation data for Zn. The shipyard values were clearly higher than those measured here. The cause of this bias is not known, but may be attributable to differences in analytical methods.

Tissue organics data, summary statistics, and upper 95% predictive limits for the Baseline Pool are shown in Table 11-9. Tissue organics concentrations in the Baseline Pool were generally low, with concentrations typically lower than those at the Chollas-Paleta the reference stations but slightly higher than those from animals living on the control sediment. For PAHs, naphthalene ranged from about 4.9 to 8.2 μg/kg and averaged 7.2 μg/kg, while benzo-a-pyrene ranged from about 6 to 118 μg/kg and averaged 65 μg/kg. The prediction limit for naphthalene was calculated using an N of five instead of nine because of an apparent bias detected in the four shipyard station's bioaccumulation data as previously mentioned for Zn. TPCB ranged from about 39 to 164 μg/kg and averaged 98 μg/kg. The chlordanes, α-chlordane and γ-chlordane averaged 0.55 and 0.47 μg/kg respectively and their concentrations ranged from 0.1 to 1.3 μg/kg and 0.08 to 0.89 μg/kg respectively. The chlorinated pesticide DDE ranged from about 6.4 to 8.4 μg/kg and averaged 7.3 μg/kg. DDD ranged from about 0.6 to 3.7 μg/kg and averaged 2.1 μg/kg. DDT ranged from about 0.27 to 0.44 μg/kg and averaged 0.34 μg/kg. The Baseline Pool for the pesticides was restricted to stations only from the Chollas-Paleta study because the shipyard study did not analyze for pesticides. Therefore, the predictive limits for all pesticides were calculated using an N of five instead of nine.

Table 11-1. Data transforms used to produce normally distributed data for use in statistical testing against the Baseline and Reference Pools.

	Baseline Pool	Reference Pool
Parameter	**Transform**	**Transform**
Metals		
Ag	NA	Square root
As	NA	Natural log
Cd	NA	Square root
Cr	NA	Natural log
Cu	NA	Natural log
Hg	NA	Natural log
Ni	NA	No transformation
Pb	NA	Natural log
Zn	NA	Natural log
Organics		
PPPAH	Natural log	No transformation
PCBs	Natural log	No transformation
Chlordane	None	No transformation
DDTs	Natural log	No transformation
SQGQ1	Natural log	Natural log
Toxicity		
Amphipod survival	No transformation	No transformation
Sea urchin development	No transformation	No transformation
Sea urchin fertilization	Cube	Cube
Benthos		
Abundance	Natural log	Natural log
Taxa	Natural log	Natural log
Diversity	No transformation	No transformation
BRI	No transformation	Cube

Table 11-2. Individual station characteristics and summary statistics for physical properties (%) and metals (mg/kg) in the Baseline Pool. None of the station data exceeded their respective ERM.

Station	% Fines	%TOC	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
CP 2231	41.2	1.0	0.288	7.78	0.025	46.6	71.1	0.364	11.5	40.3	129
CP 2238	69.0	1.0	0.510	7.80	0.133	59.2	71.0	0.262	16.5	28.8	214
CP 2243	30.3	0.6	0.651	5.94	0.143	40.2	56.4	0.332	10.2	30.7	125
CP 2433	38.4	0.5	0.385	5.55	0.288	42.2	43.3	0.251	11.2	23.3	115
CP 2441	82.8	1.8	0.388	8.82	0.411	54.0	78.4	0.238	17.5	26.7	143
SY 2231	45.0	1.3	0.260	8.30	0.100	37.0	82.0	0.430	10.0	42.0	120
SY 2243	28.0	0.5	0.560	4.30	0.120	23.0	47.0	0.250	5.6	21.0	93.0
SY 2433	41.0	0.7	0.390	4.60	0.290	24.0	40.0	0.210	7.4	19.0	92.0
SY 2441	41.0	1.1	0.240	5.40	0.290	22.0	37.0	0.160	9.9	13.0	80.0
2235	45.0	0.6	0.476	6.40	0.095	37.5	58.2	0.239	10.7	21.3	136
2241	18.0	0.5	0.538	4.53	0.088	27.5	59.2	0.213	7.3	26.3	104
2242	31.0	0.7	0.493	4.27	0.096	25.4	42.0	0.300	6.8	17.8	89.8
2243	35.0	0.5	0.504	3.66	0.101	20.8	38.8	0.239	5.1	19.9	81.2
2256	67.0	1.3	1.29	7.47	0.200	54.3	128	0.632	14.3	54.1	197
2257	77.0	1.6	1.25	9.08	0.175	66.7	157	0.511	18.7	64.1	233
2258	71.0	1.4	0.954	7.75	0.161	60.0	143	0.664	16.4	53.0	211
2260	27.0	0.5	0.452	4.06	0.092	23.9	50.8	0.216	7.1	20.4	87.5
2265	13.0	0.4	0.192	2.48	0.069		18.0	0.065	1.5	12.0	43.2
N	18	18	18	18	18	18	18	18	18	18	18
Minimum	13.0	0.4	0.192	2.48	0.025	20.8	18.0	0.065	1.5	12	43.2
Maximum	82.8	1.8	1.29	9.08	0.411	66.7	157	0.664	18.7	64.1	233
Mean	44.5	0.9	0.546	6.01	0.160	39.1	67.8	0.310	10.4	29.6	127.4
Std Dev	20.5	0.4	0.315	1.98	0.100	15.4	38.3	0.158	4.7	15.0	53.4
RSD	46.1%	49.6%	57.8%	33.0%	62.5%	39.4%	56.4%	50.9%	45.5%	50.6%	41.9%
ERM	NA	NA	3.7	70	9.6	370	270	0.71	51.6	218	410

Table 11-3. Metal threshold values (mg/kg) derived from the fines-metals regression as a function of percent fines for the Baseline Pool. Sediment metal concentrations exceeding these thresholds are considered enriched.

% Fines	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
0	0.73	3.4	0.23	25.2	54.4	0.36	4.4	31.7	87.6
5	0.76	3.8	0.24	28.1	60.4	0.38	5.4	33.6	97.3
10	0.79	4.2	0.25	31.1	66.6	0.39	6.4	35.5	107.2
15	0.82	4.6	0.26	34.1	72.9	0.41	7.4	37.5	117.2
20	0.85	5	0.27	37.1	79.4	0.43	8.4	39.6	127.4
25	0.89	5.4	0.28	40.2	85.9	0.45	9.5	41.7	137.7
30	0.92	5.8	0.29	43.4	92.6	0.47	10.5	43.9	148.2
35	0.96	6.2	0.3	46.6	99.5	0.5	11.6	46.1	158.8
40	1	6.6	0.31	49.8	106.5	0.52	12.6	48.4	169.6
45	1.04	7.1	0.32	53.2	113.6	0.54	13.7	50.8	180.6
50	1.08	7.5	0.33	56.5	120.9	0.57	14.8	53.2	191.8
55	1.13	7.9	0.35	60	128.3	0.59	15.9	55.8	203.1
60	1.17	8.3	0.36	63.5	135.9	0.62	17	58.3	214.6
65	1.22	8.8	0.37	67	143.6	0.64	18.1	61	226.2
70	1.27	9.2	0.39	70.6	151.5	0.67	19.2	63.7	238.1
75	1.32	9.7	0.4	74.3	159.5	0.7	20.3	66.5	250
80	1.37	10.1	0.42	78	167.6	0.72	21.5	69.3	262.1
85	1.42	10.6	0.43	81.7	175.9	0.75	22.6	72.2	274.4
90	1.48	11	0.45	85.5	184.2	0.78	23.8	75.1	286.8
95	1.53	11.5	0.46	89.3	192.7	0.81	24.9	78.1	299.3
100	1.59	11.9	0.48	93.2	201.2	0.84	26.1	81.1	311.9

Table 11-4. Individual station characteristics, summary statistics, SQG, and 95% upper predictive limits for organic contaminants in the Baseline Pool.

Station	PPPAH ng/g	CBPAH ug/gOC	TPCB ng/g	CBPCB ng/g	TCHLOR ng/g	TDDT ng/g	TDDT ug/g OC
CP 2231	1063	84.0	43	28	0.9	10.8	1.1
CP 2238	199	14.8	11	7	0.2	1.3	0.1
CP 2243	267	35.2	21	13	0.2	1.5	0.3
CP 2433	780	121.6	27	17	0.6	2.1	0.4
CP 2441	2143	105.1	34	20	0.8	3.8	0.2
SY 2231	687	40.0	77	57			
SY 2243	204	27.2	22	18			
SY 2433	486	56.7	21	16			
SY 2441	343	25.5	11	8			
2235	234	30.9	50	35	0.6	1.7	
2241	234	38.3	50	35	0.6	1.7	
2242	359	39.4	50	35	0.6	3.3	
2243	234	40.7	50	35	0.6	1.7	
2256	369	24.9	50	35	0.6	1.7	
2257	449	23.6	51	36	0.6	1.7	
2258	424	25.6	50	35	0.6	1.7	
2260	234	38.6	50	35	0.6	1.7	
2265	234	55.9	50	35	0.6	1.7	
N	18	18	18	18	5	5	5
Minimum	199	15	11	7	0.2	1	0.1
Maximum	2143	122	77	57	0.9	10.8	1.1
Mean	497	46	40	28	0.6	2.6	0.4
Std Dev	472	29	18	13	0.2	2.5	0.4
RSD	95%	64%	44%	47%	33%	96%	92%
SQG		**1800**		**400**	**4.8**		**100**
95% PL	**1234***		**84***		**1.3**	**21***	

* Values were derived from natural log transformed data

Table 11-5. Calculated SQGQ1, summary statistics and 95% upper predictive limit for the Baseline Pool.

Station	SQGQ1
CP 2231	0.18
CP 2238	0.18
CP 2243	0.16
CP 2433	0.15
CP 2441	0.19
SY 2231	0.21
SY 2243	0.15
SY 2433	0.13
SY 2441	0.10
2235	0.17
2241	0.17
2242	0.14
2243	0.14
2256	0.31
2257	0.35
2258	0.30
2260	0.14
2265	0.09
N	18
Minimum	0.09
Maximum	0.35
Mean	0.18
Std Dev	0.07
RSD	39%
95% PL	**0.32***

Table 11-6. Individual station characteristics, summary statistics, and 95% lower predictive limits for control adjusted amphipod survival (%), urchin development (% normal), and urchin fertilization (%) in the Baseline Pool.

Station	Amphipod	Urchin interface	Urchin pore water
CP 2231	76		66
CP 2238	90	88	36
CP 2243	84	106	97
CP 2433	84	115	100
CP 2441	82	89	102
SY 2231	84		99
SY 2243	92		92
SY 2433	96		79
SY 2441	95		90
2235	71		
2241	98		
2242	92		
2243	96		
2256	100		
2257	91		
2258	92		
2260	73		
2265	85		
N	18	4	9
Minimum	71	88	36
Maximum	100	115	102
Mean	88	100	85
Std Dev	8.4	13	22
RSD	10%	13%	26%
95% PL	72.9	64.7	41.9

Table 11-7. Individual station characteristics, summary statistics, and 95% lower predictive limits for abundance, number of taxa, Shannon-Weiner diversity index and BRI in the Baseline Pool.

Station	Abundance	# Taxa	S-W Diversity	BRI	BRI Level
CP 2231					
CP 2238	419	32	2.6	60.3	III
CP 2243	691	41	2.3	55.1	III
CP 2433	421	57	2.8	22.8	Reference
CP 2441	476	66	2.9	30.0	Reference
SY 2231					
SY 2243	989	78	2.5	45.1	II
SY 2433	441	77	2.6	16.8	Reference
SY 2441	506	108	2.8	19.9	Reference
2235	551	29	2.1	42.1	II
2241	1526	44	2.3	34.7	I
2242	1117	28	1.8	36.6	I
2243	966	47	2.7	36.4	I
2256	237	28	2.7	37.9	I
2257	503	37	2.3	38.1	I
2258	826	36	2.3	43.2	II
2260	2263	49	1.8	39.1	I
2265	1543	48	2.4	26.7	Reference
N	16	16	16	16	
Minimum	237	28	1.8	17	
Maximum	2263	108	2.9	60	
Mean	793.6	48.3	2.4	35.3	
Std dev	563.8	23.1	0.3	12.4	
RSD	71%	48%	14%	35%	
95% PL	239*	22*	1.8	57.7	

* Values were derived from natural log transformed data

Table 11-8. Individual station characteristics, summary statistics, and 95% upper predictive limits for tissue solids (%), lipids (%), and metals (mg/kg) in the Baseline Pool.

Station ID	Solids	Lipid	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
CP 2231	11.5	7.2	0.24	21.8	0.20	2.8	14.1	0.11	2.6	3.2	82.5
CP 2243	10.4	8.1	0.39	22.2	0.28	2.4	14.0	0.08	2.3	2.8	73.1
CP 2433	12.1	6.7	0.37	20.7	0.24	2.5	12.1	0.06	2.6	2.6	73.9
CP 2441	11.7	6.8	0.41	18.7	0.27	3.2	12.8	0.05	4.0	2.1	77.9
CP 2238	11.8	4.8	0.48	19.3	0.22	3.6	12.6	0.05	3.8	1.9	77.5
SY 2441	12.6	3.2	0.51	21.1	0.42	3.2	20.3	0.08	3.9	2.4	*
SY 2433	14.7	3.4	0.29	19.0	0.25	2.4	10.5	0.08	2.9	1.9	*
SY 2231	15.5	3.5	0.15	19.0	0.21	1.4	8.9	0.14	2.0	1.7	*
SY 2243	15.1	2.9	0.26	20.3	0.20	2.0	11.5	0.11	2.4	2.0	*
N	9	9	9	9	9	9	9	9	9	9	5
Min	10.4	2.9	0.15	18.7	0.20	1.4	8.9	0.05	2.0	1.7	73.1
Max	15.5	8.1	0.51	22.2	0.42	3.6	20.3	0.14	4.0	3.2	82.5
Mean	12.8	5.2	0.34	20.2	0.25	2.6	13.0	0.09	3.0	2.3	77.0
Std Dev	1.8	2.0	0.12	1.3	0.07	0.7	3.2	0.03	0.7	0.5	3.7
RSD	14%	39%	34%	6%	27%	25%	25%	38%	25%	22%	5%
Upper 95% PL			0.57	22.8	0.39	3.9	19.2	0.15	4.4	3.3	85.7

*Stations not used due to observed bias between studies

Table 11-9. Individual station characteristics, summary statistics, and 95% upper predictive limits for tissue organic contaminants (μg/kg) in the Baseline Pool.

Station ID	Naph	BAP	TPCB	α-Chlor	γ-Chlor	DDE	DDD	DDT
CP 2231	8.1	58	164	1.30	0.89	6.4	2.2	0.27
CP 2243	7.9	35	159	0.83	0.64	7.1	3.7	0.30
CP 2433	8.2	69	138	0.10	0.62	8.4	2.3	0.44
CP 2441	7.0	110	77	0.12	0.11	8.0	1.7	0.43
CP 2238	4.9	6	56	0.42	0.08	6.4	0.6	0.27
SY 2441	*	118	39	**	**	**	**	**
SY 2433	*	63	83	**	**	**	**	**
SY 2231	*	65	86	**	**	**	**	**
SY 2243	*	59	80	**	**	**	**	**
N	5	9	9	5	5	5	5	5
Min	4.9	6	39	0.10	0.08	6.4	0.6	0.27
Max	8.2	118	164	1.30	0.89	8.4	3.7	0.44
Mean	7.2	65	98	0.55	0.47	7.3	2.1	0.34
Std Dev	1.4	34	45	0.51	0.36	0.9	1.1	0.08
RSD	19%	53%	45%	92%	77%	12%	53%	25%
Upper 95% PL	10.4	132	186	1.75	1.30	9.3	4.7	0.54

*Stations not used due to observed bias between studies
**Chemical was not analyzed at these stations

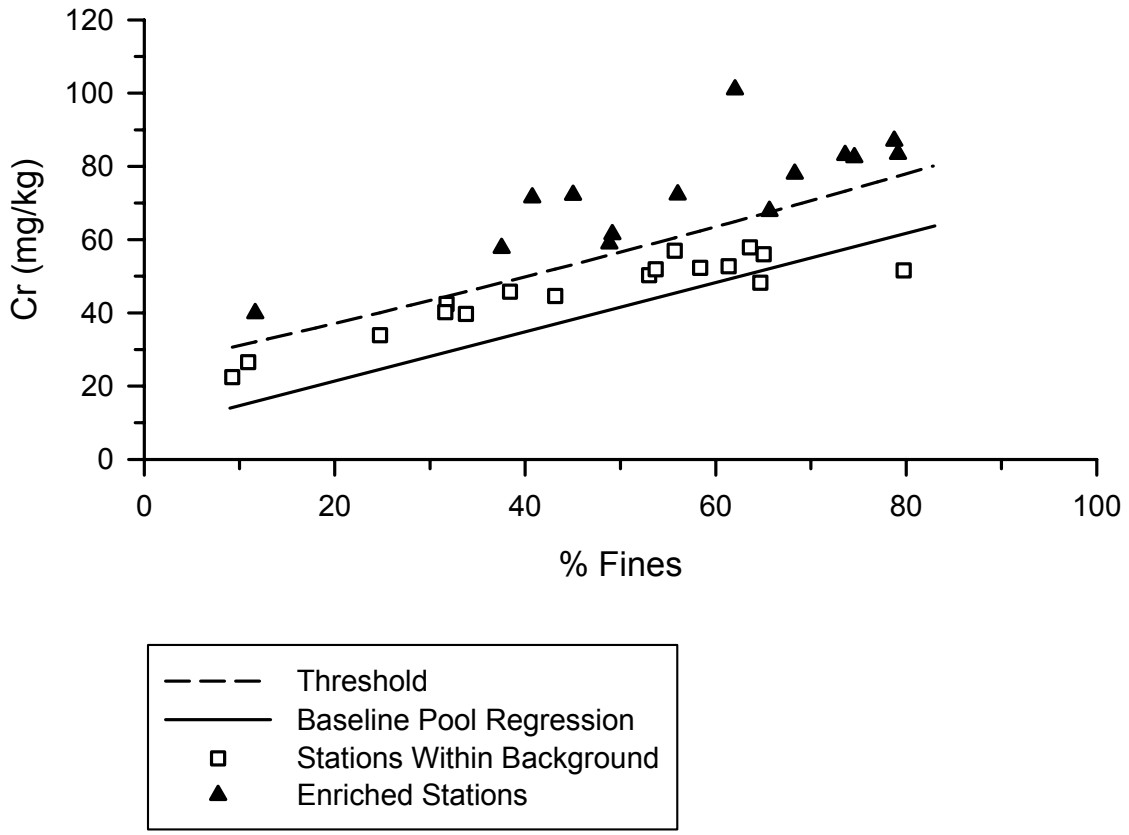


Figure 11-1. Example of the use of the %fines regression method to identify metal concentrations that exceed the baseline condition. Chromium concentrations for the Chollas and Paleta stations are overlaid on the threshold and regression lines from the Baseline Pool. Sites that lie above the threshold are considered enriched relative the baseline condition.

11.2 AQUATIC LIFE

11.2.1 Sediment Chemistry

Effects on aquatic life were assessed using three lines of evidence (LOE): sediment chemistry, toxicity, and benthic community composition. The relative degree of effect (or likelihood of an impact) was evaluated using the criteria described in Section 4.2 and used to classify each station as having low, moderate, or high impact for each LOE.

The relative likelihood that bulk sediment CoPCs were a site-specific causative agent for effects was ranked into three general categories of low, moderate, or high. The rankings were based on a comparison to the Baseline Pool (95 percentile predictive limit of the reference stations) and gave increasing weight or confidence that an effect to aquatic life will occur given an increasing number and magnitude of chemicals exceeding the SQG thresholds. The process used to apply the chemistry ranking criteria and classify the stations is illustrated in Figure 11-2.

Results of the sediment chemistry LOE for each station in the Chollas and Paleta sites are shown in Table 11-10. The results for the Chollas site showed that the three inner creek stations (C12, C13, C14) and three outer creek stations (C2, C3, and C5) contain chemical levels that have a high likelihood to cause effects to organisms living or feeding on these sediments. One station (C7) was categorized as having a low likelihood of impact from chemistry. The remaining Chollas stations were categorized as "Moderate" indicating that certain CoPCs (copper, PCB and Chlordane) at these stations may play a role in causing effects to the biota but that the levels are not sufficiently elevated to provide a high level of certainty.

The sole driver for inclusion of the six Chollas stations into the “High” category was their elevated SQGQ1 (Table 11-10). These stations were not necessarily different from other Chollas stations in number of individual exceedances of an SQG or even of an exceedance of a reference condition, but rather, in the magnitude of the exceedance in the group of chemicals making up the SQGQ1. The SQGQ1 of the three inner creek stations appeared to be driven by elevated organics, particularly PAH, chlordane, and DDT as well as by cadmium, copper and zinc. The three outer creek stations appeared to elevated in PCB, DDT, along with the full suite of metals in the SQGQ1 calculation. Station C7 was in an area having the lowest fines levels that likely resulted in the relatively lower levels of chemistry found there.

Results for the Paleta site categorize four stations as “Low” (P1, P3, P9, and P13), two stations (P11 and P15) as “High”, and 11 stations as “Moderate”. The four stations categorized as “Low” had all individual chemical concentrations falling below their respective SQGs and their baseline condition predictive limit. Tow of the “low” stations grouped in the northwest portion of outer creek coincident with an area of lower fines content. Stations P9 and P13 located along the northern side of the inner creek region were also located in an area of relatively lower fines. The main chemicals resulting in placing inner creek stations P11 and P15 into the ”High” category were mercury and chlordane that exceeded their individual SQGs at these stations. Additionally, elevated DDT, PAH, and PCB at these stations resulted in an elevated SQGQ1.The remaining 11 Paleta stations categorized as having moderate chemistry were scattered throughout the site. A few stations in the outer creek area had an exceedance only of the mercury SQG and several inner creek stations had an exceedance of only the chlordane SQG.

Stations in the moderate category were scattered throughout the site. Placement of stations into this category was sometimes the result of a single elevation above a SQG such as mercury in the outer creek region or chlordane in the inner creek area.

Table 11-10. Results of sediment chemistry LOE for each station in the Chollas and Paleta sites. Results are categorized as No/Low (○), Moderate (⊙), or High (●).

Station	# Chemicals exceeding SQG and UPL	SQGQ1 Level	SQGQ1 > Reference	Chem Class
C01	1	II	+	⊙
C02	1	III	+	●
C03	2	III	+	●
C04	1	II	+	⊙
C05	1	III	+	●
C06	1	II	+	⊙
C07	0	II	-	○
C08	1	II	+	⊙
C09	1	II	+	⊙
C10	2	II	+	⊙
C11	1	II	+	⊙
C12	2	III	+	●
C13	1	III	+	●
C14	1	III	+	●
P01	0	I	-	○
P02	0	II	+	⊙
P03	0	I	-	○
P04	0	II	+	⊙
P05	1	II	+	⊙
P06	1	II	+	⊙
P07	1	II	+	⊙
P08	0	II	+	⊙
P09	0	I	-	○
P10	1	II	+	⊙
P11	2	III	+	●
P12	1	II	+	⊙
P13	0	II	-	○
P14	1	II	+	⊙
P15	1	III	+	●
P16	1	II	+	⊙
P17	1	II	+	⊙

11.2.2 Toxicity

The results from all three toxicity tests were used to classify the relative magnitude of sediment toxicity into three general categories of low, moderate, or high. The rankings were based on a comparison to the control and the Baseline Pool. Increasing weight or confidence that a toxic effect to aquatic life will occur was given when a severe effect on amphipod survival was present t or toxicity was observed in multiple tests. The process used to apply the toxicity ranking criteria and classify the stations is illustrated in Figure 11-3.

Results of the toxicity LOE evaluation for each station in the Chollas and Paleta sites are shown in Table 11-11. The three inner Chollas stations received either High or Moderate toxicity classifications, with the station located closest to the creek mouth (C14) receiving the highest category of concern. Classification of the stations located in the outer portion of the Chollas site (C1-C11) was more varied, with five stations classified as Low, and the remaining stations classified as Moderate. Two of the three outermost Chollas stations (C1-C3) received the moderate classification.

All of the classifications into either the Moderate or High categories were based on the presence or absence of toxicity, rather than on the magnitude of response (i.e., <50% of control). The single site that was classified as “High” was toxic to both amphipods and sea urchin embryos at levels that exceeded the baseline condition. Six of the nine stations in the Moderate or High categories contained significant toxicity to amphipods and four of these stations also showed evidence of toxicity in more than one test.

Evaluation of toxicity at the Paleta stations indicated a lower level of impacts overall. Only four of the 17 stations had evidence of substantial toxic impacts and all of these stations were located in the innermost portion of the site (P11, P15-P17). P11 was the only station classified in the High category. All of the stations located in the outer portion of the Paleta site had no or little evidence of impact due to toxicity.

The toxicity characteristics responsible for the Moderate and High classifications of the Paleta stations differed from those present at the Chollas Site. Amphipod toxicity was absent at most stations and the amphipod survival results influenced the toxicity classification only for station P11. Severe toxicity to sea urchin embryos in the sediment-water interface test was the principal factor that determined the final classification for the toxicity LOE.

Table 11-11. Results of the toxicity LOE for each station in the Chollas and Paleta sites. Results were categorized as No/Low (O), Moderate (⊙), or High (●). NA reflects SWI ammonia interferences.

Station	Amphipod Survival			SWI Sea Urchin Development			PW Sea Urchin Fertilization			Tox Class
	<Control	<Ref	<50%	<Control	<Ref	<50%	<Control	<Ref	<50%	
C01	+	+	-	-	-	-	-	-	-	⊙
C02	+	+	-	-	-	-	-	-	-	⊙
C03	-	-	-	-	+	-	-	-	-	O
C04	+	+	-	-	-	-	-	-	-	⊙
C05	-	-	-	-	-	-	-	-	-	O
C06	+	+	-	-	+	-	-	-	-	⊙
C07	-	-	-	-	-	-	-	-	-	O
C08	-	-	-	-	-	-	-	-	-	O
C09	-	-	-	+	+	+	-	-	-	⊙
C10	+	+	-	-	+	-	-	-	-	⊙
C11	-	-	-	-	-	-	-	-	-	O
C12	-	-	-	+	+	+	+	-	-	⊙
C13	-	-	-	-	-	-	+	+	+	⊙
C14	+	+	-	+	+	+	-	-	-	●
P01	-	-	-	-	-	-	+	-	-	O
P02	-	-	-	-	-	-	+	-	-	O
P03	-	-	-	NA	NA	NA	-	-	-	O
P04	-	-	-	-	-	-	-	-	-	O
P05	-	-	-	-	-	-	-	-	-	O
P06	-	-	-	-	-	-	-	-	-	O
P07	-	-	-	-	-	-	-	-	-	O
P08	-	-	-	-	-	-	-	-	-	O
P09	-	-	-	-	-	-	-	-	-	O
P10	-	-	-	NA	NA	NA	-	-	-	O
P11	+	+	-	+	+	+	-	-	-	●
P12	-	-	-	-	+	-	-	-	-	O
P13	-	-	-	-	-	-	-	-	-	O
P14	-	-	-	-	-	-	-	-	-	O
P15	-	-	-	+	+	+	-	-	-	⊙
P16	-	-	-	+	+	+	-	-	-	⊙
P17	-	-	-	+	+	+	-	-	-	⊙

11.2.3 Benthic Community

The results from all the four benthic community parameters (BRI, abundance, number of taxa, Shannon-Weiner diversity index) were used to classify the relative response of the benthic community into three general categories of low, moderate, or high. The rankings were based on a comparison to the Baseline Pool for each parameter and, for the BRI, a comparison to five response level thresholds that indicate the degree departure from the reference condition expected in the absence of contamination. Increasing weight or confidence that a benthic community impact was present was given when a severe departure from the BRI reference condition was present or when effects were observed for multiple parameters. The process used to apply the benthos ranking criteria and classify the stations is illustrated in Figure 11-4.

Results of the benthic community LOE evaluation for each station in the Chollas and Paleta sites are shown in Table 11-12. Five stations in the Chollas site were classified as having a Moderate level of impact and three stations were classified as High. All of the stations located in the inner part of the study site showed evidence of impact to the benthic community. The other impacted stations were dispersed throughout the outer part of the study site and were generally located in the middle region of the channel (midway between the docks lining the channel sides). Assignment of the Moderate classification was prompted by reduced abundance and number of taxa in most cases.

Two of the stations that were classified as High and exhibited a relatively high BRI in combination with a reduced values for 2-3 of the other parameters. Six of the Chollas stations contained elevated BRI scores (>41) that indicated a clear disturbance of the community (BRI response level II-III), but these scores were not significantly different from the condition typical of the Baseline Pool and were therefore assigned a Low impact classification.

Similar to Chollas, most of the stations in the Paleta site received a Moderate or High classification, indicating that the benthic community condition was different from the Baseline Pool. Eight stations received a Moderate classification and three stations were in the High category. Benthic community impacts were most prevalent and severe at stations located in the innermost area of the Paleta site (P15-P17).

Most of the impacted Paleta stations had significant reductions in abundance and number of taxa relative to the Baseline Pool. A significantly elevated BRI score was only present at three of the inner Paleta stations. Five of the Paleta Site stations had BRI scores indicating an impact relative to non-contaminated reference conditions, but received a Low classification due to the presence of a similar level of impact in the Baseline Pool.

Table 11-12. Results of the benthic community analysis LOE for each station in the Chollas and Paleta sites, categorized as No/Low (○), Moderate (⊙), or High (●).

Station	Abun<Ref	Taxa<Ref	SW<Ref	BRI>Ref	BRI Response Level	BCA Class
C01	-	-	-	-	III	○
C02	-	-	-	-	III	○
C03	-	-	-	-	IV	○
C04	-	-	-	-	IV	○
C05	-	-	-	-	IV	○
C06	-	-	-	-	III	○
C07	-	-	-	-	III	○
C08	-	+	+	+	IV	●
C09	-	-	-	-	IV	○
C10	-	-	-	-	IV	○
C11	-	+	-	-	I	⊙
C12	-	-	-	-	IV	○
C13	-	-	-	+	IV	⊙
C14	-	+	+	+	V	●
P01	-	-	-	-	II	○
P02	-	-	-	-	III	○
P03	-	-	-	-	IV	○
P04	-	-	-	-	III	○
P05	-	-	+	-	III	⊙
P06	-	-	-	-	IV	○
P07	-	-	-	-	IV	○
P08	-	-	-	-	III	○
P09	-	-	-	-	III	○
P10	-	-	-	-	IV	○
P11	-	-	-	-	IV	○
P12	-	-	-	-	III	○
P13	-	-	-	-	III	○
P14	-	-	-	-	IV	○
P15	-	-	-	+	IV	⊙
P16	-	-	-	+	IV	⊙
P17	-	-	-	+	IV	⊙

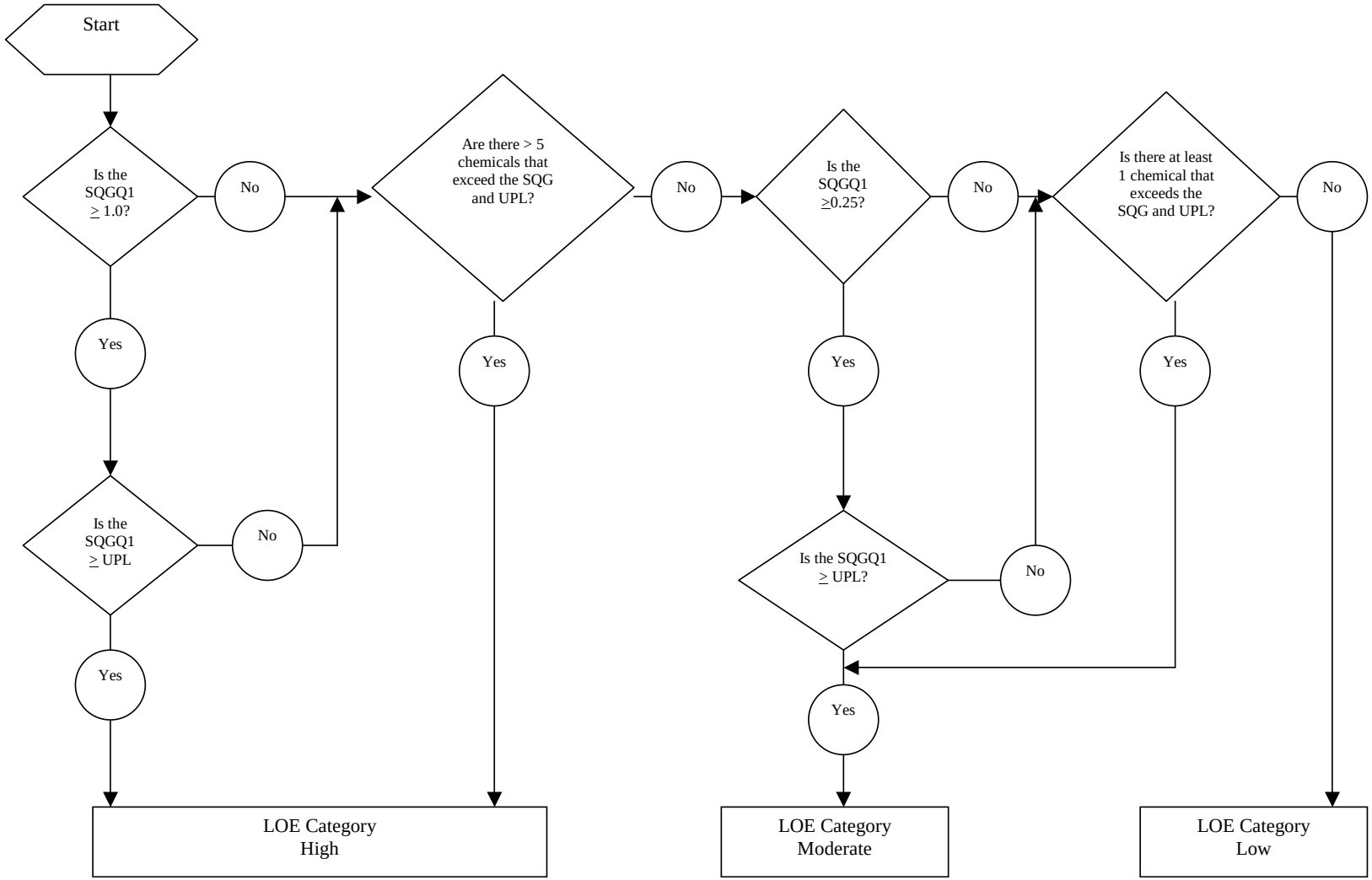


Figure 11-2. Schematic of decision tree used to apply station ranking criteria for chemistry.

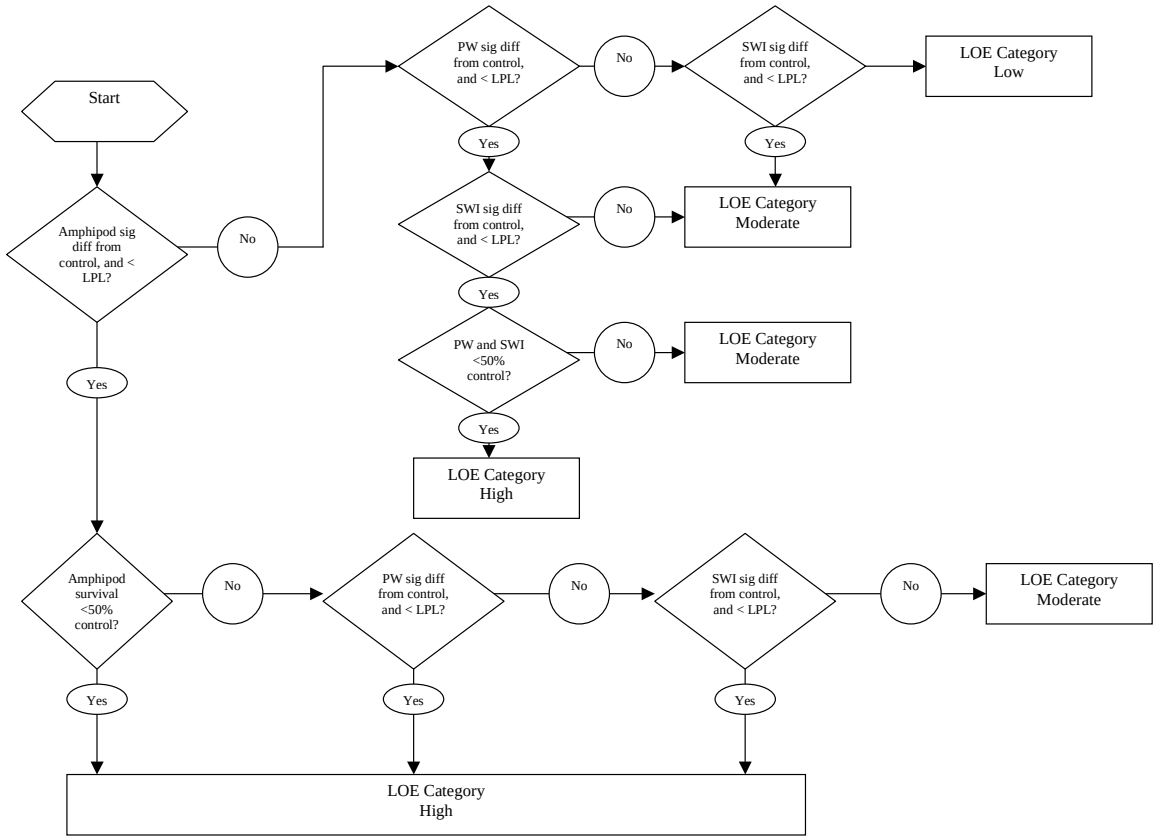


Figure 11-3. Schematic of decision tree used to apply station ranking criteria for toxicity.

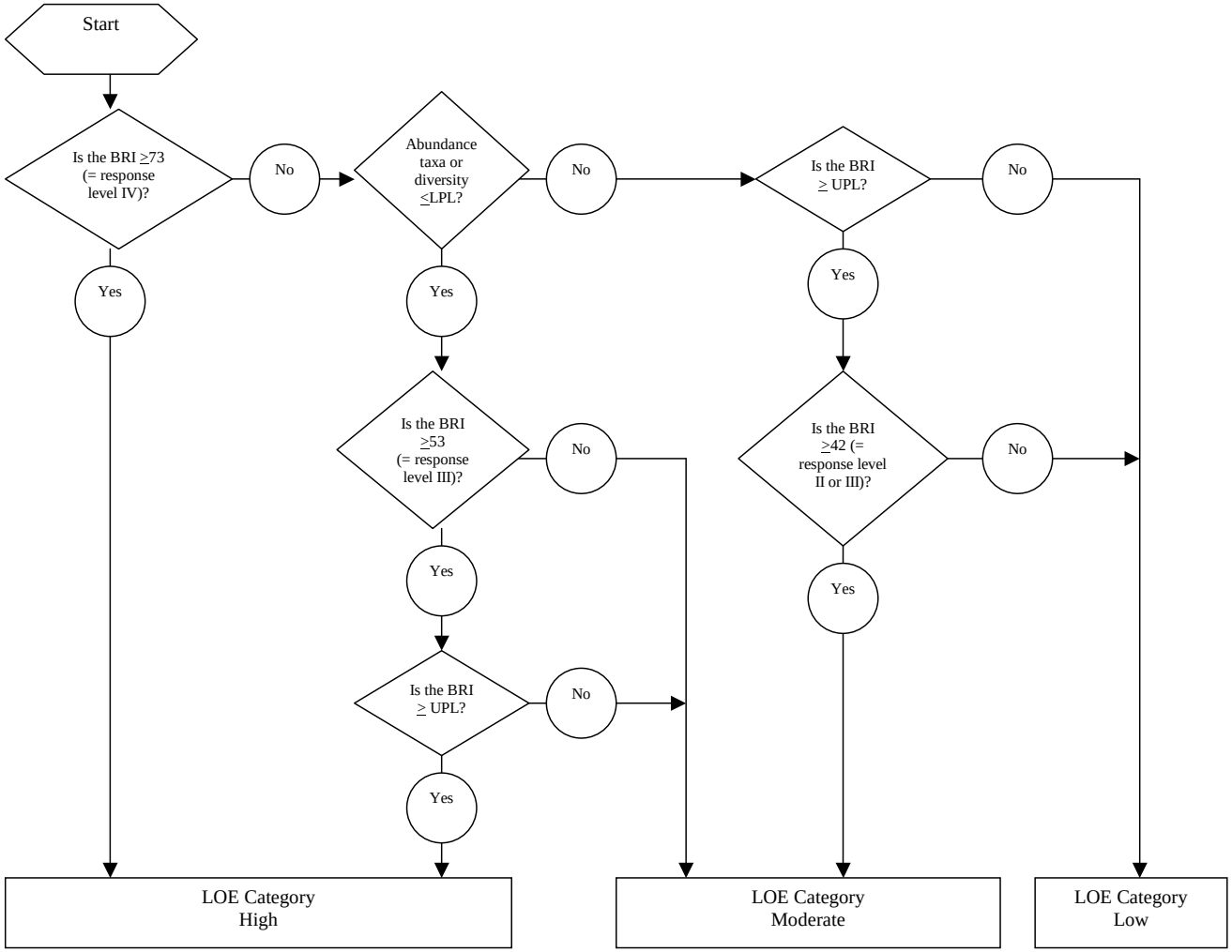


Figure 11-4. Schematic of decision tree used to apply station ranking criteria for benthos.

11.3 AQUATIC DEPENDENT WILDLIFE

A screening level risk assessment was performed to assess potential impairment to aquatic-dependent wildlife. For this assessment, bioaccumulation of CoPCs in the clam *Macoma nasuta* exposed to site sediments was used to estimate exposure for representative wildlife receptors including surface feeding birds (Least Tern and Brown Pelican), diving birds (Surf Scoter and Western Grebe), and marine mammals (California Sea Lion). For the screening level assessment, conservative exposure assumptions included 100% dietary fraction from the site, 100% area use factor for the site, and the low toxicity reference value. As previously discussed, the tissue chemistry for chromium and nickel was compromised during the analysis process. To estimate tissue concentrations for these metals, we calculated BSAFs based on the tissue and sediment data collected in the NASSCO/Southwest Shipyards study. Estimated BSAFs were 0.06 for chromium and 0.23 for nickel.

The screening level risk assessment for aquatic-dependent wildlife was based on the following procedure. First, chemical concentrations in clam tissue were compared to measurements made on control samples to detect the presence of contaminant bioaccumulation. Control samples were compared to pooled Paleta and Chollas stations using a one-sided t-test to detect statistical differences at $p<0.05$. For the Paleta site, copper, mercury, lead, Benzo[a]pyrene, TPCB, alpha-Chlordane, gamma-Chlordane, DDE and DDD all showed statistically significant bioaccumulation relative to controls (Table 11-20). For the Chollas site, copper, lead, Benzo[a]pyrene, TPCB, alpha-Chlordane, gamma-Chlordane, DDE and DDD all showed statistically significant bioaccumulation relative to controls (Table 11-21).

Next, the site-maximum tissue concentrations of clams exposed to study site sediments were compared with the 95% upper predictive interval of tissue concentrations from clams exposed to reference sediments to determine if the elevated concentrations were above those characteristic of relatively undegraded conditions in the bay. For the Paleta site, chromium, nickel, lead, zinc, Benzo[a]pyrene, TPCB, alpha-Chlordane, gamma-Chlordane, DDE, DDD and DDT all had maximum tissue concentrations greater than reference (Table 11-20). For the Chollas site, arsenic, chromium, copper, lead, zinc, Naphthalene, TPCB, alpha-Chlordane, gamma-Chlordane, DDE, DDD and DDT all had maximum tissue concentrations greater than reference (Table 11-21).

Finally, the site-maximum concentrations from each site (Chollas and Paleta) were used to estimate doses to wildlife receptors including surface feeding birds (Least Tern and Brown Pelican), diving birds (Surf Scoter and Western Grebe), and marine mammals (California Sea Lion). Doses for each receptor were estimated as

$$D = C_{tiss} \times NFR \times FR \times AE \times AUF$$

where: C_{tiss} is the tissue wet-weight concentration of the chemical, NFR is the normalized feeding rate, FR is the fraction of the food that is contaminated, AE is the assimilation efficiency, and AUF is the area use factor. These parameters are summarized in Table 11-13. Estimated doses were then compared to the low Biological Technical Assistance Group (BTAG) TRVs (USEPA, 2002) where available, or other

published thresholds in the case where BTAG TRVs were not available as shown in Table 11-14. Hazard quotients were then calculated as HQ=Dose/TRV (Table 11-15 through Table 11-19). For the Paleta site, no chemicals had HQ>1 for any of the wildlife receptors (Table 11-20). For the Chollas site, only copper had HQ>1 (HQ=1.1) for the Least Tern and Brown Pelican (Table 11-21).

For copper at the Chollas site where HQ≥1 for the Least Tern and Brown Pelican, and tissue levels were greater than reference and control, a station-by-station assessment was made following the same procedure as described above, but using the individual station tissue concentration instead of the maximum concentration of all stations. For stations where bioaccumulation was not measured, tissue concentrations were estimated based on a site-specific Biota-Sediment Accumulation Factor (BSAF) calculated from tissue and sediment concentrations at stations where bioaccumulation was measured (Table 11-22). For copper, the best tissue-sediment relationship was found between fines normalized sediment concentration, and dry-weight tissue concentration (r^2=0.65; Figure 11-5). The results of the station-by-station assessment indicated three stations, C07, C10 and C11 with HQ≥1 for the Least Tern, and only one station (C11) with HQ≥1 for the Brown Pelican (HQ=1.1). HQ Values ranged from 1.0 at C07 to 1.6 at C11 for the Least Tern. The HQ values at C07 and C10 were based on BSAF estimates, while the values at C11 were based on direct measurement.

Table 11-13. Wildlife receptor characteristics.

Receptor	Body Weight (kg)	Food type	Area Use Factor	Fraction Food Contaminated	Assimilation Efficiency	Feeding Rate (kg_{dry}/d)	Average Dry Weight Fraction (kg_{dry}/kg_{wet})	Normalized Feeding Rate ($kg_{wet}/kg_{BW}/d$)
Brown pelican	2.845	Macoma	1	1	1	0.23	0.114	0.71
Least Tern	0.036	Macoma	1	1	1	0.0044	0.114	1.07
Western Grebe	0.808	Macoma	1	1	1	0.046	0.114	0.50
Surf Scoter	0.859	Macoma	1	1	1	0.048	0.114	0.49
Sea Lion	45	Macoma	1	1	1	0.99	0.114	0.19

Table 11-14. Avian and mammal TRVs (mg/kg/d).

TRV	Avian TRV_{low}	Mammal TRV_{low}	Toxic Endpoint	Source
Ag	180	0.38	Avian: Reproduction Mammal: Hypoactivity	Rungby and Danscher (1984)
As	5.5	0.32	Avian: Reproduction Mammal: Growth, cancer	U.S. EPA (2002)
Cd	0.08	0.06	Avian: Kidney Mammal: Reproduction	U.S. EPA (2002)
Cr	0.86	3.3	Avian: Survival Mammal: Liver, kidney	Haseltine et al. (1985) MacKenzie et al. (1958)
Cu	2.3	2.7	Avian: Growth Mammal: Immunotixicity	U.S. EPA (2002)
Hg	0.039	0.027	Avian: Reproduction Mammal: Mortality, anorexia, neurological	U.S. EPA (2002)
Ni	1.4	0.13	Avian: Growth Mammal: Reproduction	U.S. EPA (2002)
Pb	3.9	11	Avian: Reproduction Mammal: Reproduction	Pattee (1984) Azar et al. (1973)
Zn	17	9.6	Avian: Growth, reproduction Mammal: Pancreas, adrenal cortex	U.S. EPA (2002)
Naph	2.9	50	Avian: Mortality Mammal: Developmental	Ogden (2004) U.S. EPA (2002)
BAP	2	1.3	Avian: Growth Mammal: Cancer	Ogden (2004) U.S. EPA (2002)
TPCB	0.09	0.36	Avian: Reproduction Mammal: Reproduction	U.S. EPA (2002)
α-Chlor	0.21	4.6	Avian: Reproduction Mammal: Reproduction	Sample et al. (1996)
γ-Chlor	0.21	4.6	Avian: Reproduction Mammal: Reproduction	Sample et al. (1996)
DDE	0.009	0.8	Avian: Reproduction Mammal: Reproduction	U.S. EPA (2002)
DDD	0.009	0.8	Avian: Reproduction Mammal: Reproduction	U.S. EPA (2002)
DDT	0.009	0.8	Avian: Reproduction Mammal: Reproduction	U.S. EPA (2002)

Table 11-15. Estimated dose and HQ for the Brown Pelican.

	Paleta			Chollas		
	Tiss. Conc. (mg/kg_{wet})	Dose (mg/kg/d)	HQ	Tiss. Conc. (mg/kg_{wet})	Dose (mg/kg/d)	HQ
Ag	0.047	0.036	0.00020	0.062	0.059	0.00033
As	2.5	1.8	0.34	2.7	2.0	0.37
Cd	0.031	0.023	0.29	0.031	0.024	0.30
Cr	0.60	0.44	0.51	0.49	0.35	0.41
Cu	1.9	1.5	0.64	2.4	2.4	1.1
Hg	0.0078	0.0057	0.15	0.0068	0.0051	0.13
Ni	0.56	0.41	0.30	0.47	0.35	0.25
Pb	0.85	0.83	0.21	0.74	0.72	0.19
Zn	9.9	7.8	0.45	10	7.8	0.45
Naph	0.0012	0.00093	0.00032	0.0015	0.0013	0.00045
BAP	0.067	0.050	0.025	0.052	0.068	0.034
TPCB	0.052	0.043	0.47	0.028	0.026	0.29
α-Chlor	0.0020	0.0019	0.0089	0.0018	0.0014	0.0067
γ-Chlor	0.0024	0.0023	0.011	0.0016	0.0013	0.0063
DDE	0.0036	0.0031	0.34	0.0017	0.0014	0.15
DDD	0.0033	0.0028	0.31	0.0010	0.0010	0.11
DDT	0.00021	0.00021	0.023	0.000090	0.00011	0.012

Table 11-16. Estimated dose and HQ for the Least Tern.

	Paleta			Chollas		
	Tiss. Conc. (mg/kg_{wet})	Dose (mg/kg/d)	HQ	Tiss. Conc. (mg/kg_{wet})	Dose (mg/kg/d)	HQ
Ag	0.047	0.055	0.00031	0.062	0.089	0.00050
As	2.5	2.8	0.51	2.7	3.1	0.56
Cd	0.031	0.035	0.44	0.031	0.036	0.45
Cr	0.60	0.67	0.78	0.49	0.53	0.62
Cu	1.9	2.2	0.97	2.4	3.7	1.6
Hg	0.0078	0.0086	0.22	0.0068	0.0078	0.20
Ni	0.56	0.62	0.45	0.47	0.52	0.38
Pb	0.85	1.25	0.32	0.74	1.1	0.28
Zn	9.9	12	0.69	10	12	0.68
Naph	0.0012	0.0014	0.00049	0.0015	0.0019	0.00068
BAP	0.067	0.076	0.038	0.052	0.103	0.052
TPCB	0.052	0.065	0.72	0.028	0.039	0.43
α-Chlor	0.0020	0.0028	0.013	0.0018	0.0021	0.010
γ-Chlor	0.0024	0.0035	0.016	0.0016	0.0020	0.0095
DDE	0.0036	0.0046	0.51	0.0017	0.0021	0.23
DDD	0.0033	0.0042	0.47	0.0010	0.0015	0.17
DDT	0.00021	0.00032	0.035	0.000090	0.00016	0.018

Table 11-17. Estimated dose and HQ for the Western Grebe.

	Paleta			Chollas		
	Tiss. Conc. (mg/kg_{wet})	Dose (mg/kg/d)	HQ	Tiss. Conc. (mg/kg_{wet})	Dose (mg/kg/d)	HQ
Ag	0.047	0.026	0.00014	0.062	0.041	0.00023
As	2.5	1.3	0.24	2.7	1.4	0.26
Cd	0.031	0.017	0.21	0.031	0.017	0.21
Cr	0.60	0.31	0.36	0.49	0.25	0.29
Cu	1.9	1.0	0.45	2.4	1.7	0.74
Hg	0.0078	0.0040	0.10	0.0068	0.0036	0.09
Ni	0.56	0.29	0.21	0.47	0.24	0.18
Pb	0.85	0.58	0.15	0.74	0.51	0.13
Zn	9.9	5.5	0.32	10	5.5	0.32
Naph	0.0012	0.00065	0.00023	0.0015	0.00090	0.00032
BAP	0.067	0.035	0.018	0.052	0.048	0.024
TPCB	0.052	0.030	0.33	0.028	0.018	0.20
α-Chlor	0.0020	0.0013	0.0062	0.0018	0.00099	0.0047
γ-Chlor	0.0024	0.0016	0.0076	0.0016	0.00093	0.0044
DDE	0.0036	0.0022	0.24	0.0017	0.00096	0.11
DDD	0.0033	0.0020	0.22	0.0010	0.00070	0.078
DDT	0.00021	0.00015	0.016	0.000090	0.000075	0.0083

Table 11-18. Estimated dose and HQ for the Surf Scoter.

	Paleta			Chollas		
	Tiss. Conc. (mg/kg_{wet})	Dose (mg/kg/d)	HQ	Tiss. Conc. (mg/kg_{wet})	Dose (mg/kg/d)	HQ
Ag	0.047	0.025	0.00014	0.062	0.041	0.00023
As	2.5	1.3	0.23	2.7	1.4	0.25
Cd	0.031	0.016	0.20	0.031	0.016	0.21
Cr	0.60	0.31	0.36	0.49	0.24	0.28
Cu	1.9	1.0	0.44	2.4	1.7	0.73
Hg	0.0078	0.0039	0.10	0.0068	0.0036	0.09
Ni	0.56	0.28	0.20	0.47	0.24	0.17
Pb	0.85	0.57	0.15	0.74	0.50	0.13
Zn	9.9	5.4	0.31	10	5.4	0.31
Naph	0.0012	0.00064	0.00022	0.0015	0.00089	0.00031
BAP	0.067	0.035	0.017	0.052	0.047	0.024
TPCB	0.052	0.030	0.33	0.028	0.018	0.20
α-Chlor	0.0020	0.0013	0.0061	0.0018	0.00097	0.0046
γ-Chlor	0.0024	0.0016	0.0075	0.0016	0.00092	0.0043
DDE	0.0036	0.0021	0.23	0.0017	0.00094	0.10
DDD	0.0033	0.0019	0.22	0.0010	0.00069	0.077
DDT	0.00021	0.00015	0.016	0.000090	0.000074	0.0082

Table 11-19. Estimated dose and HQ for the Sea Lion.

	Paleta			Chollas		
	Tiss. Conc. (mg/kg_{wet})	Dose (mg/kg/d)	HQ	Tiss. Conc. (mg/kg_{wet})	Dose (mg/kg/d)	HQ
Ag	0.047	0.0099	0.000056	0.062	0.016	0.000090
As	2.5	0.50	0.091	2.7	0.55	0.10
Cd	0.031	0.0064	0.080	0.031	0.0065	0.081
Cr	0.60	0.12	0.14	0.49	0.10	0.11
Cu	1.9	0.40	0.17	2.4	0.66	0.29
Hg	0.0078	0.0016	0.040	0.0068	0.0014	0.036
Ni	0.56	0.11	0.081	0.47	0.094	0.068
Pb	0.85	0.23	0.058	0.74	0.20	0.050
Zn	9.9	2.1	0.12	10	2.1	0.12
Naph	0.0012	0.00025	0.000088	0.0015	0.00035	0.00012
BAP	0.067	0.014	0.0069	0.052	0.019	0.0093
TPCB	0.052	0.012	0.13	0.028	0.0070	0.078
α-Chlor	0.0020	0.00051	0.0024	0.0018	0.00038	0.0018
γ-Chlor	0.0024	0.00062	0.0029	0.0016	0.00036	0.0017
DDE	0.0036	0.00083	0.092	0.0017	0.00037	0.041
DDD	0.0033	0.00076	0.085	0.0010	0.00027	0.030
DDT	0.00021	0.000057	0.0064	0.000090	0.000029	0.0032

Table 11-20. Summary of the screening level wildlife risk assessment for the Paleta site.

	>Control	>Baseline	Brown Pelican HQ>1	Least Tern HQ>1	Western Grebe HQ>1	Surf Scoter HQ>1	Sea Lion HQ>1
Ag	-	-	-	-	-	-	-
As	-	-	-	-	-	-	-
Cd	-	-	-	-	-	-	-
Cr	-	+	-	-	-	-	-
Cu	+	-	-	-	-	-	-
Hg	+	-	-	-	-	-	-
Ni	-	+	-	-	-	-	-
Pb	+	+	-	-	-	-	-
Zn	-	+	-	-	-	-	-
Naph	-	+	-	-	-	-	-
BAP	+	+	-	-	-	-	-
TPCB	+	+	-	-	-	-	-
α-Chlor	+	+	-	-	-	-	-
γ-Chlor	+	+	-	-	-	-	-
DDE	+	+	-	-	-	-	-
DDD	+	+	-	-	-	-	-
DDT	-	+	-	-	-	-	-

Table 11-21. Summary of the screening level wildlife risk assessment for the Chollas site.

	>Control	>Baseline	Brown Pelican HQ>1	Least Tern HQ>1	Western Grebe HQ>1	Surf Scoter HQ>1	Sea Lion HQ>1
Ag	-	+	-	-	-	-	-
As	-	+	-	-	-	-	-
Cd	-	-	-	-	-	-	-
Cr	-	+	-	-	-	-	-
Cu	+	+	+	+	-	-	-
Hg	-	-	-	-	-	-	-
Ni	-	-	-	-	-	-	-
Pb	+	+	-	-	-	-	-
Zn	-	+	-	-	-	-	-
Naph	-	+	-	-	-	-	-
BAP	+	+	-	-	-	-	-
TPCB	+	+	-	-	-	-	-
α-Chlor	+	+	-	-	-	-	-
γ-Chlor	+	+	-	-	-	-	-
DDE	+	+	-	-	-	-	-
DDD	+	+	-	-	-	-	-
DDT	-	+	-	-	-	-	-

Table 11-22. Station-by-station assessment for Least Tern and Brown Pelican exposure to copper at the Chollas site.

Site	Station	Copper in Sediment (mg/kg)	Copper in Tissue (mg/kgdry)	Tissue Solids (%)	Copper in Tissue (mg/kgwet)	Least Tern Dose (mg/kg/d)	Least Tern HQ	Brown Pelican Dose (mg/kg/d)	Brown Pelican HQ
Chollas	C01	139	14.2*	11.4**	1.62	1.74	0.8	1.15	0.5
	C02	130	16.5	11.3	1.86	2.00	0.9	1.32	0.6
	C03	155	14.8*	11.4**	1.69	1.82	0.8	1.20	0.5
	C04	97.4	14.4*	11.4**	1.64	1.76	0.8	1.17	0.5
	C05	108	13.5	11.3	1.53	1.64	0.7	1.08	0.5
	C06	141	14.3*	11.4**	1.64	1.75	0.8	1.16	0.5
	C07	47.9	19.7*	11.4**	2.25	2.41	**1.0**	1.60	0.7
	C08	68	13.7	11.6	1.60	1.71	0.7	1.13	0.5
	C09	119	14.4*	11.4**	1.64	1.76	0.8	1.16	0.5
	C10	314	20.9*	11.4**	2.39	2.56	**1.1**	1.69	0.7
	C11	104	31.0	11.0	3.41	3.66	**1.6**	2.42	**1.1**
	C12	78.5	14.2	11.2	1.59	1.71	0.7	1.13	0.5
	C13	103	12.6	11.4	1.44	1.54	0.7	1.02	0.4
	C14	94.9	12.3	11.1	1.37	1.46	0.6	0.97	0.4

*Value shown was estimated from the BSAF at measured stations
**Value shown was taken as the mean value of measured stations

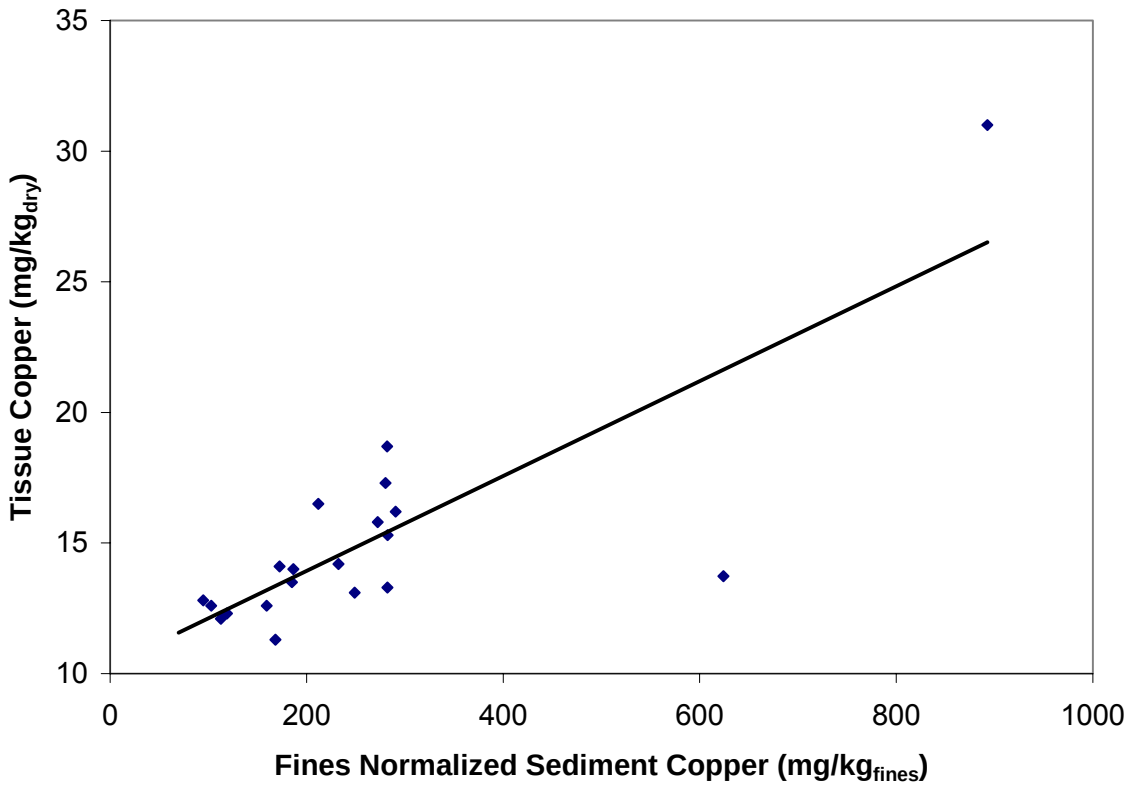


Figure 11-5. BSAF regression for copper in clam tissues as a function of fines-normalized sediment copper concentration (r^2=0.65).

11.4 HUMAN HEALTH

A screening level risk assessment was also used to assess potential impairment to human health. For this assessment, bioaccumulation of CoPCs in clams exposed to site sediments were be used to estimate exposure. In this case it was assumed that clam tissue is representative of all marine life harvested and consumed by humans from the sites. Conservative assumptions for this assessment included 100% of seafood consumption from site, 100% assumed contaminated at 95% upper confidence limit, a conservative consumption rate, and conservative exposure duration.

The screening level risk assessment for human health followed a similar procedure to that described above for aquatic-dependent wildlife. Comparisons to control and reference were carried out in an identical manner. Control samples were compared to pooled Paleta and Chollas stations using a one-sided t-test to detect statistical differences at $p<0.05$. For the Paleta site, copper, mercury, lead, Benzo[a]pyrene, TPCB, alpha-Chlordane, gamma-Chlordane, DDE and DDD all showed statistically significant bioaccumulation relative to controls (Table 11-26). For the Chollas site, copper, lead, Benzo[a]pyrene, TPCB, alpha-Chlordane, gamma-Chlordane, DDE and DDD all showed statistically significant bioaccumulation relative to controls (Table 11-26).

Next, the site-maximum tissue concentrations of clams exposed to study site sediments were compared with the 95% upper predictive interval of tissue concentrations from clams exposed to reference sediments to determine if the elevated concentrations were above those characteristic of relatively undegraded conditions in the bay. For the Paleta site, chromium, nickel, lead, zinc, Naphthalene, Benzo[a]pyrene, TPCB, alpha-Chlordane, gamma-Chlordane, DDE, DDD and DDT all had site-maximum tissue concentrations greater than reference (Table 11-26). For the Chollas site, silver, arsenic, chromium, copper, lead, zinc, Naphthalene, Benzo[a]pyrene, TPCB, alpha-Chlordane, gamma-Chlordane, DDE, DDD and DDT all had site-maximum tissue concentrations greater than reference (Table 11-26).

Finally, the site-maximum clam tissue concentrations from each site (Chollas and Paleta) were compared to tissue screening levels. For carcinogens, the TSL_c was defined as

$$TSL_c = \frac{TRL \times BW}{CSF \times CR \times FI \times ABS}$$

where TRL is the target risk level, BW is the body weight, CSF is the cancer slope factor, CR is the consumption rate, FI is the fractional intake from the site, and ABS is the absorbed fraction; values were obtained from OEHHA (1999). These parameters are summarized in Table 11-23 and Table 11-24. For non-carcinogens, the TSL_t was defines as

$$TSL_t = \frac{RfD \times BW}{CR \times FI \times ABS}$$

where RfD is the toxic reference dose (Table 11-24). In the case where a chemical had both a TSL_c and TSL_t, the final human health screening level was then taken as the minimum of the two (Table 11-24). The site-maximum tissue concentrations of clams exposed to study site sediments were then compared to the TSL_{min}. The results of this analysis indicated that tissue concentrations of arsenic, Benzo[a]pyrene, and TPCB in clams exceeded the tissue screening levels (Table 11-25).

For those chemicals that exceeded human health screening thresholds and had tissue levels greater than reference and control, a station-by-station assessment was made following the same procedure as described above, but using the individual station tissue concentration instead of the maximum of all stations. These chemicals included Benzo[a]pyrene, and TPCB. Although arsenic exceeded the human health screening level, it did not exceed reference and control at either of the sites. For stations where bioaccumulation was not measured, tissue concentrations of Benzo[a]pyrene, and TPCB were estimated based on site-specific BSAFs calculated from tissue and sediment concentrations at stations where bioaccumulation was measured (Table 11-27 and Table 11-28). For Benzo[a]pyrene, the best tissue-sediment relationship was found between TOC-normalized sediment concentration, and lipid-normalized tissue concentration (r^2=0.85; Figure 11-6). For Benzo[a]pyrene, measured and calculated tissue concentrations exceeded the screening level at all Chollas and Paleta stations by factors ranging from 1.3-21.1 at Chollas and 5.6-15.6 at Paleta. For TPCB, measured and calculated tissue concentrations exceeded the screening level at all Chollas and Paleta stations except C13 and C14. TPCB screening levels were exceeded by factors ranging from 1.1-2.7 at Chollas and 1.1-3.7 at Paleta.

Table 11-23. Human health risk screening parameters.

Parameter	Value	Units
Consumption Rate	0.021	kg/d
Fraction Ingested	1	
Body Weight	70	kg
Target Risk Level	1.0E-05	
Absorbed Fraction	1	

Table 11-24. Human health risk tissue screening levels.

	CSF $(mg/kg/day)^{-1}$	RfD mg/kg/day	TSL_c mg/kg	TSL_t mg/kg	TSL_{min} mg/kg	Reference
Ag		5.0E-03		17	17	EPA (2004)
As		3.0E-04		1.0	1.0	EPA (2004)
Cd		5.0E-04		1.7	1.7	EPA (2004)
Cr		3.0E-03		10	10	EPA (2004)
Cu		3.7E-02		123	123	EPA (2004)
Hg		1.0E-04		0.33	0.33	EPA (2004)
Ni		2.0E-02		67	67	EPA (2004)
Pb				1.7	1.7	FDA (1993)
Zn		3.0E-01		1000	1000	EPA (2004)
Naph		2.0E-02		67	67	EPA (2004)
BAP	7.3		0.0046		0.0046	EPA (2004)
TPCB	2.0	2.0E-05	0.017	0.067	0.017	EPA (2004)
α-Chlor	0.35	5.0E-04	0.095	1.7	0.095	EPA (2004)
γ-Chlor	0.35	5.0E-04	0.095	1.7	0.095	EPA (2004)
DDE	0.34		0.098		0.098	EPA (2004)
DDD	0.24		0.14		0.14	EPA (2004)
DDT	0.34	5.0E-04	0.098	1.7	0.098	EPA (2004)

Table 11-25. Maximum tissue concentrations for the Chollas and Paleta sites, and corresponding normalized human health risk levels (tissue concentration/screening level).

	Paleta		Chollas	
	Tiss. Conc. (mg/kg_{wet})	C_{tiss}/TSL	Tiss. Conc. (mg/kg_{wet})	C_{tiss}/TSL
Ag	0.047	0.0031	0.051	0.0050
As	2.5	**2.6**	2.1	**2.9**
Cd	0.031	0.020	0.033	0.020
Cr	0.60	0.062	0.45	0.049
Cu	1.9	0.017	1.4	0.028
Hg	0.0078	0.024	0.0045	0.022
Ni	0.56	0.0086	0.48	0.0073
Pb	0.85	0.69	0.50	0.60
Zn	9.9	0.011	9.6	0.011
Naph	0.0012	0.000020	0.0010	0.000027
BAP	0.067	**16**	0.0060	**21**
TPCB	0.052	**3.6**	0.012	**2.2**
α-Chlor	0.0020	0.028	0.0014	0.021
γ-Chlor	0.0024	0.034	0.0013	0.020
DDE	0.0036	0.044	0.0013	0.020
DDD	0.0033	0.029	0.00022	0.010
DDT	0.00021	0.0030	0.00015	0.0015

Table 11-26. Summary of the screening level human health risk assessment for the Chollas and Paleta sites.

	Paleta				Chollas			
	>Control	>Baseline	>TSL_{min}	Station Analysis	>Control	>Baseline	>TSL_{min}	Station Analysis
Ag	-	-	-	no	-	+	-	no
As	-	-	+	no	-	+	+	no
Cd	-	-	-	no	-	-	-	no
Cr	-	+	-	no	-	+	-	no
Cu	+	-	-	no	+	+	-	no
Hg	+	-	-	no	-	-	-	no
Ni	-	+	-	no	-	-	-	no
Pb	+	+	-	no	+	+	-	no
Zn	-	+	-	no	-	+	-	no
Naph	-	+	-	no	-	+	-	no
BAP	+	+	+	yes	+	+	+	yes
TPCB	+	+	+	yes	+	+	+	yes
α-Chlor	+	+	-	no	+	+	-	no
γ-Chlor	+	+	-	no	+	+	-	no
DDE	+	+	-	no	+	+	-	no
DDD	+	+	-	no	+	+	-	no
DDT	-	+	-	no	-	+	-	no

Table 11-27. Station-by-station assessment for human health risk from Benzo[a]pyrene at the Chollas and Paleta sites.

Site	Station	BAP in Sediment (mg/kg)	BAP in Tissue (mg/kg_{lip})	Tissue Solids (%)	Lipid Content (%)	BAP in Tissue (mg/kg_{wet})	C_{tiss}/TSL_{min}
Paleta	P01	0.043	0.0047	11.4*	6.7*	0.036	**7.9**
	P02	0.040	0.0053	10.9	6.7*	0.038	**8.4**
	P03	0.028	0.0030	11.4*	6.7*	0.023	**5.0**
	P04	0.030	0.0051	11	8	0.045	**9.9**
	P05	0.043	0.0047	11.4*	6.7*	0.036	**8.0**
	P06	0.049	0.0054	11.4*	6.7*	0.042	**9.1**
	P07	0.043	0.0046	11.4*	6.7*	0.036	**7.8**
	P08	0.067	0.0059	11.8	7.2	0.051	**11.1**
	P09	0.031	0.0033	11.4*	6.7*	0.026	**5.6**
	P10	0.033	0.0035	11.4*	6.7*	0.027	**5.9**
	P11	0.065	0.0094	11.9	6.3	0.071	**15.5**
	P12	0.050	0.0055	11.4*	6.7*	0.042	**9.3**
	P13	0.023	0.0070	11.9	7.8	0.064	**14.1**
	P14	0.038	0.0041	11.4*	6.7*	0.032	**6.9**
	P15	0.061	0.0085	11	6.6	0.062	**13.5**
	P16	0.035	0.0038	11.4*	6.7*	0.029	**6.4**
	P17	0.037	0.0085	11.1	7.5	0.071	**15.6**
Chollas	C01	0.028	0.0029	11.4*	6.7*	0.023	**5.0**
	C02	0.034	0.0025	11.3	6.4*	0.018	**4.0**
	C03	0.050	0.0055	11.4*	6.7*	0.042	**9.2**
	C04	0.032	0.0034	11.4*	6.7*	0.026	**5.8**
	C05	0.034	0.0030	11.3	4.7	0.016	**3.5**
	C06	0.030	0.0032	11.4*	6.7*	0.025	**5.4**
	C07	0.059	0.0066	11.4*	6.7*	0.050	**11.1**
	C08	0.043	0.0023	11.6	7.5	0.020	**4.3**
	C09	0.073	0.0081	11.4*	6.7*	0.063	**13.7**
	C10	0.047	0.0052	11.4*	6.7*	0.040	**8.8**
	C11	0.026	0.0032	11.0	6.0	0.021	**4.6**
	C12	0.179	0.0120	11.2	7.2	0.096	**21.1**
	C13	0.032	0.0037	11.4*	6.6	0.027	**6.0**
	C14	0.007	0.0009	11.1	6.4	0.006	**1.3**

*Value shown was estimated from the BSAF at measured stations
**Value shown was taken as the mean value of measured stations

Table 11-28. Station-by-station assessment for human health risk from TPCB at the Chollas and Paleta sites.

Site	Station	TPCB in Sediment (mg/kg)	TPCB in Tissue (mg/kg_{lip})	Tissue Solids (%)	Lipid Content (%)	TPCB in Tissue (mg/kg_{wet})	C_{tiss}/TSL_{min}
Paleta	P01	0.010	0.0047	11.4*	6.7*	0.025	**1.5**
	P02	0.006	0.0053	10.9	6.7	0.021	**1.3**
	P03	0.006	0.0030	11.4*	6.7*	0.019	**1.1**
	P04	0.007	0.0051	11	8	0.022	**1.3**
	P05	0.047	0.0047	11.4*	6.7*	0.062	**3.7**
	P06	0.008	0.0054	11.4*	6.7*	0.023	**1.4**
	P07	0.007	0.0046	11.4*	6.7*	0.021	**1.3**
	P08	0.011	0.0059	11.8	7.2	0.029	**1.8**
	P09	0.011	0.0033	11.4*	6.7*	0.027	**1.6**
	P10	0.009	0.0035	11.4*	6.7*	0.024	**1.4**
	P11	0.033	0.0094	11.9	6.3	0.060	**3.6**
	P12	0.010	0.0055	11.4*	6.7*	0.026	**1.6**
	P13	0.009	0.0070	11.9	7.8	0.044	**2.6**
	P14	0.015	0.0041	11.4*	6.7*	0.032	**1.9**
	P15	0.025	0.0085	11	6.6	0.059	**3.5**
	P16	0.009	0.0038	11.4*	6.7*	0.024	**1.5**
	P17	0.009	0.0085	11.1	7.5	0.042	**2.5**
Chollas	C01	0.010	0.0029	11.4*	6.7*	0.026	**1.6**
	C02	0.026	0.0025	11.3	6.4	0.036	**2.2**
	C03	0.018	0.0055	11.4*	6.7*	0.036	**2.2**
	C04	0.012	0.0034	11.4*	6.7*	0.029	**1.7**
	C05	0.017	0.0030	11.3	4.7	0.019	**1.1**
	C06	0.011	0.0032	11.4*	6.7*	0.027	**1.6**
	C07	0.027	0.0066	11.4*	6.7*	0.045	**2.7**
	C08	0.015	0.0023	11.6	7.5	0.020	**1.2**
	C09	0.011	0.0081	11.4*	6.7*	0.028	**1.7**
	C10	0.013	0.0052	11.4*	6.7*	0.030	**1.8**
	C11	0.012	0.0032	11.0	6.0	0.024	**1.4**
	C12	0.014	0.0120	11.2	7.2	0.028	**1.7**
	C13	0.008	0.0037	11.4	6.6	0.014	0.9
	C14	0.003	0.0009	11.1	6.4	0.012	0.7

*Value shown was estimated from the BSAF at measured stations
**Value shown was taken as the mean value of measured stations

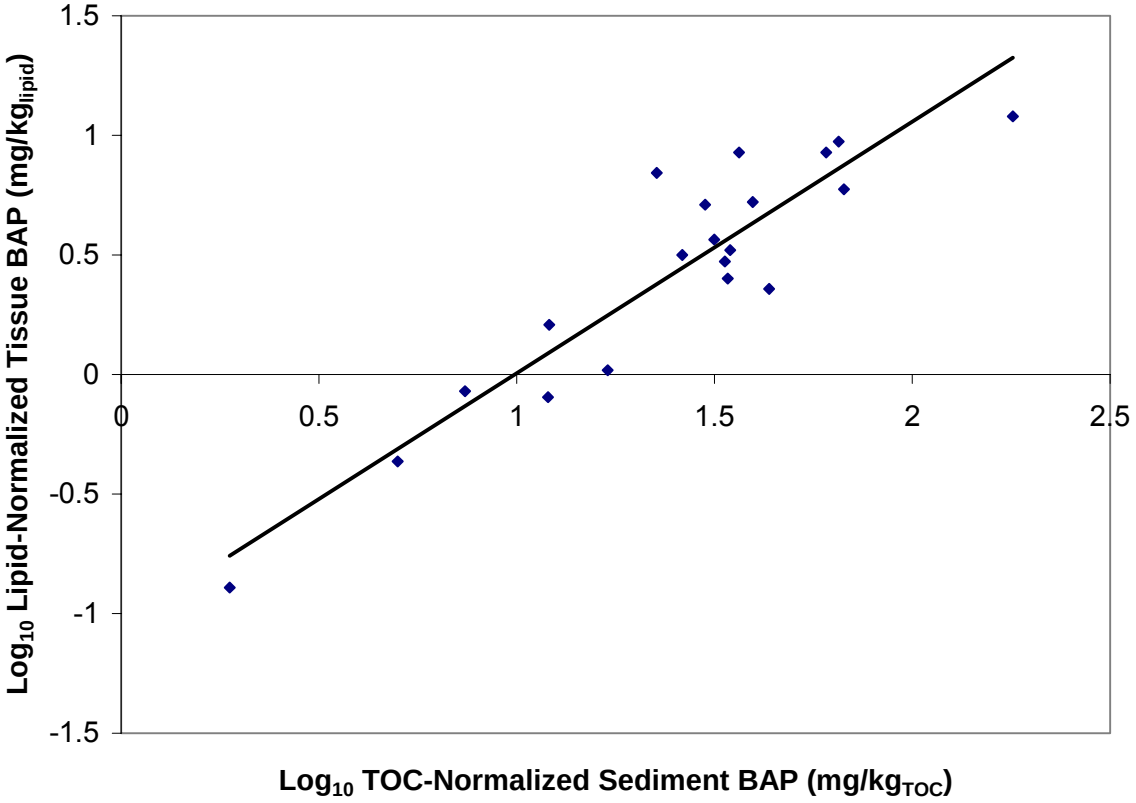


Figure 11-6. BSAF log-log regression for lipid-normalized BAP in clam tissues as a function of TOC-normalized sediment BAP concentration (r^2=0.85).

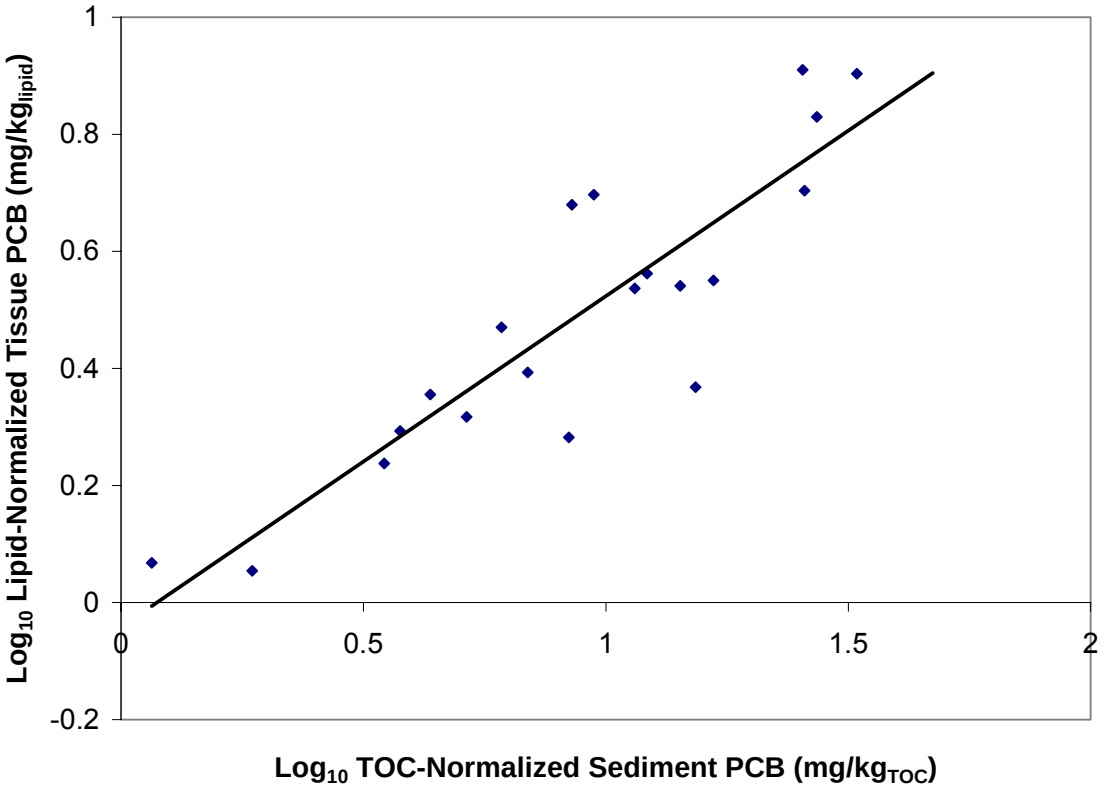


Figure 11-7. BSAF log-log regression for lipid-normalized TPCB in clam tissues as a function of TOC-normalized sediment TPCB concentration (r^2=0.79).

12.0 POTENTIAL IMPAIRMENT TO BENEFICIAL USES

The potential for impairment to the three beneficial uses most sensitive to sediment contamination at the Chollas and Paleta study sites was determined using three independent evaluations. A WOE using the three LOE of sediment chemistry, toxicity, and benthic community composition was used to evaluate the potential for impairment to the Aquatic Life Beneficial Use, specifically, the benthic community. A screening level ecological risk assessment was used to evaluate the potential for impairment to the Aquatic-Dependent Wildlife Life Beneficial Use, specifically related to consumption of aquatic organisms by birds and marine mammals. A screening level human health risk assessment was used to evaluate the potential for impairment to the Human Health Beneficial Use, specifically related to consumption of shellfish. The outcome of each of these three evaluations is discussed below.

12.1 AQUATIC LIFE

The WOE framework for categorizing stations as “Unlikely”, “Possible” or “Likely” to be impaired by site CoPCs was discussed in Section 4.2.2.1. Each of three LOE developed in section 11 were integrated into these three categories as shown in (Table 12-1).

12.1.1 Chollas Site

Six Chollas stations, located in both the inner (C12, C13, and C14) and outer (C2, C3, and C5) areas of the study site, were categorized as likely to be impaired. One Chollas station was categorized as unlikely to be impaired. The remaining seven stations were categorized as having a possible likelihood of impairment, primarily due to the presence of both elevated chemistry and toxicity. The spatial distribution of the station WOE categorization is shown in Figure 12-1.

All three stations in the inner creek area were classified as likely to be impaired. There was a decreasing gradient of impacts among these stations moving out from the creek mouth. Only station C14 had high impacts indicated in all three LOEs. The next station out from mouth, C13, had high impacts from the chemistry and benthic LOE, but contained only moderate toxicity impacts. The next station out, C12, had high impacts from chemistry, but contained only moderate toxicity and benthic community impacts. Based on comparison of CoPC levels among the stations, exceedance of SQGs, and correlation between chemistry and toxicity, CoPCs that appear most likely to be responsible for observed aquatic life impairment include PAH, PCB, chlordane and DDT. The observed spatial gradient, combined with the CoPCs identified as likely drivers of impairment are consistent with an urban runoff source from Chollas Creek.

Most of the stations in the outer creek area were classified as possibly impaired. One station located near the inner/outer creek boundary (C07) was the only location classified as unlikely to be impaired. This station, along with two other stations (C08, C11) were in an area of exceptionally low fines most likely caused by sediment erosion associated with ship engine tests performed at the NASSCO shipyard. The characteristics of low fines and TOC at these stations also corresponded to relatively low contamination levels. The concentrations of metals and organics at C07 and C08 were the lowest measured at the Chollas site. The SQGQ1s for these three stations (0.31-0.56) were in the range of stations that did not show benthic community impacts at the Paleta site relative to the Baseline Pool (0.23-0.72). While the WOE for stations C08

and C11 points to impairment of the benthic community from CoPCs, the physical impacts caused by sediment erosion on the benthos cannot be ruled out as a contributing factor to the impairment.

12.1.2 Paleta Site

Sediments from four Paleta inner creek stations (P11, P15, P16, and P17) were categorized as likely to be impaired (Table 12-1). Five stations were categorized as possibly impaired and the remaining 8 stations had sediments that were categorized as unlikely to be impaired. The general spatial pattern is a decreasing gradient of impairment from inner creek stations to outer creek stations (Figure 12-2).

The three innermost creek stations (P15, P16, and P17) were classified as likely impaired based on high benthos impacts and moderate to high impacts for each of the other LOE. These stations group together in closest proximity to the urban creek source and had common sediment quality characteristics. They were all characterized by elevated levels of copper, lead, zinc, PAH, PCBs, chlordane, and DDT. They all were placed into the moderate toxicity category based on poor urchin embryo development in the sediment-water interface test and were placed into high benthic community impacts category based on multiple types of impacts. Based on comparison of CoPC levels at likely stations with unlikely and possible stations, exceedance of SQGs, and correlation between chemistry and toxicity, CoPCs that appear most likely to be responsible for observed aquatic life impairment include lead, PAH, PCB, chlordane and DDT.

The other station categorized as likely impaired, P11, had similar concentrations of CoPCs as the three innermost creek stations except for mercury, which was about twice as high. This resulted in a high ranking in the chemistry LOE. Similar to the other three stations, P11 had poor urchin embryo development but it also had the lowest amphipod survival of any station in the study area. This resulted in a ranking of high toxicity. There was only a moderate level of benthic community impact at this station due to a lack of statistical difference from the Baseline Pool for the BRI. The commonalities in P11 chemistry to the three innermost creek stations would suggest a common contaminant source but the spatial separation together with the differences in toxicity and benthic community LOEs suggest an additional contaminant source(s).

The WOE evaluation indicated that the outer Paleta stations tended to have a lower degree of impairment than the inner stations. None of the outer Paleta stations had a significant amount of toxicity relative to the baseline. In addition, the degree of benthic impacts at several stations, as indicated by the BRI, was less than the innermost stations. Station P05 had a relatively higher level of impairment than the other outer Paleta stations; this station differed from the other outer stations by having a higher SQGQ1 value and having reduced values for benthos abundance, taxa, and diversity.

12.1.3 Uncertainty

Uncertainty in the potential risk related to CoPC exposure to aquatic life receptors results from statistical limitations of the sampling design, classification of the LOE, and selection of the background condition. In general, the conservative nature of the assumptions applied in these areas more likely overestimates than underestimates the aquatic life risk.

Inherent uncertainty results from statistical limitations of the sampling design, the size of the various sampling pools, and the large number of comparisons performed. In general, the sample size of the Baseline Pool for aquatic life (18) was considered sufficient for a reasonable level of statistical power in developing the predictive intervals. However, for some parameters, the size of the baseline pool was more limited, ranging from 4 to 9 stations, resulting in somewhat lower statistical power and higher uncertainty. We cannot be sure if this uncertainty would result in an over or underestimation of risk. Because multiple comparisons were made to Baseline Pool (18 CoPCs, SQGQ1, 3 toxicity tests and 4 BCA metrics), and each comparison carries with it a low probability (%) of falsely identifying a statistical difference, there is significant potential for multiple comparison error. Although there are methods to correct for this error, they were not applied in this study. The resulting uncertainty is likely to result in an overestimation of the actual risk at the site.

Uncertainty in the aquatic life assessment also stems from the choice of background conditions. The Baseline Pool used to represent background for this study was defined as the existing ambient condition characterized by a pool of reference stations selected in stepwise process that met the requirements of remoteness from source and similar habitat to the sites. The Reference Pool represented a more conservative background condition characterized by a pool of reference stations selected by setting specific thresholds of acceptability for biological effects after the stations had been characterized. Comparative results for the Reference Pool are presented in Appendix F. Differences that resulted from the application of the Reference Pool rather than the Baseline Pool included a general shift in the WOE classification of impairment at Paleta stations from unlikely to possible, and at Chollas stations from possible to likely. Most of these shifts resulted from differences in the classification of the benthic community LOE as a result of lower and less variable BRI values among the stations selected for the Reference Pool.

Table 12-1. Results of the weight of evidence analysis applied to Chollas and Paleta sites.

Aquatic Life Impairment WOE					
Station	**Chem Class**	**Tox Class**	**BCA Class**	**OVERALL WOE**	**Impairment from CoPC?**
C01	⊙	⊙	○	⊙	Possible
C02	●	⊙	⊙	●	Likely
C03	●	○	⊙	●	Likely
C04	⊙	⊙	○	⊙	Possible
C05	●	○	⊙	●	Likely
C06	⊙	⊙	○	⊙	Possible
C07	○	○	○	○	UnLikely
C08	⊙	○	●	⊙	Possible
C09	⊙	⊙	○	⊙	Possible
C10	⊙	⊙	○	⊙	Possible
C11	⊙	○	⊙	⊙	Possible
C12	●	⊙	⊙	●	Likely
C13	●	⊙	●	●	Likely
C14	●	●	●	●	Likely
P01	○	○	⊙	○	UnLikely
P02	⊙	○	⊙	⊙	Possible
P03	○	○	○	○	UnLikely
P04	⊙	○	⊙	○	Possible
P05	⊙	○	⊙	⊙	Possible
P06	⊙	○	⊙	⊙	Possible
P07	⊙	○	⊙	⊙	Possible
P08	⊙	○	○	○	UnLikely
P09	○	○	⊙	○	UnLikely
P10	⊙	○	○	○	UnLikely
P11	●	●	⊙	●	Likely
P12	⊙	○	○	○	UnLikely
P13	○	○	○	○	UnLikely
P14	⊙	○	○	○	UnLikely
P15	●	⊙	●	●	Likely
P16	⊙	⊙	●	●	Likely
P17	⊙	⊙	●	●	Likely

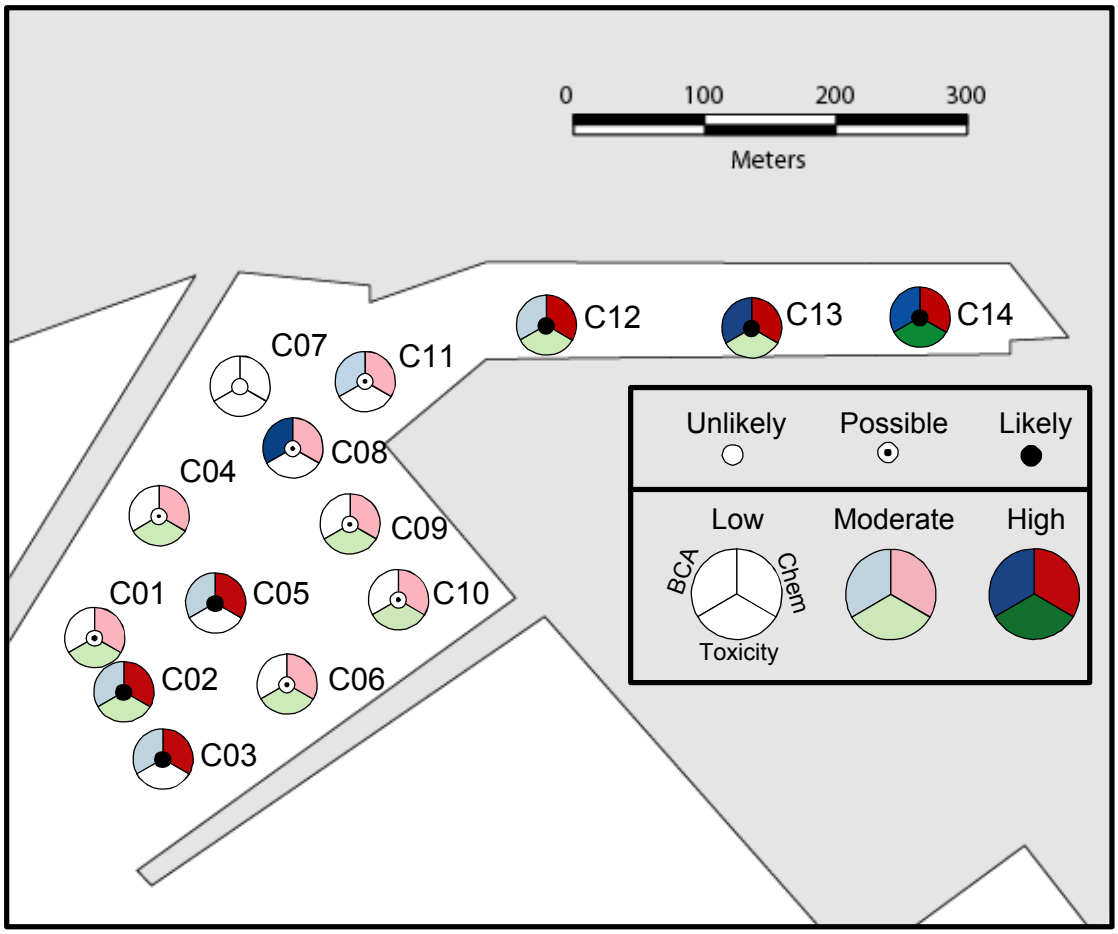


Figure 12-1. Spatial classification of impairment at the Chollas site based on the weight of evidence analysis.

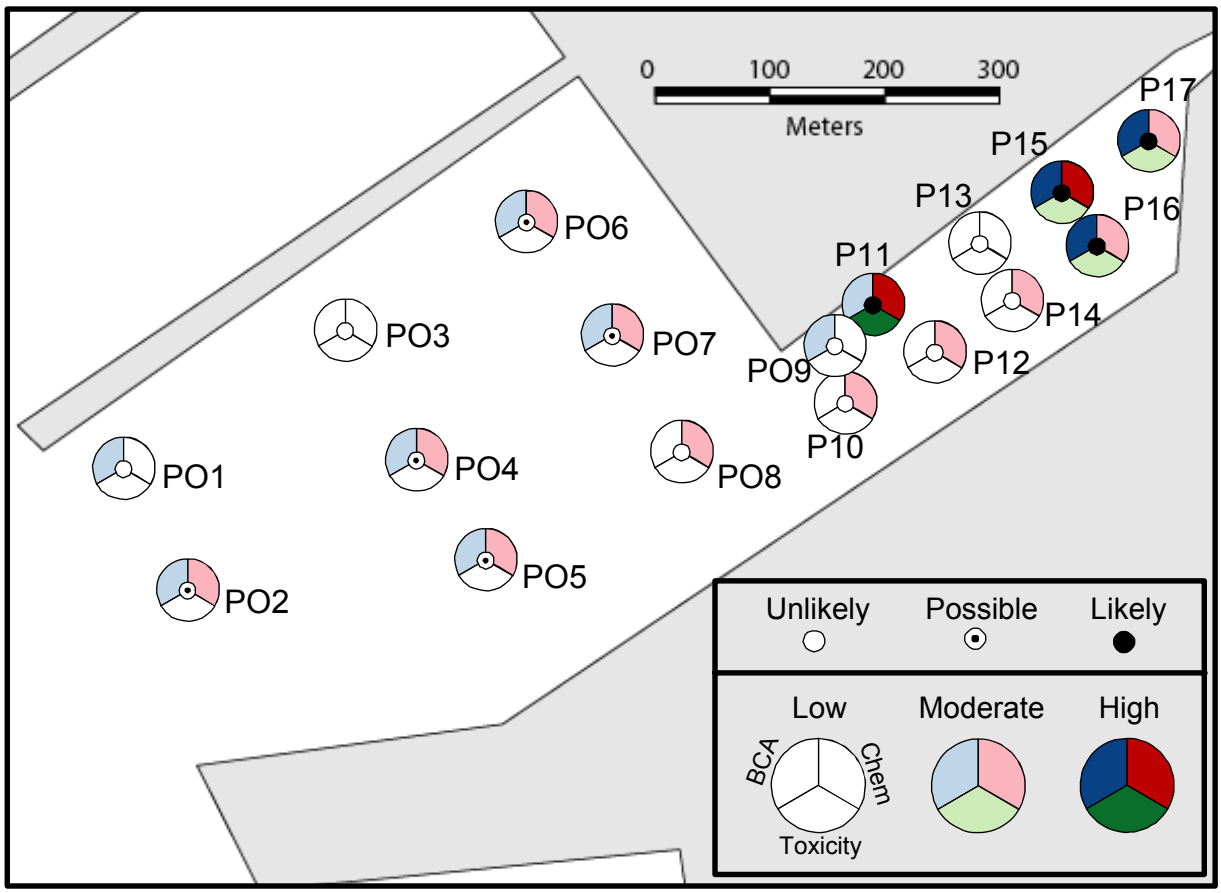


Figure 12-2. Spatial classification of impairment at the Paleta site based on the weight of evidence analysis.

12.2 AQUATIC DEPENDENT WILDLIFE

The likelihood of aquatic dependent wildlife impairment at the Chollas and Paleta sites was categorized as either “Unlikely” or “Possible” based on the screening level ecological risk assessment described in Section 11. Impairment to wildlife from the consumption of aquatic prey exposed to site sediments was considered unlikely for a CoPC if: (1) the bioaccumulation measured at the site was not statistically different that observed in controls or (2) the estimated HQ was less than 1 or (3) the bioaccumulation was not statistically different from the baseline condition. Alternately, impairment to wildlife from the consumption of aquatic prey exposed to site sediments was considered possible for a CoPC if: (1) the bioaccumulation measured at the site was statistically different that observed in controls and (2) the estimated HQ was greater than 1 and (3) there was statistically different bioaccumulation relative to the baseline condition. For this assessment, bioaccumulation of CoPCs in the clam *Macoma nasuta* was used to estimate exposure for representative wildlife receptors including surface feeding birds (Least Tern and Brown Pelican), diving birds (Surf Scoter and Western Grebe), and marine mammals (California Sea Lion).

12.2.1 Chollas Site

Potential for impairment to aquatic dependent wildlife at the Chollas site was categorized as unlikely for all receptors with respect to all CoPCs with the exception of copper for the Least Tern and Brown pelican. While several CoPCs showed bioaccumulation exceeding control and baseline (lead, BAP, TPCB, α-chlor, γ-chlor, DDE and DDD), only copper exceeded control and baseline, and had an HQ>1 for the maximum concentration of the site (Table 11-21).

Based on the spatial analysis described in Section 11, three of the fourteen Chollas stations (C07, C10 and C11) were categorized as possibly impaired. Of these three stations, the Least Tern and Brown Pelican dose at C11 was based on direct tissue measurement, while the Least Tern doses at C07 and C10 were estimated based on the BSAF. To visualize the spatial distribution of the potential impairment, a contour map was developed for the Least Tern copper HQ at the Chollas site (Figure 12-3). The area of stations C07 and C11 is not an area of elevated copper in the sediment (see Figure 7-9), but rather corresponds to the area of very low fines at the boundary between the inner and outer regions of the study site at Chollas. The higher bioaccumulation of copper and other metals in this area relative to the rest of the site appears to be related to higher bioavailability associated with the low binding characteristics of this sediment. Station C10 near the base of Pier 1 had the highest sediment copper concentration of all Chollas stations. Fines and TOC in this region were moderate, thus the higher bioaccumulation at this station appears to relate primarily to higher copper concentrations in the sediment. On the basis of this analysis, a limited area of the Chollas site in the regions described above was classified as possibly impaired for potential effects of copper on growth for the Least Tern and Brown pelican.

12.2.2 Paleta Site

Potential for impairment to aquatic dependent wildlife at the Paleta site was categorized as unlikely for all receptors with respect to all CoPCs. While several CoPCs showed bioaccumulation exceeding control and baseline (lead, BAP, TPCB, α-Chlordane, γ-Chlordane, DDE and DDD), no CoPCs had an HQ>1 for the maximum concentration of the site. Copper for the Least Tern had the highest HQ (0.97) of all CoPCs among all receptors. Because impairment was categorized as unlikely, not spatial analysis was conducted.

12.2.3 Uncertainty

Uncertainty in the potential risk related to CoPC exposure to the selected aquatic-dependent wildlife receptors results from statistical limitations of the sampling design, assumptions used to estimate exposure and response, and selection of the background condition. In general, the conservative nature of the assumptions more likely overestimates than underestimates the ecological risk.

For this assessment, bioaccumulation of CoPCs in the clam *Macoma nasuta* exposed to site sediments was used to estimate exposure for representative wildlife receptors including surface feeding birds and marine mammals. Because clams are not the primary food source for several of these receptors, there is uncertainty associated with potential variations in accumulation between the laboratory-exposed clams, and the actual food source of the receptors. In general, this assumption is believed to provide a conservative assessment of impairment because the clams are surface deposit filter-

feeders and are therefore directly exposed to CoPCs in the surface sediments. However, the relatively short duration of the laboratory exposure (28 days) and the potential for certain CoPCs to biomagnify could lead to under-prediction of exposure in some cases.

Additional conservative exposure assumptions included 100% dietary fraction from the site, 100% assimilation efficiency, 100% area use factor for the site, minimum adult female body weight, application of the low consensus-based TRVs from the BTAG (or alternatives where not available), and 100% of diet contaminated at the maximum concentration of all site stations. Uncertainty in all of these assumptions is likely to result in an overestimation of the actual risk at the site.

Inherent uncertainty results from statistical limitations of the sampling design, the size of the various sampling pools, and the large number of comparisons performed. In general, the sample size of the Baseline Pool (9) was considered sufficient for a reasonable level of statistical power in developing the predictive intervals. However, for some CoPCs (Zn, Chlordane, DDT, DDD and DDE), the size of the baseline pool was limited to 5 stations, resulting in somewhat lower statistical power and higher uncertainty. It is not known if this uncertainty would result in an over or underestimation of risk. Because multiple comparisons were made to the Baseline Pool (17 CoPCs), and each comparison carries with it a low probability (5%) of falsely identifying a statistical difference, there is significant potential for multiple comparison error. Although there are methods to correct for this error, they were not applied in this study. The resulting uncertainty is likely to result in an overestimation of the actual risk at the site.

Uncertainty also stems from the choice of background conditions. The Baseline Pool used to represent background for this study was defined as the existing ambient condition characterized by a pool of reference stations selected in a stepwise process that met the that met the requirements of remoteness from source and similar habitat to the sites. The Reference Pool represented a more conservative background condition characterized by a pool of reference stations selected by setting specific thresholds of acceptability after the stations had been characterized. Comparative results for the Reference Pool are presented in Appendix F. Based on the Reference Pool, potential for impairment to aquatic dependent wildlife at the Chollas and Paleta sites was categorized as unlikely for all receptors with respect to all CoPCs. Although the Reference Pool was intended to be more conservative, the result of selectively removing stations resulted in a smaller pool, which in turn led to a higher predictive limit than in the Baseline Pool, at least in the case of copper (which was the only CoPC identified as a risk driver in the original analysis).

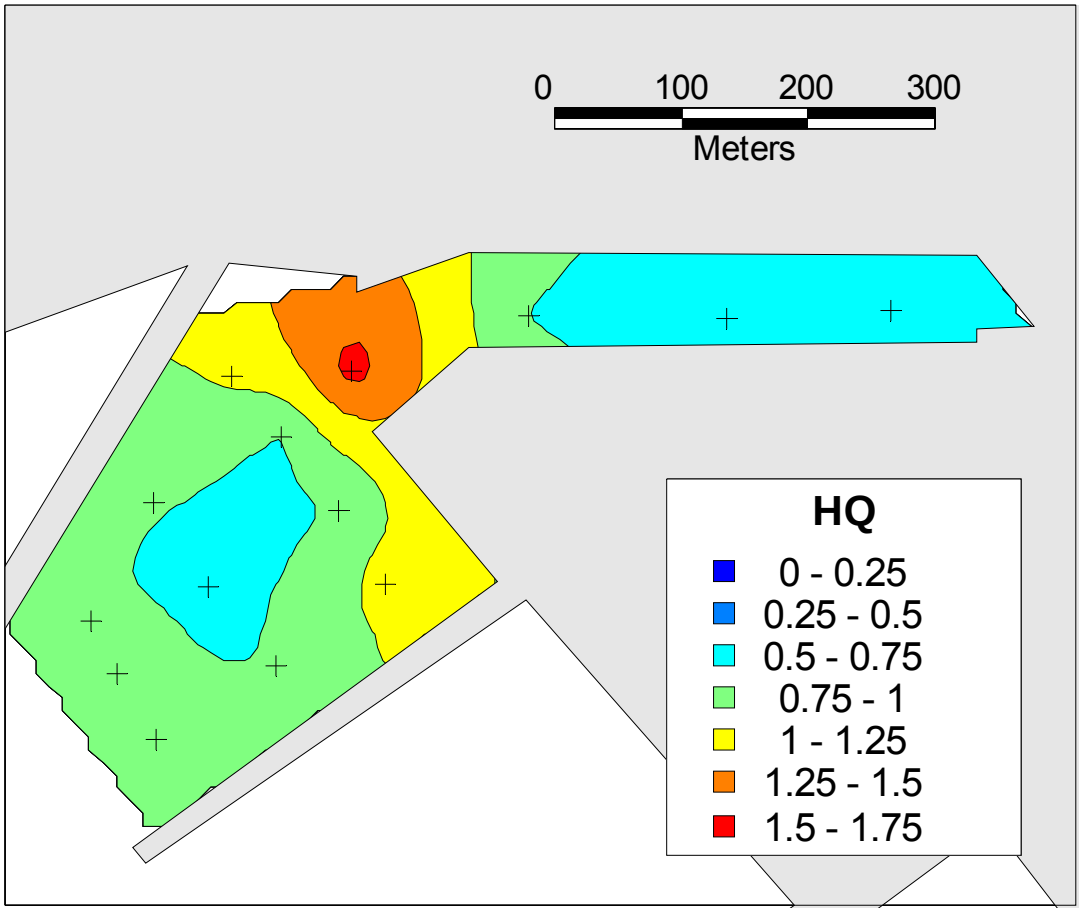


Figure 12-3. Spatial distribution of the copper HQ for the Least Tern at the Chollas Site.

12.3 HUMAN HEALTH

The likelihood of human health impairment at the Chollas and Paleta sites was categorized as either “Unlikely” or “Possible” based on the screening level human health risk assessment described in Section 11. As described in Section 4, impairment to human health from the consumption of fish or shellfish exposed to site sediments was considered unlikely for a CoPC if: (1) the bioaccumulation measured at the site was not statistically different that observed in controls or (2) the concentration in the fish or shellfish was less than the TSL or (3) the bioaccumulation was not statistically different from the baseline condition. Alternately, impairment to human health from the consumption of fish or shellfish exposed to site sediments was considered possible for a CoPC if: (1) the bioaccumulation measured at the site was statistically different that observed in controls and (2) the concentration in the fish or shellfish was greater than the TSL and (3) there was statistically different bioaccumulation relative to the baseline condition. For this assessment, bioaccumulation of CoPCs in the clam *Macoma nasuta* was used to estimate exposure for humans from the consumption of fish or shellfish exposed to site sediments.

12.3.1 Chollas Site

Potential for impairment to human health at the Chollas site was categorized as unlikely for all CoPCs with the exception of BAP and TPCB. Arsenic levels in tissues exceed the baseline and the TSL, but were not statistically different from control. Several other CoPCs (copper, lead, α-Chlordane, γ-Chlordane, DDE and DDD) had bioaccumulation exceeding control and baseline, but did not exceed the TSL for the maximum concentration of the site. For BAP and TPCB, the possible impairment was related to cancer risk. At the Chollas site, the estimated risk level for BAP based on the maximum concentration for the site exceeded the TSL by a factor of 21, while the estimated risk level for TPCB exceeded the TSL by a factor of 2.2.

Based on the spatial analysis described in Section 11, all of the fourteen Chollas stations were categorized as possibly impaired for BAP, and twelve of the fourteen were categorized as possibly impaired for TPCB. Of these stations, the doses at seven stations were based on direct tissue measurement (C02, C05, C08, C11, C12, C13, and C14), while the doses at the seven other stations were estimated based on the BSAF (C01, C03, C04, C06, C07, C09, and C10). To visualize the spatial distributions of the potential impairment related to BAP and TPCB, contour maps were developed for the ratio of the measured or estimated tissue concentration to the TSL at the Chollas site (Figure 12-4 and Figure 12-5). For BAP, individual station tissue concentrations ranged from 1.3 (C14) to 21.1 (C12) times higher than the TSL. Spatially, the highest magnitude of impairment related to BAP was found in the mid-inner Creek area (C12-C13) and near the base of Pier 1 (C09-C10) with more isolated elevations near the end of Pier 1 (C03) and the base of the NASSCO pier (C07). In general, the areas with higher magnitude of impairment related to BAP corresponded closely with high levels in the sediment, but were not strongly related to the distribution of TOC or fines. On the basis of this analysis, the entire Chollas site was classified as possibly impaired for potential human health effects related to the consumption of BAP in fish and shellfish.

For TPCB at the Chollas site, individual station tissue concentrations ranged from 0.7 (C14) to 2.7 (C07) times higher than the TSL. Spatially, the highest magnitude of impairment related to TPCB was found near the base of the NASSCO pier (C07) and the

end of Pier 1 (C02-C03), while the inner Creek area (C13-C14) had tissue concentrations below the TSL. The area of station C07 was not an area of elevated TPCB in the sediment (see Figure 7-21), but rather corresponded to the area of very low fines at the boundary between the inner and outer regions of the study site at Chollas. The higher bioaccumulation of TPCB in this area relative to the rest of the site appeared to be related to higher bioavailability associated with the low binding characteristics of this sediment. Stations C02-C03 near the end of Pier 1 had the highest sediment TPCB concentrations of all Chollas stations. Fines and TOC in this region were moderate, thus the higher bioaccumulation at this station appears to relate primarily to higher TPCB concentrations in the sediment. On the basis of this analysis, the majority of the Chollas site, excepting the inner Creek area, was classified as possibly impaired for potential human health effects related to the consumption of PCBs in fish and shellfish.

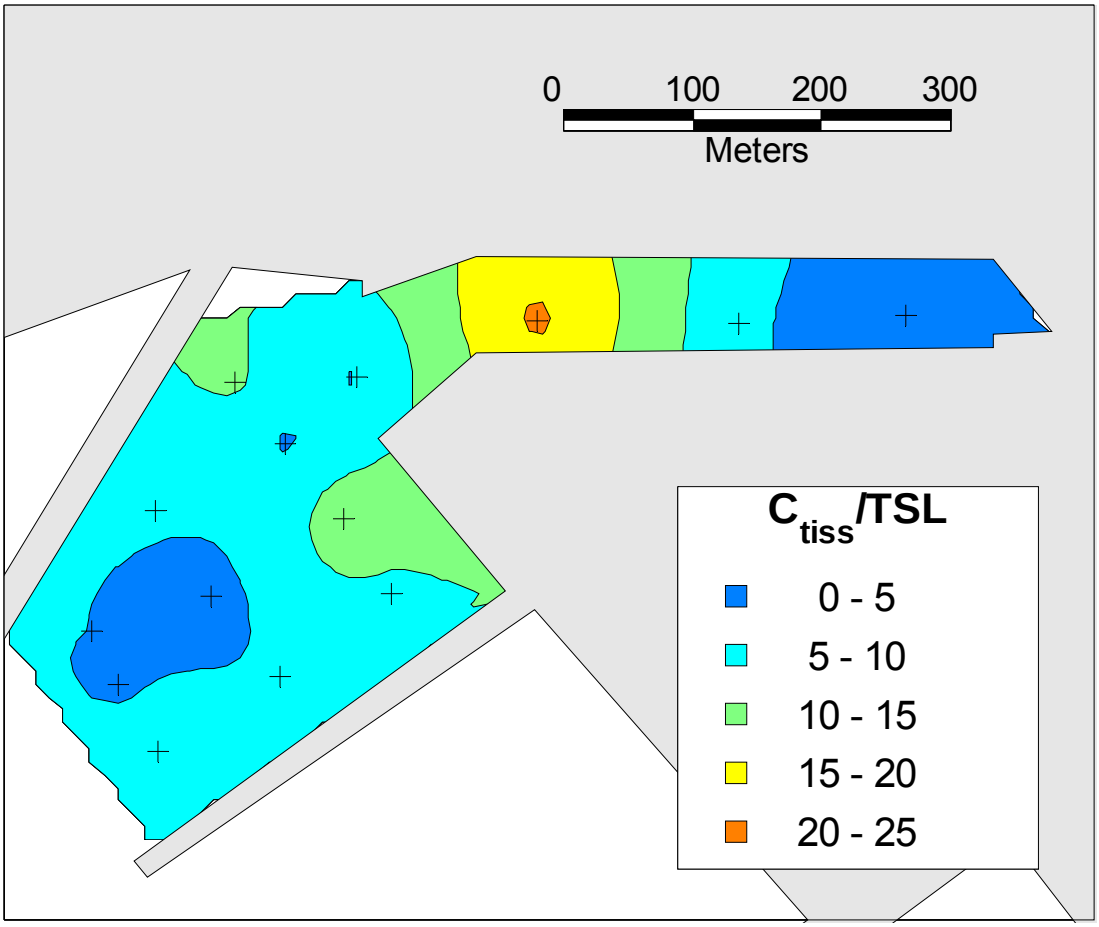


Figure 12-4. Spatial distribution of the BAP tissue concentration (c_{tiss}):TSL ratio for human health risk at the Chollas Site .

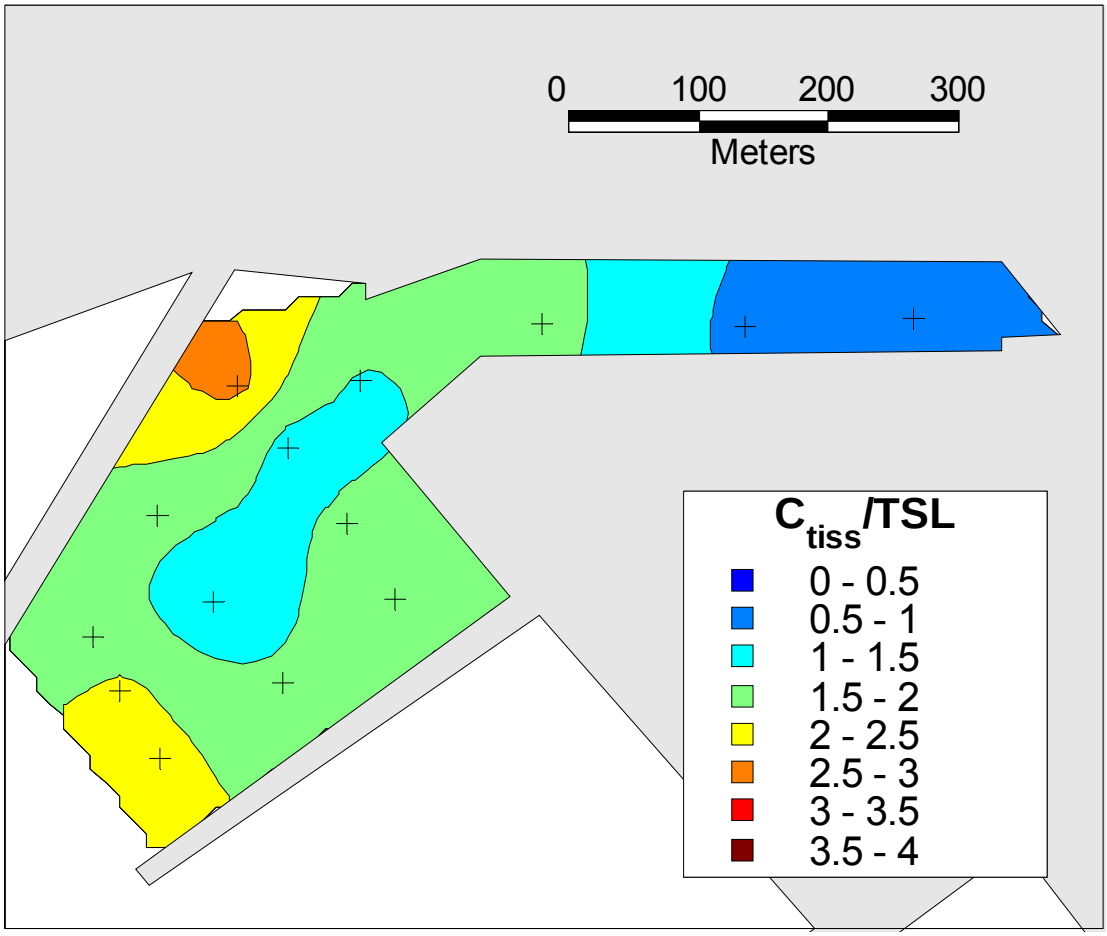


Figure 12-5. Spatial distribution of the TPCB tissue concentration (c_{tiss}):TSL ratio for human health risk at the Chollas Site.

12.3.2 Paleta Site

Potential for impairment to human health at the Paleta site was categorized as unlikely for all CoPCs with the exception of BAP and TPCB. Arsenic levels in tissues exceed the TSL, but were not statistically different from control or baseline. Several other CoPCs (lead, α-Chlordane, γ-Chlordane, DDE and DDD) had bioaccumulation exceeding control and baseline, but did not exceed the TSL for the maximum concentration of the site. For BAP and TPCB, the possible impairment was related to cancer risk. At the Paleta site, the estimated risk level for BAP based on the maximum concentration for the site exceeded the TSL by a factor of 16, while the estimated risk level for TPCB exceeded the TSL by a factor of 3.6.

Based on the spatial analysis described in Section 11, all of the seventeen Paleta stations were categorized as possibly impaired for both BAP and TPCB. Of these stations, the doses at seven stations were based on direct tissue measurement (P02, P04, P08, P11, P13, P15, P17), while the doses at the ten other stations were estimated based on the BSAF (P01, P03, P05, P06, P07, P09, P10, P12, P14, and P16). To visualize the spatial distributions of the potential impairment related to BAP and TPCB, contour maps were developed for the ratio of the measured or estimated tissue concentration to the TSL at the Paleta site (Figure 12-6 and Figure 12-7). For BAP, individual station tissue concentrations ranged from 5.0 (P03) to 15.6 (P17) times higher than the TSL. Spatially, the highest magnitude of impairment related to BAP was found along the northern extent of the inner Creek area (P11, P13, P15 and P17). In general, the inner Creek area with higher magnitude of impairment related to BAP corresponded with high levels in the sediment, as well as higher levels of TOC. On the basis of this analysis, the entire Paleta site was classified as possibly impaired for of potential human health effects related to the consumption of BAP in fish and shellfish.

For TPCB at the Paleta site, individual station tissue concentrations ranged from 1.1 (P03) to 3.7 (P05) times higher than the TSL. Spatially, the highest magnitude of impairment related to TPCB along the northern extent of the inner Creek area (P11, P13, P15 and P17) and at station (P05) near the Mole Pier. In general, the areas with higher magnitude of impairment related to TPCB corresponded with high levels in the sediment. Station P05 near the Mole Pier had the highest sediment TPCB concentrations of all Paleta stations. On the basis of this analysis, the entire Paleta site was classified as possibly impaired for potential human health effects related to the consumption of PCBs in fish and shellfish.

12.3.3 Uncertainty

Uncertainty in the potential risk related to CoPC exposure to humans results from statistical limitations of the sampling design, assumptions used to estimate exposure and response, and selection of the background condition. In general, the conservative nature of the assumptions applied more likely overestimates than underestimates the human health risk.

For this assessment, bioaccumulation of CoPCs in the clam *Macoma nasuta* exposed to site sediments was used to estimate exposure for fish and shellfish consumption by humans. Because clams are not the primary fish and shellfish harvested from the site, there is uncertainty associated with potential variations in accumulation between the laboratory-exposed clams, and the actual fish and shellfish that may be harvested at the

site. In general, this assumption is believed to provide a conservative assessment of impairment because the clams are surface deposit filter-feeders and are therefore directly exposed to CoPCs in the surface sediments. However, the relatively short duration of the laboratory exposure (28 days) and the potential for certain CoPCs to biomagnify could lead to under-prediction of exposure in some cases.

Additional conservative exposure assumptions included 100% of seafood consumption from the site, a conservative seafood consumption rate of 21g/day, and 100% of seafood contaminated at the maximum concentration of all site stations. Uncertainty in all of these assumptions is likely to result in an overestimation of the actual risk at the site. A range of alternative seafood consumption rates were considered in the analysis. Based on current restrictions on access and fishing at the sites, it is expected that the direct consumption rate from the site is probably close to zero. In this case, risk levels would also approach zero. At the opposite range it is conceivable that, under a future use scenario, a subsistence-based consumption rate could be applicable (e.g. 160 g/day). A screening level analysis of human health risk using this higher subsistence-based consumption rate identified no additional contaminants exceeding the TSL, but resulted in proportionally higher risk levels for BAP and TPCB.

Inherent uncertainty results from statistical limitations of the sampling design, the size of the various sampling pools, and the large number of comparisons performed. In general, the sample size of the Baseline Pool (9) was considered sufficient for a reasonable level of statistical power in developing the predictive intervals. However, for some CoPCs (Zn, Chlordane, DDT, DDD and DDE), the size of the baseline pool was limited to 5 stations, resulting in somewhat lower statistical power and higher uncertainty. It is not known if this uncertainty would result in an over or underestimation of risk. Because multiple comparisons were made to Baseline Pool (17 CoPCs), and each comparison carries with it a low probability (5%) of falsely identifying a statistical difference, there is significant potential for multiple comparison error. Although there are methods to correct for this error, they were not applied in this study. The resulting uncertainty is likely to result in an overestimation of the actual risk at the site.

Uncertainty in the human health risk assessment also stems from the choice of background conditions. The Baseline Pool used to represent background for this study was defined as the existing ambient condition characterized by a pool of reference stations selected in a stepwise process that met the requirements of remoteness from source and similar habitat to the sites. The Reference Pool represented a more conservative background condition characterized by a pool of reference stations selected by setting specific thresholds of acceptability after the stations had been characterized. Comparative results for the Reference Pool are presented in Appendix F. The outcomes were the same for the screening level human health risk assessment using either the Reference Pool or the Baseline Pool. In both cases, BAP and TPCB were identified as potential risk drivers at both the Paleta and Chollas sites.

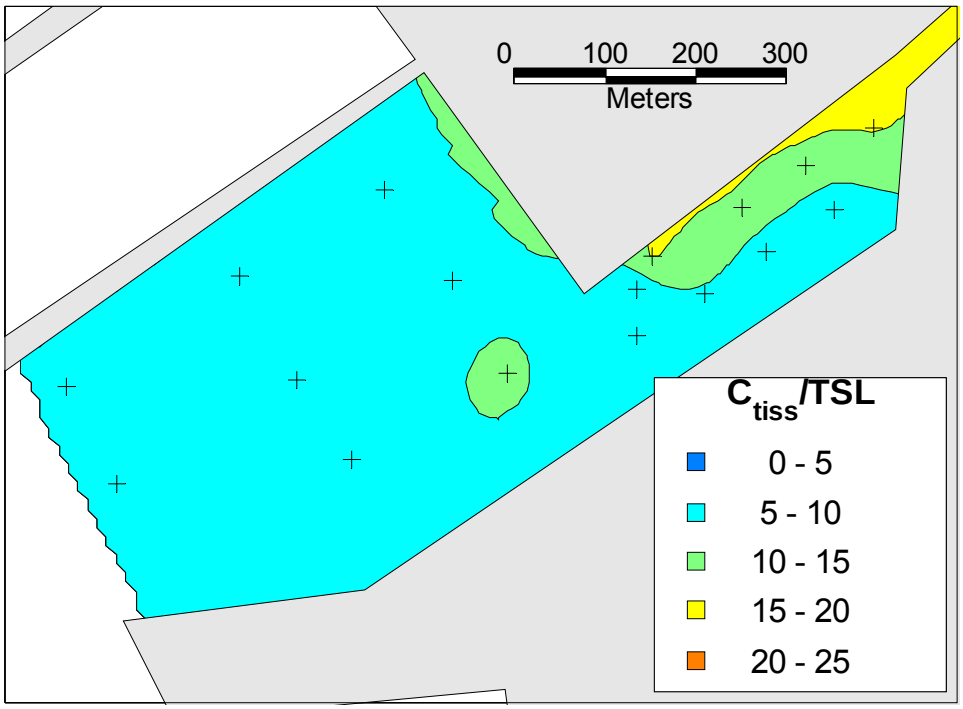


Figure 12-6. Spatial distribution of the BAP tissue concentration (c_{tiss}):TSL ratio for human health risk at the Paleta Site.

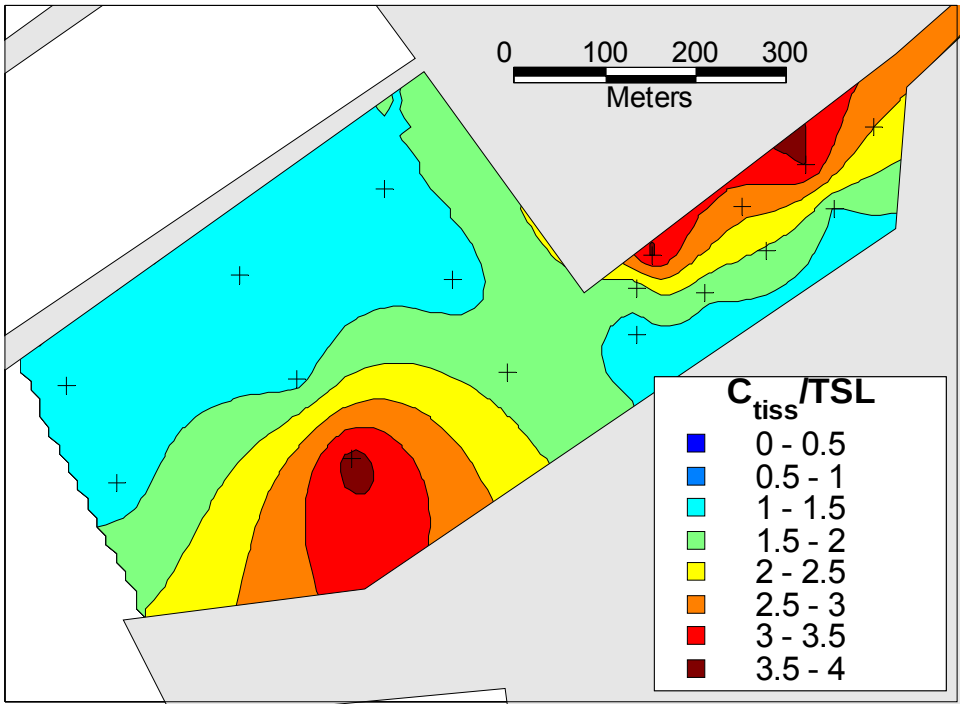


Figure 12-7. Spatial distribution of the TPCB tissue concentration (c_{tiss}):TSL ratio for human health risk at the Paleta Site.

13.0 CONCLUSION AND RECOMMENDATIONS

13.1 CHOLLAS SITE

Conclusions for potential aquatic life impairment at the Chollas site are summarized below:

- Most areas of the Chollas site had evidence of possible or likely impairment, indicating that contamination by CoPCs at levels of concern to aquatic life was widespread. All but one of the sites contained chemical concentrations that were above Baseline Pool levels and the majority of stations showed alterations in benthic community parameters.

- Two stations near the inner/outer creek boundary (C8 and C11) showed benthic community impacts co-occurring with exceptionally low fines and low contamination levels. Recurring sediment physical disturbance associated with ship engine tests performed at the NASSCO shipyard may contribute to the observed benthic community impacts in this area.

- The greatest magnitude of likely impairment was present at the inner creek Chollas stations (C12, C13 and C14). Contaminant concentrations at these sites were associated with a high probability of adverse biological effects and relatively high toxicity test or benthic community responses were also usually present at these stations.

- The increasing gradient of impairment toward the inner creek stations was spatially consistent with a source of contaminants entering the site either from Chollas Creek itself, or from the shoreline activities adjacent to the site.

- The high fines content of the sediments at the inner creek stations indicate that this area is highly depositional, while the enriched TOC levels indicate organic matter loading higher than normal for the bay and most likely related to urban runoff from the creek.

- CoPCs that appear most likely to be responsible for observed aquatic life impairment at the Chollas site include PAH, PCB, chlordane and DDT.

Conclusions for potential aquatic-dependent wildlife impairment based on the screening level assessment at the Chollas site are summarized below:

- Potential for impairment to aquatic dependent wildlife at the Chollas site was categorized as unlikely for all receptors with respect to all CoPCs with the exception of copper for the Least Tern and Brown Pelican.

- Spatial assessment indicted three of the fourteen Chollas stations (C07, C10 and C11) were categorized as possibly impaired. The higher bioaccumulation of copper at C07 and C11 appears to be related to higher bioavailability associated with the low binding (TOC and fines) characteristics of this sediment. The higher

bioaccumulation at C10 appears to relate primarily to higher copper concentrations in the sediment.

- On the basis of this analysis, a limited area of the Chollas site in the regions described above was classified as possibly impaired for potential effects of copper on growth for the Least Tern and Brown Pelican.

Conclusions for potential human health impairment based on the screening level assessment at the Chollas site are summarized below:

- Potential for impairment to human health at the Chollas site was categorized as unlikely for all CoPCs with the exception of BAP and TPCB. The possible impairment was related to cancer risk.

- The estimated risk level for BAP based on the maximum concentration for the site exceeded the TSL by a factor of 21, while the estimated risk level for TPCB exceeded the TSL by a factor of 2.2.

- From the spatial analysis, all of the fourteen Chollas stations were categorized as possibly impaired for BAP, and twelve of the fourteen were categorized as possibly impaired for TPCB.

- Spatially, the highest magnitude of impairment related to BAP was found in the mid-inner Creek area (C12, C13) and near the base of Pier 1 (C09, C10). In general, the areas with higher magnitude of impairment related to BAP corresponded closely with high levels in the sediment, but were not strongly related to the distribution of TOC or fines.

- The highest magnitude of impairment related to TPCB was found near the base of the NASSCO pier (C07) and the end of Pier 1 (C02, C03), while the inner Creek area (C13, C14) had tissue concentrations below the TSL. The higher bioaccumulation of TPCB in at C07 appeared to be related to higher bioavailability associated with the low binding characteristics of this sediment. Higher bioaccumulation at C02, C03 appears to relate primarily to higher TPCB concentrations in the sediment.

- On the basis of this analysis, the entire Chollas site was classified as possibly impaired for potential human health effects related to the consumption of BAP in fish and shellfish, and the majority of the Chollas site, excepting the inner Creek area, was classified as possibly impaired for potential human health effects related to the consumption of PCBs in fish and shellfish.

13.2 PALETA SITE

Conclusions for potential aquatic life impairment at the Paleta site are summarized below:

- The frequency and magnitude of impairment to aquatic live at the Paleta site was less than at the Chollas site. None of the outer Paleta Creek sites were classified as having likely impairment. The classification of some outer Paleta stations as possibly impaired was driven by the co-occurrence of elevated

chemistry and benthic community impacts; sediment toxicity at the outer stations was not elevated relative to the baseline conditions.

- The area of likely impairment for aquatic life at the Paleta site was restricted to a subset of four inner creek stations (P11, P15, P16, and P17).

- The increasing gradient of impairment toward the inner creek stations was spatially consistent with a source of contaminants entering the site either from Paleta Creek itself, or from the shoreline activities adjacent to the site.

- The high fines content of the sediments at the inner creek stations indicate that this area is highly depositional, while the enriched TOC levels indicate organic matter loading higher than normal for the bay and most likely related to urban runoff from the creek.

- CoPCs that appear most likely to be responsible for observed aquatic life impairment at the Paleta site include lead, PAH, PCB, chlordane and DDT.

Conclusions for potential aquatic-dependent wildlife impairment based on the screening level assessment at the Paleta site are summarized below:

- Potential for impairment to aquatic dependent wildlife at the Paleta site was categorized as unlikely for all receptors with respect to all CoPCs.

Conclusions for potential human health impairment based on the screening level assessment at the Paleta site are summarized below:

- Potential for impairment to human health at the Paleta site was categorized as unlikely for all CoPCs with the exception of BAP and TPCB. The possible impairment was related to cancer risk.

- The estimated risk level for BAP based on the maximum concentration for the site exceeded the TSL by a factor of 16, while the estimated risk level for TPCB exceeded the TSL by a factor of 3.6.

- From the spatial analysis, all of the seventeen Paleta stations were categorized as possibly impaired for both BAP and TPCB.

- Spatially, the highest magnitude of impairment related to BAP was found along the northern extent of the inner Creek area (P11, P13, P15 and P17). In general, the higher magnitude of impairment in the inner Creek area related to BAP corresponded with high levels in the sediment, as well as higher levels of TOC.

- The highest magnitude of impairment related to TPCB along the northern extent of the inner Creek area (P11, P13, P15 and P17) and at station (P05) near the Mole Pier. In general, the areas with higher magnitude of impairment related to TPCB corresponded with high levels in the sediment.

- On the basis of this analysis, the entire Paleta site was classified as possibly impaired for potential human health effects related to the consumption of BAP and TPCB in fish and shellfish.

13.3 RECOMMENDAITONS

Recommendations based on the findings and conclusions for the Chollas and Paleta sites are summarized below:

- Complete the Phase II TIE work to validate the findings of this study and guide the TMDL source quantification and control efforts.

- Complete the Phase II source evaluation studies to determine the strength and origin of sources for identified chemicals that are driving the impairment.

- Following identification and control of sources, conduct Phase III sediment cleanup studies including

    - Refine the wildlife risk assessment for copper and the human health risk assessments for BAP and TPCB using tissue concentrations from resident fish and shellfish and site-specific exposure parameters.

    - Develop cleanup thresholds based on aquatic live, aquatic-dependent wildlife, and human heath related impairments.

    - Determine potential cleanup boundaries including vertical and horizontal extent.

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