BIGHT'03

Sediment Toxicity

Southern California Bight
2003 Regional Monitoring
Program
Vol. 1

Southern California Bight 2003 Regional Monitoring Program:
I. Sediment Toxicity

May 19, 2005

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FOREWORD

The 2003 Southern California Bight Regional Monitoring Project (Bight'03) is part of an effort to provide an integrated assessment of the SCB through cooperative regional-scale monitoring. Bight'03 is a continuation of regional surveys conducted in 1994 and 1998, and represents the joint efforts of 58 organizations (Appendix A). Bight'03 is organized into three technical components: (1) Coastal Ecology, (2) Shoreline Microbiology, and (3) Water Quality. This report presents the results of the sediment toxicity portion of Bight'03, which is a part of the coastal ecology component. Copies of this and other Bight'03 reports are available for download at www.sccwrp.org.

The proper citation for this report is: Bay, S. M., T. Mikel, K. Schiff, S. Mathison, B. Hester, D. Young, and D. Greenstein. 2005. Southern California Bight 2003 Regional Monitoring Program: I. Sediment Toxicity. Southern California Coastal Water Research Project. Westminster, CA.

The data described in this report are available for download at www.sccwrp.org.

ACKNOWLEDGMENTS

This report is a product of the dedication and hard work of many individuals who share a common goal of improving our understanding of the environmental quality of the Southern California Bight. The authors wish to thank the members of the Bight'03 Steering Committee and Coastal Ecology Planning Committee for supporting the application of sediment toxicity tests in regional monitoring. This study would not have been possible without the exceptional skill of the field sampling personnel from the following organizations: City of San Diego, Weston Solutions, Orange County Sanitation District, County Sanitation Districts of Los Angeles County, City of Los Angeles, Southern California Coastal Water Research Project, and Aquatic Bioassay and Consulting Laboratories. We also wish to express our gratitude to Jeff Brown (SCCWRP) for assistance with the graphics, and to Kerry Ritter (SCCWRP) and Bryn Phillips (UC Davis) for assistance with the statistical analyses.

Toxicity testing was provided by three laboratories including Aquatic Bioassay and Consulting Laboratories (Ventura, CA), Orange County Sanitation District (Fountain Valley, CA), and Weston Solutions (Carlsbad, CA).

Funding for portions of this study was provided by the California State Water Resources Control Board (Agreement Number 02-160-250-0) and by the Los Angeles County Department of Public Works.

EXECUTIVE SUMMARY

Although more than $30 M is spent annually monitoring the effects of anthropogenic discharges to the coastal ocean of the southern California Bight (SCB), virtually no sediment toxicity monitoring occurs. The goal of this study was to answer two questions: 1) What percent of area in the SCB contains sediments toxic to marine organisms?; and 2) How does sediment toxicity compare among specific areas of interest?

Two hundred and twenty-eight sites between Point Conception, California, and the United States-Mexico international border were sampled between July 1 and September 30, 2003. Two hundred and eight sites were selected using a stratified random design to ensure representativeness and minimize bias. A total of six strata were sampled. Three strata were located offshore and included the mainland shelf (5-200 m depth), the mainland slope (200-500 m depth), and the Channel Islands (30-120m depth). Three strata were located in embayments and included estuaries, marinas, and ports/bays/harbors areas. The remaining 20 sites were not randomly chosen, but were selected from within embayments based on their proximity to anthropogenic inputs and potential for sediment toxicity.

Ten-day solid phase sediment toxicity tests were conducted using the amphipod *Eohaustorius estuarius* on all samples. This standardized test has been used by EPA, NOAA, and was used in the previous SCB regional survey (Bight'98). In addition, a subset of toxic sites from estuaries in the Los Angeles region was selected for toxicity identification evaluation (TIE).

Of the 208 randomly selected stations collected, 191 (92%) were successfully tested which exceeded our data quality objectives of 90% success. Control survival, holding times, and reference toxicants were all acceptable for these samples. The remaining 17 samples were discarded because control survival (76%) did not meet quality control criteria (90%). A pre-survey intercalibration study using marine sediments split among participating laboratories demonstrated comparability between testing facilities. The intercalibration was repeated during the survey with similar results.

Three levels were delineated for assessing sediment toxicity in this study. The first level was "nontoxic" where amphipod survival was ≥83% relative to controls. The 83% level was based upon the minimum significant difference approach whereby amphipod survival <83% would be considered significant in at least 90% of the samples based on replicate variability. The second level was "moderately toxic" where amphipod survival was ≥50% and < 83% relative to control survival and was significantly different from controls using standardized t-tests. The third level was "highly toxic" where amphipod survival was <50% relative to control survival. The 50% level corresponds to a high probability of degraded benthos based on previous regional monitoring results from Bight'98.

Sediment toxicity was not widespread in the SCB. No sediment toxicity was observed in an estimated 7,807 km^2 (83%) of the SCB. Stations located near the Channel Islands Marine Sanctuary were found to have the lowest incidence of toxicity (4%). Marinas and estuaries contained the greatest incidence of observed sediment toxicity. Toxicity was present in marinas and estuaries at 50% and 41% of their area, respectively. In addition, marina and estuary strata had the greatest relative contribution of highly toxic sediments (16% and 14%, respectively).

The extent of sediment toxicity in the SCB has changed little over the past five years. Comparisons to Bight'98 indicate a similar level (19%) of overall observed sediment toxicity throughout the SCB. Also similar to Bight'98, the relative distribution of sediment toxicity was greatest in marinas. The confidence in temporal comparisons will improve as additional surveys are conducted.

Based on the results of preliminary sediment TIEs, estuary sediment toxicity in the Los Angeles region may have been the result of organic contaminants. The effect of TIE treatments that bind organic contaminants suggested that nonpolar organics, possibly pesticides currently used in the watershed, were responsible for a majority of the toxicity to amphipods observed in the Ballona Creek and Dominguez estuaries. Additional studies are needed to verify and provide greater specificity in the results so that the information can be used to improve the management of these waterbodies. However, the initial results are encouraging and indicate that new diagnostic tools are becoming available for assessing sediment toxicity.

Caution should be exercised in using the toxicity results reported here as the sole basis for describing sediment quality in the SCB. Toxicity tests, like other indicators of sediment quality such as chemistry and benthic community assessment, have limitations that result in a likelihood that some errors in classification will occur. Each of the stations tested for sediment toxicity was also analyzed for sediment chemistry and benthic macrofauna community composition, and the results for these parameters will be reported in future Bight'03 documents. The results from all of these lines of evidence should be used to make an assessment of sediment quality for the SCB.

DEFINITION OF TERMS

Control chart: A plot of the LC50 or EC50 values from the previous reference toxicant exposures performed by a laboratory. New tests falling between control lines representing plus and minus two times the standard deviation are considered to be within acceptable limits.

Dose-response effect: Observed effect of different concentrations of a toxicant on bioassay test organisms. Generally, the magnitude of the effect increases with concentration.

Elutriate: An aqueous sample produced by mixing water with sediment, then separating the water and sediment phases. The water phase is subsequently used for testing.

Interstitial water: Water that is between the grains of whole sediment.

LC50: Concentration of a toxicant predicted to cause a lethal effect in 50% of test organisms over the course of an exposure period.

Negative control: A sample from a site known to be uncontaminated that is tested along with samples of unknown toxicity.

POTW: Publicly owned treatment works (wastewater treatment facility).

QA Batch (Batch): A group of samples tested together with a negative control.

Reference toxicant: A single compound that is tested along with an unknown sample in order to determine the sensitivity of the test organisms. Comparing reference toxicant results between experiments allows for determination of the validity of each test (see control chart).

Stratum: A subset of stations from the stratified random sampling design. Stations within a given stratum have some characteristic in common (e.g., location near river mouths).

Toxicity test: A laboratory experiment that measures the response (e.g., survival, growth, or reproduction) of an organism following exposure to a sample suspected of containing harmful substances.

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I. INTRODUCTION

Tremendous effort is spent monitoring marine benthos for sediment quality and biological integrity in the southern California Bight (SCB). More than $30M annually is expended on monitoring of the SCB, two-thirds of which is used to assess impacts near the outfalls of treated waste discharges of publicly owned treatment works (POTWs) that discharge to the ocean environment in southern California (Schiff *et al.* 2002). The majority of the effort on sediment monitoring is spent on chemical measurements to assess sediment contamination. Most of the remaining effort is spent on monitoring soft-bottom biological communities. Virtually no effort is spent on sediment toxicity testing as part of these regulatory-based monitoring programs even though sediment chemistry and biological assemblage indicators provide only partial information on sediment quality. Sediment chemistry provides unambiguous measurements of contaminant levels, but provides inadequate information to predict potential biological impact. Biological assemblages provide a direct measure of community impacts, but are also prone to perturbations that are not contaminant driven.

Sediment toxicity plays a vital role in the assessment of sediment quality. Unlike sediment chemistry that measures one chemical at a time and may leave many chemicals unmeasured, toxicity tests integrate the effect(s) of contaminant mixtures. Laboratory toxicity testing directly measures biological impacts similar to benthic assemblage measurements, but the effects of natural variation are minimized and only the effect of sediment toxicants are measured. Finally, new techniques are being developed that allow scientists to isolate the specific toxicant(s) in a contaminant mixture that are responsible for the observed effects through the use of sediment toxicity identification evaluations (TIEs). However, measurement of sediment toxicity is not without its own drawbacks including test imprecision, species specific responses, and lack of consistent correlations with biological community effects.

Sediment toxicity tests are most effective for assessing sediment quality when used in combination with sediment chemistry and biological assemblage information. The so-called "sediment quality triad" of measurements has been used since the mid-1980's and is the basis of many large-scale monitoring programs such as the US EPA's environmental monitoring and assessment program (EMAP) and NOAA's national status and trends program (NS&T). The State of California is currently developing regulatory criteria for sediment quality and the use of multiple lines of evidence will likely be a fundamental key to these regulatory assessments. Sediment toxicity, sediment chemistry and biological assemblage information will be used for determining sediment impairments within the State because reliance on any one indicator of sediment quality is problematic.

The 2003 Southern California Bight Regional Monitoring Project (Bight'03) has a goal of assessing sediment quality from Point Conception to the US/Mexico International Border. Sediment toxicity, sediment chemistry and biological assemblage information will be used to make these assessments. This report focuses specifically on the sediment toxicity component. The sediment toxicity portion of Bight'03 was designed to answer the following two questions:

- What percent of area in the SCB contains sediments toxic to marine organisms?

- How does sediment toxicity compare among specific areas of interest?

These questions are similar to those asked in previous regional surveys, but with some unique differences. First, we are examining three new areas, or subpopulations, of interest. One is the mainland slope, which is deeper than previously examined and not within the typical monitoring areas of most regulatory-based programs. This subpopulation is important because contaminants discharged from multiple anthropogenic activities may accumulate in this depth zone and exert greater effects than observed near a single discharge location in shallower waters. The second new subpopulation is the Channel Islands National Marine Sanctuary. This subpopulation was sampled for chemistry, benthic macrofauna, and fish in Bight'98, but this survey marks the first time that sediment toxicity in the area has been measured. The final new subpopulation examined in Bight'03 are estuaries; the area where watershed discharges meet the ocean. Estuaries have the potential to act as a trap, accumulating contaminants washed downstream from anthropogenic activities in the watershed. The second unique difference in Bight'03 is the capability to compare to previous surveys. Similarities with the 1994 pilot project and Bight'98 were designed into Bight'03 so that temporal changes in sediment toxicity within the SCB could be examined.

This report is structured in eight chapters. Chapter II of this report describes the methods used to prepare the samples and measure toxicity. A quality assurance evaluation of the test results is provided in Chapter III, which addresses issues of data comparability and laboratory performance during the study. Chapter IV describes the test results and illustrates patterns in the prevalence and severity of toxicity among the sampling subpopulations. A regional assessment of the percent area affected and a description of temporal patterns is included in Chapter V. Discussion and interpretation of the results is contained in Chapter VI. Conclusions from the study are presented in Chapter VII and recommendations for future studies are presented in Chapter VIII.

Evaluation of the relationships between sediment toxicity, chemistry, and benthic community responses is not included in this report. These comparisons will be incorporated into a future Bight'03 integrative report, scheduled for completion in Fall 2006.

II. METHODS

A. Sampling Design

Two hundred and eight sites on the continental shelf between Point Conception, California, and the United States-Mexico international border (Figure II-1) were sampled between July 1 and September 30, 2003. Sites were selected using a stratified random design (Stevens 1997). A total of six strata were sampled. Three offshore strata included the Channel Islands National Marine Sanctuary and two strata that were characterized by depth; Shelf (5-200 m) and Slope (mainland upper slope at depths of 200-500 m). Three strata were located within embayments; Estuaries, Ports/Bays/Harbors, and Marinas. In addition to the stratified random sites, 20 non-random sites were located in areas expected to have benthic community impacts, in order to refine the Benthic Response Index (BRI) (Smith *et al.* 2001). Methods for the selection of the BRI stations are presented in Appendix C of this report.

Sites were selected randomly within each stratum, rather than by investigator pre-selection, to ensure that they were representative and could be extrapolated to the response of the entire stratum. For all strata, a systematic component was added to the selection process to minimize clustering of sample sites. The systematic element was accomplished by using an extension of the sampling design used in the Bight'98 regional survey and in the Environmental Protection Agency's (EPA's) Environmental Monitoring and Assessment Program (EMAP) (Stevens 1997). A hexagonal grid was placed over a map of the sampling area, a random subsample of hexagon cells was chosen from this population, and one sample was obtained at a randomly selected site within each grid cell. The hexagonal grid structure ensures systematic separation of the sampling effort, while the random selection of sites within grid cells ensures an unbiased estimate of ecological condition. Additional details of this site selection process are provided in the Coastal Ecology Work Plan (Bight'03 Steering Committee 2003).

B. Field Methods

Sediment samples were collected with a 0.1 m^2 modified Van Veen grab. Up to 2.5 L of sediment were collected for measurement of sediment toxicity using the amphipod survival test. A plastic (high-density polyethylene [HDPE], polycarbonate, or Teflon) scoop was used to collect sediment from the top 2 cm of the undisturbed surface material in the grab. Contact with sediment within 1 cm of the side of the grab was avoided in order to minimize cross-contamination. The sediment was placed in clean HDPE containers and distributed to the testing laboratories. Following collection, samples were stored on wet ice or refrigerated in the dark at 4° C for no longer than four weeks prior to testing.

C. Laboratory Methods

Toxicity to amphipods was determined using a 10-d survival test (U.S. Environmental Protection Agency 1994) with *Eohaustorius estuarius*. Amphipods and negative control sediment were collected from Beaver Creek, Oregon, a non-contaminated estuarine site. The target laboratory holding time for the amphipods was at least 2 d, but no longer than 10 d, prior to the test. Testing was conducted in 1 L glass test containers. Sediment samples were pre-sieved through a 2 mm mesh screen and homogenized in the laboratory before testing. Sediment samples were added to the test containers to form a sediment layer approximately 2 cm deep. Filtered seawater (20 g/kg salinity) was added slowly until a final volume of 800 mL was reached. Pipettes connected to an air source provided aeration. Sediments were allowed to equilibrate overnight. Each sample consisted of five randomly arranged replicates, along with two surrogate containers for water quality measurements of overlying water and pore water which were measured at time zero and at the end of the exposure. A negative control (amphipod collection site sediment) was included with each batch of samples tested.

At the start of the test, amphipods were added randomly until a total of 20 animals per container were present. Tests were conducted at 15 ± 2 °C under constant illumination. Test animals were exposed to the sediment samples for 10 d. Each test chamber was examined daily to verify that adequate aeration was present and to record observations of mortality or changes in sediment appearance. Any floating animals were submerged by gently pushing them beneath the surface with a probe. At the end of the exposure period, the sediment was screened through a 0.5 mm screen and the number of surviving amphipods was recorded.

Samples of overlying water and interstitial water were obtained from the surrogate test containers for measurement of initial water quality (temperature, pH, dissolved oxygen, salinity, and total ammonia). Overlying water quality was also measured at the end of the exposure period. Temperature of overlying water was measured daily throughout the test. In addition, if the unionized ammonia in the initial pore water measurement exceeded 0.8 mg/L (the concentration known to have an effect on amphipods), the laboratory was required to perform a simultaneous ammonia reference toxicant test with that batch.

A cadmium reference toxicity test was conducted concurrently with each sediment toxicity test batch. The reference toxicant test consisted of three replicates of five concentrations of cadmium dissolved in seawater, plus a control. No sediment was included in the reference toxicant tests. Ten amphipods were added to each replicate and exposed to the reference toxicant for 4 d. Water quality measurements made for the reference toxicant tests were conducted using a similar methodology to the sediment phase of the test. At the end of 4 d, the total number of surviving animals was recorded and the concentration causing 50% mortality (LC50) was calculated. The Trimmed Spearman Karber, probit or linear interpretation methods were used to calculate the LC50, which was then compared to a control chart prepared from the results of past reference toxicant tests conducted by the laboratory. A test result within two standard deviations of the mean control chart LC50 was considered acceptable.

For the data from any given test batch to considered acceptable, the mean control survival must have been greater than 90% and no control replicate could have survival less than 80%. In addition, the samples had to be tested within four weeks of collection.

D. Data Analysis

Data were analyzed using two methods: (1) calculation of the mean response relative to the control for each batch and (2) assessment of the percent area within each stratum that was classified as nontoxic, moderately toxic or highly toxic on the basis of survival thresholds.

Calculation of the response relative to the control is simply the amphipod survival at a given station divided by the mean percent survival of the associated control for that batch multiplied by 100. This adjustment is sometimes referred to as Abbott's correction.

For the amphipod test, two criteria had to be met before a sample could be classified as toxic: (1) a statistically significant reduction in survival compared to the control; and (2) a minimum percent reduction in survival between the sample and control. Statistical significance was determined by performing a t-test between the sample and control with a 0.05 level of significance. A reduction in mean survival of greater than 17% relative to the control (i.e., a control normalized survival of less than 83%) was classified as toxic. This threshold was calculated using the minimum significant difference (MSD) approach following Phillips *et al.* (2001). The 17% toxicity threshold was established by first calculating MSD relative to the control for every t-test in the Bight'03 dataset. The MSD values were then ranked and the 90^{th} percentile value was selected (Phillips *et al.* 2001). Based on this MSD calculation, samples having a survival less than 83% of the control would be expected to be significantly different from the control 90% of the time.

Samples that were identified as toxic were further separated into two categories (Table II-1). A sample with a survival that was less than 50% of the control was classified as "highly toxic". The threshold for high toxicity was chosen to correspond to a high probability of occurrence of a degraded benthos, based on the results of the Bight'98 study (Ranasinghe *et al.* 2003). The 50% survival threshold also represented a response that was certain to be significantly different from the control; there was less than a 0.001% chance of obtaining <50% survival for a sample by chance. Samples that were significantly different from the control and with survival between 50 and 82% of the control were classified as "moderately toxic".

Area weights were calculated by taking the total area (km^2) of a given strata and dividing by the number of samples in that strata. The total area determined to be nontoxic, moderately toxic and highly toxic for a given strata were calculated by summing the area weights for each station that fell into a given category of toxicity. Percent area was calculated by taking the total area for a given strata and toxicity level and dividing by the total area for the given strata. A Harvitz-Thompson ratio estimator was used to calculate the confidence intervals. Variance estimates for the proportion estimates were calculated using the simple random sampling (SRS) variance estimator. Confidence bounds were calculated using a Normal distribution multiplier (Diaz-Ramos *et al.* 1996).

Table II-1. Amphipod toxicity category criteria.

Toxicity Category	Criteria
Nontoxic	Not significantly different from control or greater than 82% survival relative to the control.
Moderately toxic	Significantly different from control and survival between 82% and 50% relative to the control.
Highly toxic	Significantly different from control and survival less than 50% relative to the control.

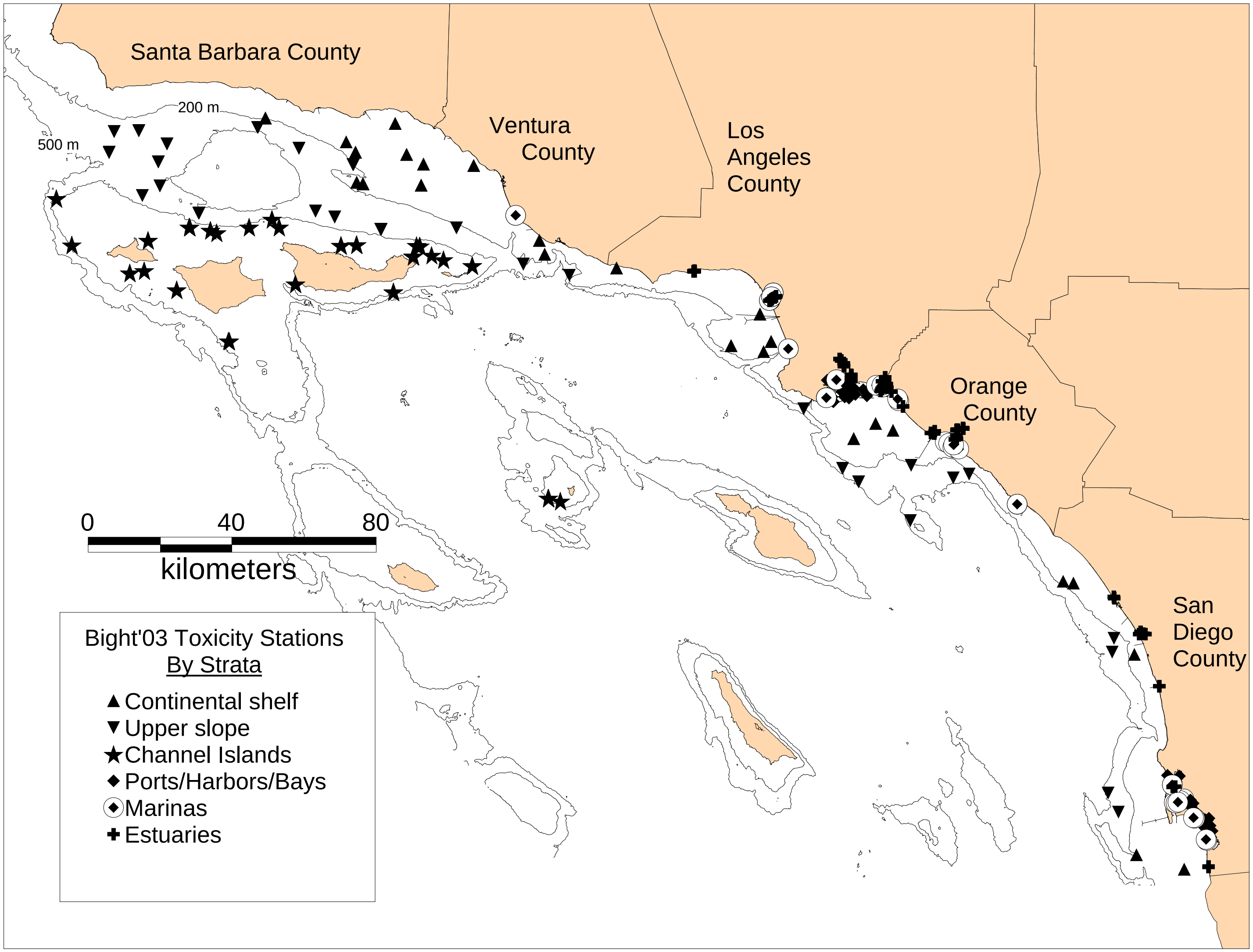

Figure II-1. Locations of all stations sampled for sediment toxicity during the Bight'03 project.

III. QUALITY ASSURANCE EVALUATION

A. Sampling Success

Samples were successfully collected at 99% of the randomly selected sites planned for sediment toxicity testing, exceeding our data quality objective (DQO) of 90% success (Table III-1). The areas with the lowest success rates were within the Slope, Ports/Bays/Harbors, and the Estuaries strata (90 – 98% success). Sampling success was hindered in some cases by impenetrable substrates or when designated coordinates were either on land or inaccessible for sampling. When samples were not able to be collected at any given station, the field personnel would attempt to collect samples at pre-designated alternate stations within the strata. In some cases the field crews collected more than the target number of samples. All 20 of the nonrandom sites for BRI development were sampled successfully.

Table III-1. Toxicity sample collection success for stratified random stations.

Strata	Number of Target Samples	Number of Successful Samples	Percent (%) of Target Sampled
Shelf	30	30	100
Slope	30	28	93
Channel Islands	30	32	107
Ports/Bays/Harbors	30	27	90
Marinas	30	32	107
Estuaries	60	59	98
TOTAL	210	208	99

B. Sample Storage

An optimum maximum holding time of 14 days was established from the time between sample collection and initiation of the amphipod tests. Samples that were analyzed 15-28 days after collection were accepted, but flagged in the database as exceeding the holding time. Any samples analyzed beyond 28 days after collection were not deemed acceptable. This optimum holding time of less than 15 days was met for 76% of the amphipod test samples (Table III-2). The remaining 24% were all analyzed within the absolute holding time of 28 days. Delays in testing were due to the rapid collection of sediment samples by multiple agencies, which overwhelmed laboratory capacity.

Table III-2. Toxicity sample holding time.

Time Interval	# Samples	Percent of Total
0-14 Days	173	76
15-28 Days	55	24

C. Organism Holding

A required holding time for organism acclimation was set at a minimum of 2 days and no greater than 10 days from the date of receipt from the supplier. Six batches of samples were tested with organisms held either less or greater than these requirements. An analysis of the reference toxicant tests conducted concurrently with these batches did not indicate any differences in the sensitivities of these animals.

D. Test Performance

Amphipod Survival

Of the 228 samples collected, 211 were successfully tested. The mean control survival rate for the valid tests was 95.6% (values ranged from 89.5-100%).

All but four batches of the amphipod sediment toxicity tests met all necessary acceptability criteria. Three test batches met the acceptability criteria of having a mean control survival of 90% or greater, but did not achieve the single replicate control survival criterion of 80%. This deviation occurred in control replicate 5 of Batch 3 (65% survival), control replicate 5 of Batch 10 (70% survival), and control replicate 4 of Batch 11 (75% survival). An investigation was performed on these batches to determine if the variability within the control survival data impacted the ability of these tests to determine significant differences between the control and each of the samples. In order to assess potential bias, a conceptual model was developed that included comparing the batch sample results to a mock control data set, which had the highest achievable coefficient of variation (CV) while still meeting acceptability criteria. All possible combinations of five-replicate data sets were generated and the CV was calculated for each. The greatest CV calculated from these data sets was 11.91 (designated CVmax). Batch 3 and Batch 11 had CV values less than the CVmax (11.5 and 8, respectively). This indicates that the ability to determine significant differences between the controls and the sample treatments of the respective batches was not less than the worst-case scenario CVmax. The data from these two batches were accepted into the database, but were flagged as not meeting control acceptability criteria. Batch 10, however, had a CV of 13.1, exceeding the CVmax of 11.91. In this case, the survival from each station was analyzed for a statistical difference to the survival of the mock control data set that generated the CVmax. This information was compared to the data generated with the original test batch control. The results of the statistical testing using the batch control and the CVmax mock control were found to be identical. Batch 10 was accepted into the database, but flagged as not meeting control acceptability criteria.

In the fourth case, the mean control survival for Batch 7 had a mean survival of 76%, falling below the acceptability criterion of 90%. Retesting of this batch fell outside of the 28 day holding time for this sample. Therefore, the data from this batch were deemed to be unreliable and were not included in the Bight'03 database. The excluded samples included 5 samples from the Shelf stratum, 5 samples from the Estuaries stratum, and 7 samples from the Channel Islands stratum.

The exclusion of 17 samples due to poor control performance resulted in a total of 211 samples that were successfully tested (191 stratified random samples). This number represented 92% of the 230 target samples (stratified random + BRI) and exceeded the DQO of 90% successful tests established for the study.

Outliers

The results for several of the test samples included a replicate with survival value that was substantially lower than the other replicates. Grubb's Test (Sokal and Rohlf 1995) was used to evaluate these samples and identify outlier replicates that were not considered as representative of the overall results. In instances where the Grubb's Test identified an outlier, that datum was removed from the database. A total of 11 replicate data points were excluded from the database.

Water Quality

Water quality parameters (pH, dissolved oxygen [DO], salinity, and ammonia) were within acceptable limits for more than 80% of the stations sampled (U.S. Environmental Protection Agency 1994). All of the deviations were considered minor and should not affect the interpretation of the test results. The desired range for salinity was 20 ± 3 g/kg. Salinity in the overlying water ranged from 15.6-23 g/kg during the Bight'03 tests. Deviations outside the desired range occurred due to gradual shifts in the overlying water salinity as it equilibrated with differing interstitial water salinities. This gradual shift should not have impacted the test results as these salinities were within the tolerance range of *E. estuarius* (1-35 g/kg). Interstitial water salinity ranged from 11-34 g/kg. The mean interstitial water salinity was 24.1 g/kg, slightly above the desired test range. These values were again within the tolerance range of this test species. Levels of unionized and total ammonia were almost always below levels likely to have an impact on the toxicity of the Bight samples. The concentration of unionized ammonia in the overlying water ranged from 0.00 to 0.99 mg/L, with only one sample slightly exceeding the ammonia acceptability criterion of 0.8 mg/L. The exceedance was due to a single high value that was measured at the end of an experiment, so no corrective action could be taken. Small deviations from the desired ranges were also observed in dissolved oxygen and pH, but should not impact the significance of the test results. The deviations from the recommended water quality objectives are indicated as a minor deviation within the Bight'03 database. The water quality parameters and measured ranges are summarized in Table III-3.

Table III-3. Amphipod test water quality summary.

Parameter	Desired Range	Measured Range
Temperature	15° ± 3 °C	13.9–17.1 °C
Salinity (overlying)	20 ± 3 ppt	15.6-23 ppt
Salinity (interstitial)	20 ± 3 ppt	11-34 ppt
Dissolved oxygen	> 5.0 mg/L	4.4-9.7 mg/L
pH (overlying)	8 ± 0.5	6.22-9.2
pH (interstitial)	8 ± 0.5	6.5-8.5
Total ammonia (overlying)	< 60 mg/L	0.00–14 mg/L
Total ammonia (interstitial)	< 60 mg/L	0.00-40.1 mg/L
Unionized ammonia (overlying)	< 0.8 mg/L	0.00-0.99 mg/L
Unionized ammonia (interstitial)	< 0.8 mg/L	0.00-0.74 mg/L

Reference Toxicant Testing

A total of 22 reference toxicant tests with cadmium were conducted by the laboratories during the survey. The purpose of reference toxicant tests was to determine whether test organism response and test procedures were comparable among different testing periods within a laboratory. Reference toxicant test results indicated that the laboratory test organisms and individual laboratory performances were similar. The mean LC50 values from participating laboratories ranged from 2.9-7.6 mg/L (with a mean value of 5.3). Control survival ranged from 77-100% (with a mean survival rate of 97%). With the exception of 1 reference toxicant test, all laboratories submitted acceptable reference toxicant results with values that were within two standard deviations of the calculated mean LC50 (Figure III-1). The one test that fell outside of two standard deviations was associated with the test batch that did not meet control acceptability criteria and, therefore, had already been excluded from the data set.

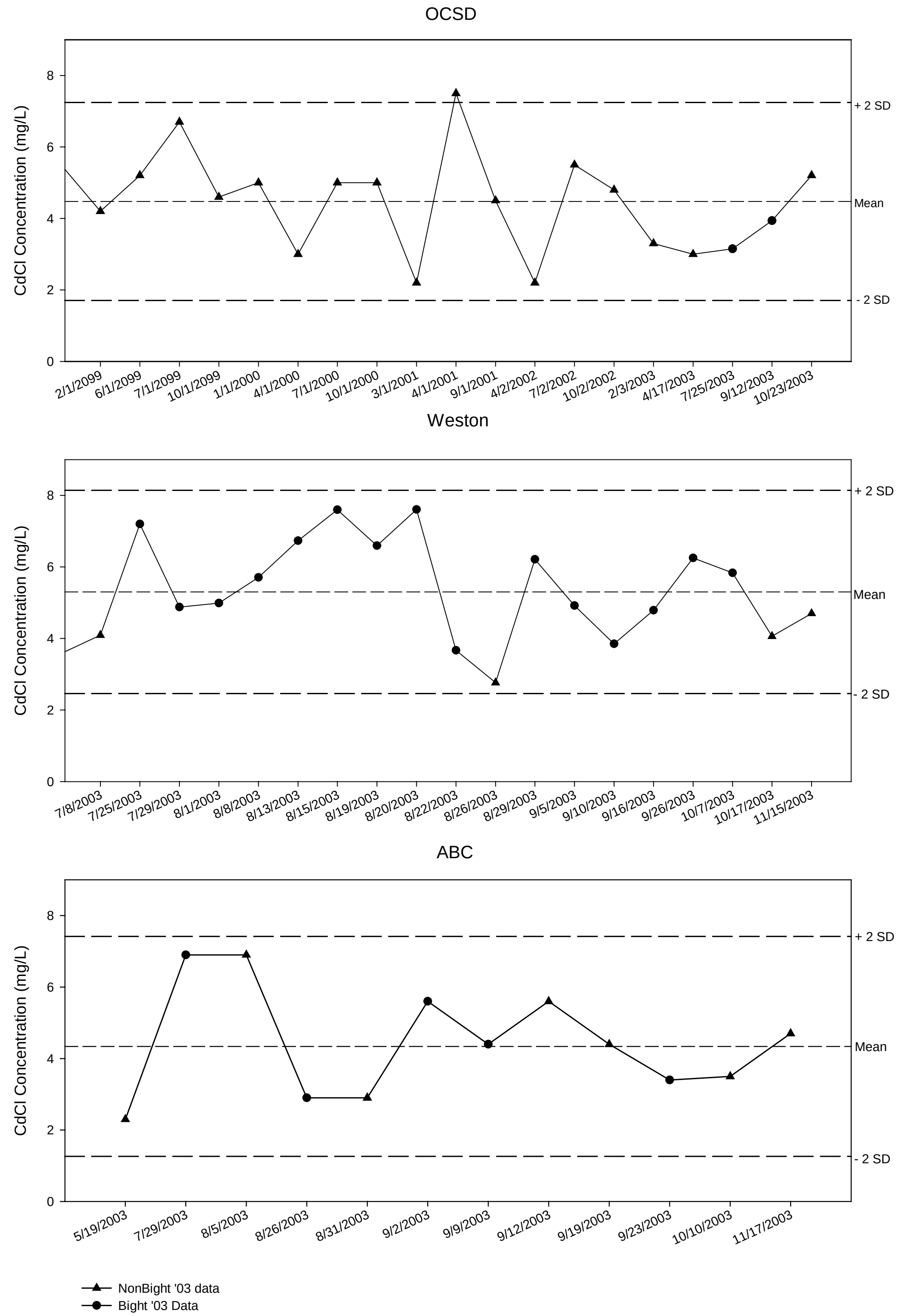

Figure III-1. Cadmium reference toxicant results for each testing laboratory.

E. Interlaboratory Study and Split Samples

Interlaboratory Study

An interlaboratory study was performed prior to the Bight'03 study to determine comparability between the multiple labs that would be performing the sediment toxicity analysis. In addition to the three labs that analyzed Bight'03 samples, two other agencies participated in the study. Four sediment samples were analyzed among five laboratories following standard protocols for the *Eohaustorius estuarius* 10-day toxicity test. The four sediment samples represented one nontoxic sample from offshore of Orange County (OC), two samples of moderate toxicity from Newport Bay (RC14 and NB3), and one highly toxic sample from San Pedro Bay (CS). These samples were chosen by SCCWRP personnel and were distributed to the five laboratories to be tested within the same time frame.

Each of the participating laboratories met the test acceptability criteria for survival in control sediment. The level of agreement among the laboratories was first assessed by comparing the station classification based on the survival results. The mean percent of control survival was calculated for each sediment sample (grouped by laboratory). T-tests were conducted versus the appropriate control to determine significance at the 0.05 level (Figure III-2). For sample OC, four of the five laboratories classified the sample as nontoxic (i.e., no significant difference from the control survival percentage). Only laboratory 3 classified this sample as moderately toxic (less than 83% of control survival and significantly different from the control). In the case of RC14, all laboratories found the sample to be toxic, with four of the laboratories classifying the sample as highly toxic. All of the laboratories had complete mortality for sample CS and classified the sample as highly toxic. For NB3, all the laboratories found the sample to be toxic and three of the laboratories assigned the same classification of highly toxic. For all of the samples tested by the Bight'03 participating laboratories (labs 1, 3, and 5) there was only one case where a sample would have been classified differently among the labs, that being station OC for laboratory 3.

The degree of agreement among the laboratories for percent survival was next assessed by analysis of variance (ANOVA). In cases where significant differences were found, Tukey pairwise multiple comparison tests were conducted to detect specific differences among the laboratories (Table III-4). All laboratories obtained the same survival percentage for sample CS: 0%. There were a few statistically significant differences in percent survival among the laboratories for each of the other samples. In each case, the result for either laboratory 2 or 4 was different from the other laboratories. For example, the survival obtained by laboratory 4 for RC14 was significantly different from all of the other laboratories. No significant differences in survival were present among the three laboratories (1,3,5) that tested the Bight'03 samples.

The relative agreement of the laboratories was also assessed by ranking the mean survival values within a laboratory. The degree of association of toxicity rankings between laboratories was assessed by Kendall's coefficient of concordance (W) (Zar 1999). The field sediments were ranked in order of toxicity for each laboratory, with a value of 1.0 assigned to the sediment with the highest survival rate and a value of 4.0 assigned to the sediment with the lowest survival rate. Kendall's W ranges from 0.0 (no degree of association) to 1.0 (perfect association). Since the sediments were tested blindly, ranking the four field sediments by survival for each laboratory provided a way to assess the ability of the participating laboratories to distinguish between sediments. All five of the laboratories ranked the sediments in exactly the same order. The Kendall coefficient of concordance was 1.0, indicating a perfect level of agreement ($p<0.01$) among laboratories.

The results of the interlaboratory comparison indicated that results obtained by the three Bight'03 testing laboratories, 1, 3, and 5, had a high degree of comparability. This conclusion was based on the fact that there were no significant differences in mean survival among the three laboratories, and that the relative ranking of stations by each laboratory was identical. The results for the other two participants in the interlaboratory study (Labs 2 and 4) tended to show greater differences when compared to Labs 1, 3, and 5. The cause for these differences was not determined, but may have been related to changes in sediment characteristics during shipment to the labs or to differences in sample preparation within each lab.

Table III-4. Matrix of significant differences observed within the interlaboratory results. Bight'03 sediment samples were tested by Labs 1, 3, and 5.

Station					
OC	4 (99)	2 (97)	1 (93)	5 (91)	3 (72)
RC14	4 (58)	2 (32)	1 (22)	3 (18)	5 (17)
NB3	4 (62)	2 (45)	1 (40)	5 (37)	3 (30)
CS	1 (0)	2 (0)	3 (0)	4 (0)	5 (0)

Values in parentheses are percent survival. Numbers not in parentheses are laboratory codes. Horizontal lines represent groups of laboratories that were not significantly different from one another.

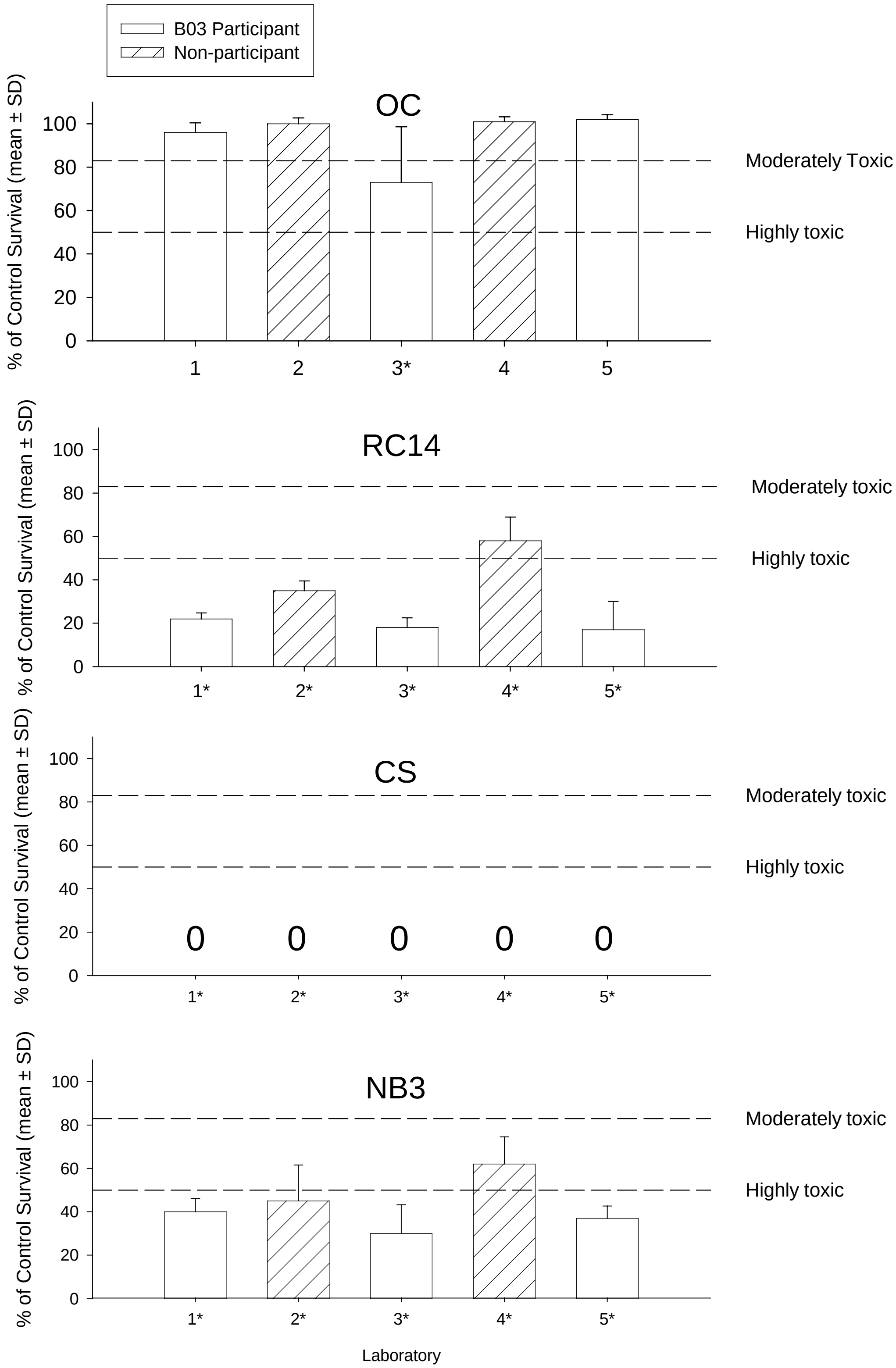

Figure III-2. Interlaboratory study results. *Indicates significantly different from control response.

Split Samples

During the course of the Bight'03 testing, one of the moderately toxic samples utilized for the interlaboratory study (NB3) was chosen as a split sample. This sample was distributed by SCCWRP to the testing laboratories and was analyzed at the same time as the Bight'03 field collected samples. Analysis of the split samples was an exploratory study intended to investigate alternative methods of documenting interlaboratory variability. The split sample results were not intended to judge the validity of the Bight'03 results, rather the analyses were conducted to determine whether this activity was feasible and to obtain baseline information for use in future surveys.

Sediment for the split sample was stored under refrigeration and delivered to the labs at 85 days and 120 days from the time of collection. The labs tested the split sample in conjunction with their next batch of Bight'03 samples. Testing of the split samples was limited to the three labs actually performing the Bight sediment toxicity analyses. The mean survival values for the first split ranged from 45-64% and was similar to the results obtained for the same sample in the interlaboratory study (30-62%). Mean survival tended to decline in the second split sample test (10-43%), but the range in values was again similar to that obtained in the interlaboratory study (Figure III-3). The source of variability in the split sample results was not identified, but may include differing organismal sensitivity from batches of animals collected at different times, in addition to other unknown factors.

The analysis of split samples as part of a cooperative regional survey was shown to be feasible and informative. It is recommended that split samples be analyzed as part of the QA program in future Bight surveys. The future implementation of a split sample testing program should include greater control over sediment storage conditions and establish an objective for maximum variation among laboratories.

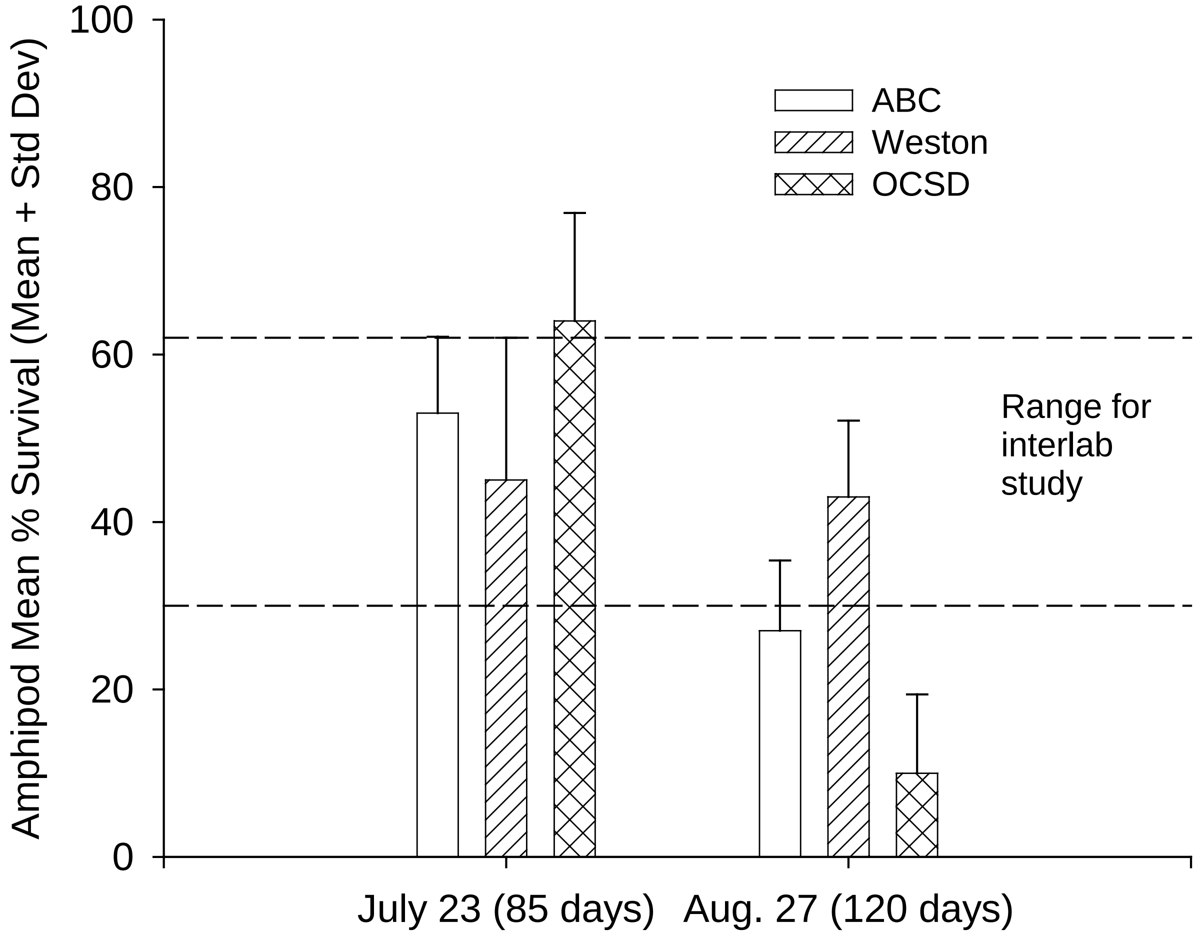

Figure III-3. Split sample summary.

IV. DESCRIPTIVE RESULTS

The results for the stratified random samples are presented in this section. Results for the BRI refinement samples are described in Appendix C.

A. Frequency of Toxicity

Sediment toxicity was detected in at least one station from every stratum tested. Among the 191 sediment samples collected throughout the SCB, 59 (31% of the total) showed some degree of toxicity (Table IV-1). Fifteen samples (8%) were classified as highly toxic, while 44 samples (23%) were classified as moderately toxic.

Amphipod survival in 2003 was closely related to proximity to embayments (i.e., Ports/Bays/Harbors, Marinas, and Estuaries strata), where 42% of the samples were classified as toxic. All of the highly toxic sediments detected in this study were collected from embayments (Figures IV-1-5). Among these areas (Table IV-1), samples from the Marinas stratum had the highest frequency of toxicity (50%). Samples from Ports/Bays/Harbors were toxic in 44% of the cases. Finally, 37% of samples collected from the Estuaries stratum were toxic to amphipods.

A much lower frequency of sediment toxicity was measured in samples from offshore regions (i.e., Shelf, Slope, and Channel Islands strata). Only one sample from the Channel Islands stratum was toxic, resulting in a frequency of 4% (Figure IV-1). This sample (Station 4155) produced a relatively small toxic response (79% of control survival) and was collected from a depth of 101 meters in an area distant from suspected areas of contamination. Samples from the mainland shelf (5-200 m depth) were toxic in 16% of the cases. Three of the toxic Shelf samples were collected offshore of Santa Barbara and Ventura Counties, in the same general region where toxicity was also observed in the Bight'98 survey (Figure IV-1). The final toxic Shelf sample was located in Santa Monica Bay, an area which contains sediments contaminated from past discharges of wastewater and urban runoff. None of the toxic Shelf samples were classified as highly toxic (Table IV-1).

Six samples from the Slope stratum (21% of the total) produced a toxic response (Table IV-1). None of these samples were classified as highly toxic. One of the toxic Slope samples was located offshore of Santa Barbara County and two samples were located offshore of Orange County in an area south of Newport Bay (Figures IV-1 and IV-2). The remaining three toxic Slope samples were located offshore of San Diego County, including two samples that were offshore of the Point Loma wastewater discharge (Figure IV-5).

Among specific embayments (Ports/Bays/Harbors or Marinas strata only), the largest percentage of highly toxic samples (63%) came from Newport Bay (Table IV-2). The only other embayment with highly toxic samples was San Pedro Bay (1 sample, representing 5% of the total). The largest number of moderately toxic samples (9, representing 47% of the total) came from San Diego Bay. Newport Bay was the only embayment in which there was a greater percentage of toxic samples (87%) than nontoxic samples. San Pedro Bay had a moderate frequency of toxicity (42%). No toxicity was found in Dana Point Harbor, Oxnard Harbor, or Redondo Harbor; however, only one sample was collected from each of these harbors.

For individual estuaries (Table IV-3), highly toxic samples were obtained from three areas: Ballona Creek (which discharges adjacent to Marina del Rey Harbor), Dominguez Channel (which discharges into the Port of Los Angeles), and Upper Newport Bay. These estuaries also had relatively high percentages of toxic (highly toxic plus moderately toxic) samples (80%, 50%, and 62%, respectively). No toxicity was found in San Diego River Estuary, Santa Ana River Estuary, Santa Margarita River Estuary, Talbert Marsh, or Tijuana River Estuary, but only a few samples were collected from these areas (1-2 samples each). Malibu Lagoon and San Gabriel River Estuary also showed no toxicity, however, a relatively large total number of samples were collected from these estuaries (5 and 7 samples, respectively).

B. Magnitude of Toxicity

Since the numbers of toxic versus nontoxic samples do not indicate the magnitude of toxicity among samples, comparisons of strata by the mean percent of controls is also presented for each toxicity classification (Table IV-1). One sample from the Ballona Creek produced the lowest survival rate (0% of the control), followed by a series of six samples from Upper and Lower Newport Bay (4-9% of the control). The remaining highly toxic samples (19-48% of control) were located in Newport Bay, San Pedro Bay, Ballona Creek, and Dominguez Channel.

Moderately toxic samples were also found mostly in embayments. The mean percentage of control survival for moderately toxic samples ranged from 51-82%, while nontoxic samples ranged from 71-105%. Two samples had mean percent of control survival below 83% but were not significantly different from their controls, extending the range down to 71%. Some samples had survival greater than the associated controls, leading to values greater than 100%. Within the SCB as a whole, the mean percent survival for highly toxic sediments was 17%, for moderately toxic sediments 70%, and for nontoxic sediments 95%.

C. Toxicity Characterization in Estuaries

Two samples each from the Ballona and Dominguez estuaries were subjected to Toxicity Identification Evaluation (TIE) treatments that were intended to characterize the type of contaminants responsible for toxicity. A variety of TIE treatments were applied to samples of whole sediment and pore water from each station (Appendix D). Both Ballona samples contained a high percentage of coarse sediment, which prevented the collection of sufficient pore water for testing. In order to obtain a sufficient volume for testing, pore water from one Ballona sample was diluted with seawater and an elutriate was prepared from the other sample.

The TIE treatments were successful in characterizing a possible cause of toxicity at all four of the stations for whole sediment and at three of the four stations for pore water or elutriate. At both of the Dominguez stations, a similar pattern was observed for both the whole sediment and pore water TIEs. The results indicated organic chemicals, perhaps pyrethroid pesticides, were responsible for the observed toxicity. At the Ballona stations, there was less agreement between TIE results from the whole sediment and aqueous samples. The whole sediment for one

Ballona station was mostly due to an organic chemical, and to a lesser extent, a trace metal component. No characterization of the toxicity was evident in the pore water. TIE results from the whole sediment at the second Ballona station indicated strong effects by an organic chemical, most likely a pyrethroid pesticide. The elutriate sample from this site had indications of both organic and metal toxicity components.

D. Comparison of Toxicity to Sediment Fines and Total Organic Carbon

Amphipod survival (percent of the control) was significantly correlated to both sediment TOC and the percent of fine sediments (Figures IV-6 and IV-7). Amphipod survival tended to decline when larger proportions of TOC (r = - 0.40) or fine particles (r = - 0.58) were present. A similar relationship was present for mean sediment grain size, skewness, and kurtosis. As mentioned above, sediment toxicity was more frequent in embayments. Since these areas tend to have sediments that are much finer and higher in organic carbon than offshore sites, it is not surprising that finer, more organic, sediments correlated well with toxicity. One other situation apparent in Figures IV-6 and IV-7 is that some samples with relatively high percent fines and TOC values also yielded high survival. This observation indicates that the amphipod toxicity observed in this study was probably not caused by either fine particle size or high TOC values alone.

Table IV-1. Sediment samples toxic to amphipods from six strata in the Southern California Bight.

	Highly Toxic				Moderately Toxic				Nontoxic			
	No.	%	Mean	95% CI	No.	%	Mean	95% CI	No.	%	Mean	95% CI
Offshore												
Mainland Shelf	0	0	na	na	4	16	77	73-81	21	84	96	94-98
Upper Slope	0	0	na	na	6	21	70	61-78	22	79	95	93-97
Channel Islands	0	0	na	na	1	4	79	na	24	96	95	94-97
Harbors/Estuaries												
Ports/Bays/Harbors	1	4	48	na	11	41	67	60-74	15	56	92	88-96
Marinas	5	16	14	5-23	11	34	71	65-76	16	50	95	92-98
Estuaries	9	17	16	8-24	11	20	71	66-75	34	63	94	92-97
All Strata	15	8	17	11-24	44	23	70	68-73	132	69	95	94-96

Table IV-2. Sediment samples toxic to amphipods from nine harbors and bays in the Southern California Bight.

	Highly Toxic		Moderately Toxic		Nontoxic	
	No.	%	No.	%	No.	%
Anaheim Bay	0	0	1	50	1	50
Dana Point	0	0	0	0	1	100
San Pedro Bay	1	5	7	37	11	58
Marina del Rey	0	0	1	25	3	75
Mission Bay	0	0	2	50	2	50
Newport Bay	5	63	2	25	1	13
Oxnard Harbor	0	0	0	0	1	100
Redondo Harbor	0	0	0	0	1	100
San Diego Bay	0	0	9	47	10	53
All Harbors	6	10	22	37	31	53

Table IV-3. Sediment samples toxic to amphipods from sixteen estuaries in the Southern California Bight.

	Highly Toxic		Moderately Toxic		Nontoxic	
	No.	%	No.	%	No.	%
Agua Hedionda Lagoon	0	0	1	25	3	75
Anaheim Bay Estuary	0	0	1	100	0	0
Ballona Creek Estuary	3	60	1	20	1	20
Bolsa Chica Estuary	0	0	1	100	0	0
Dominguez Channel	3	50	0	0	3	50
Los Alamitos Estuary	0	0	2	67	1	33
Los Angeles River Estuary	0	0	2	40	3	60
Malibu Lagoon	0	0	0	0	5	100
San Diego River Estuary	0	0	0	0	2	100
San Elijo Lagoon	0	0	1	100	0	0
San Gabriel River Estuary	0	0	0	0	7	100
Santa Ana River Estuary	0	0	0	0	2	100
Santa Margarita River Estuary	0	0	0	0	2	100
Talbert Marsh	0	0	0	0	1	100
Tijuana River Estuary	0	0	0	0	1	100
Upper Newport Bay	3	38	2	25	3	38
All Estuaries	9	17	11	20	34	63

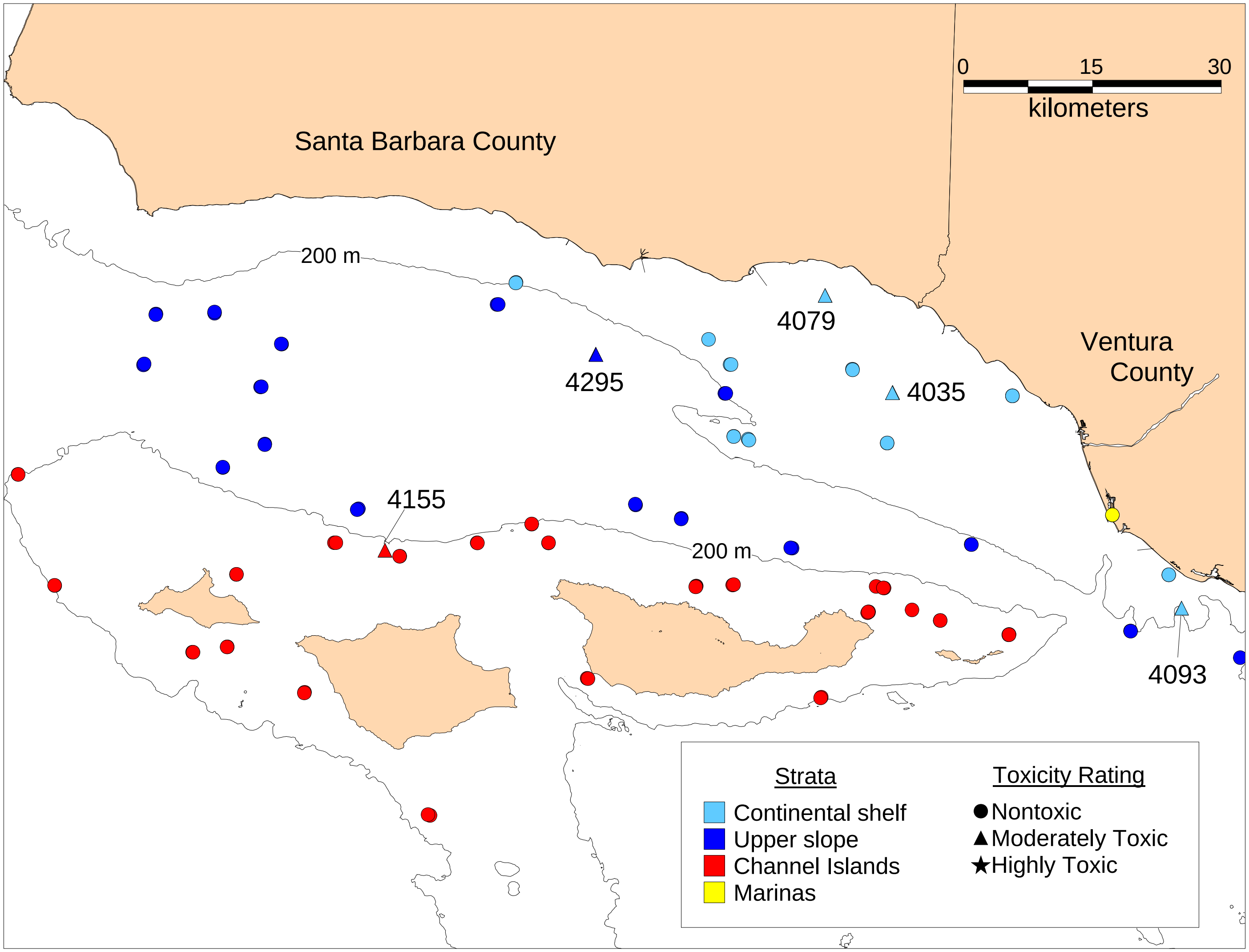

Figure IV-1. Map of sediment toxicity results for stations in the northern region of the SCB.

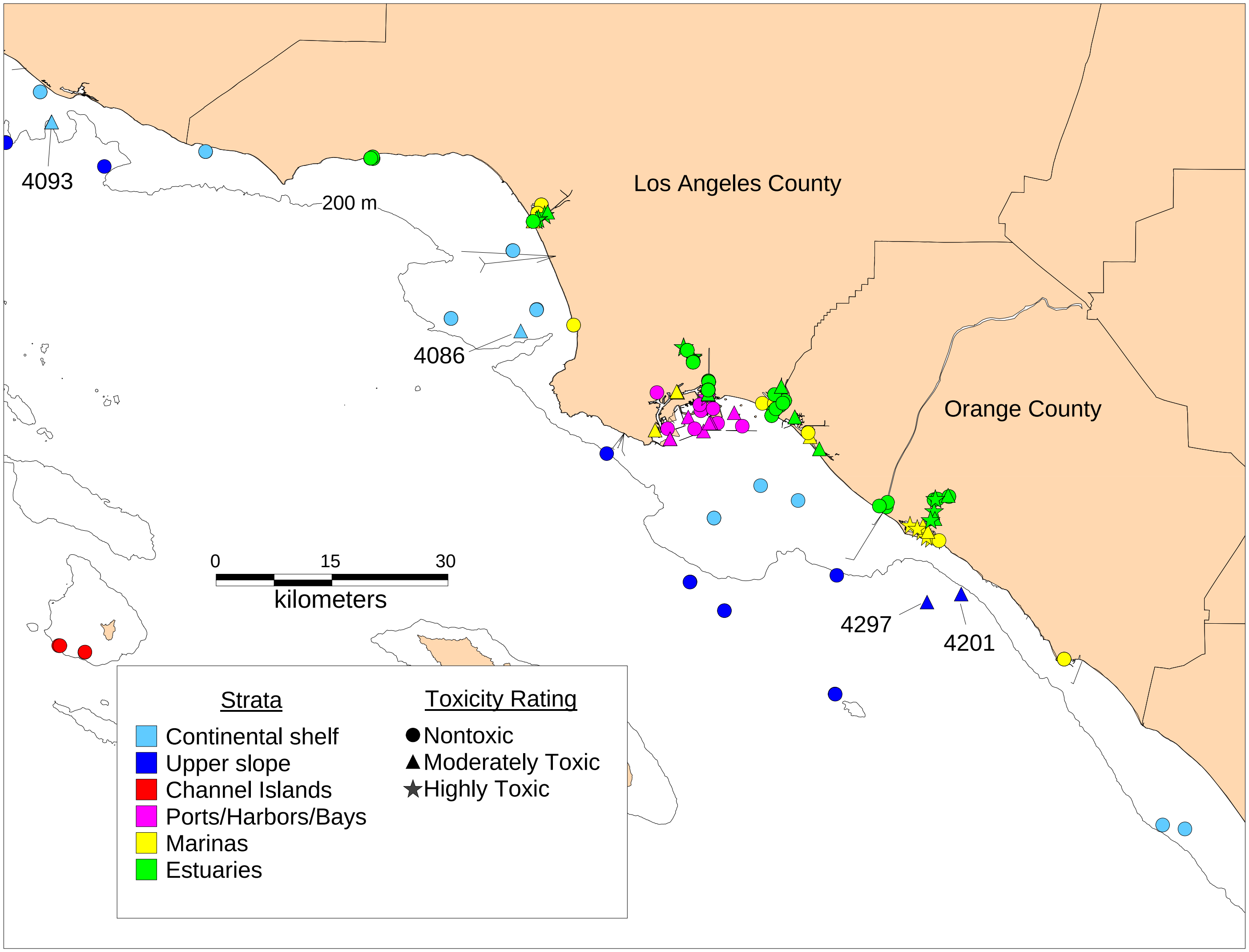

Figure IV-2. Map of sediment toxicity results for stations in the central region of the SCB.

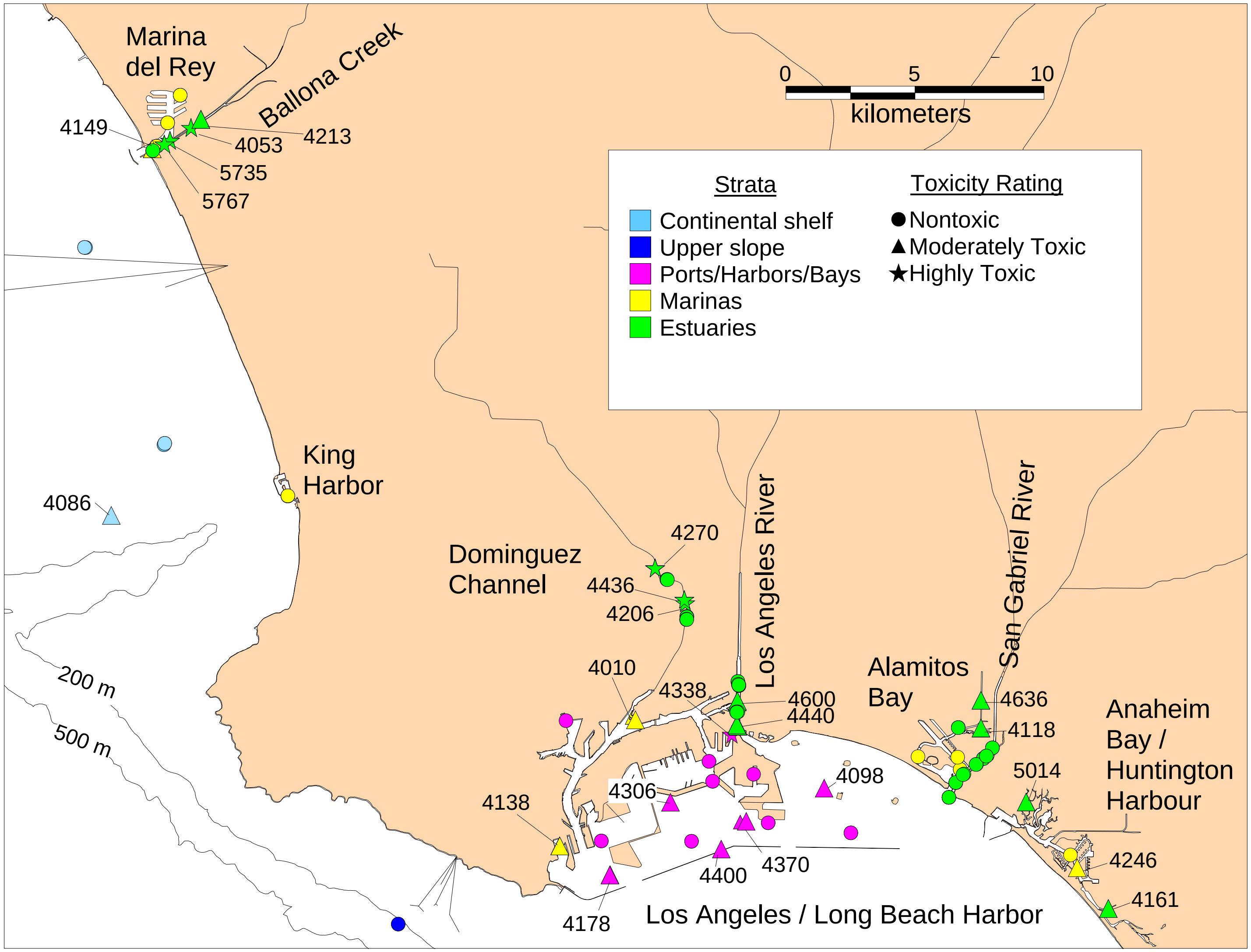

Figure IV-3. Map of sediment toxicity results for Los Angeles County embayments.

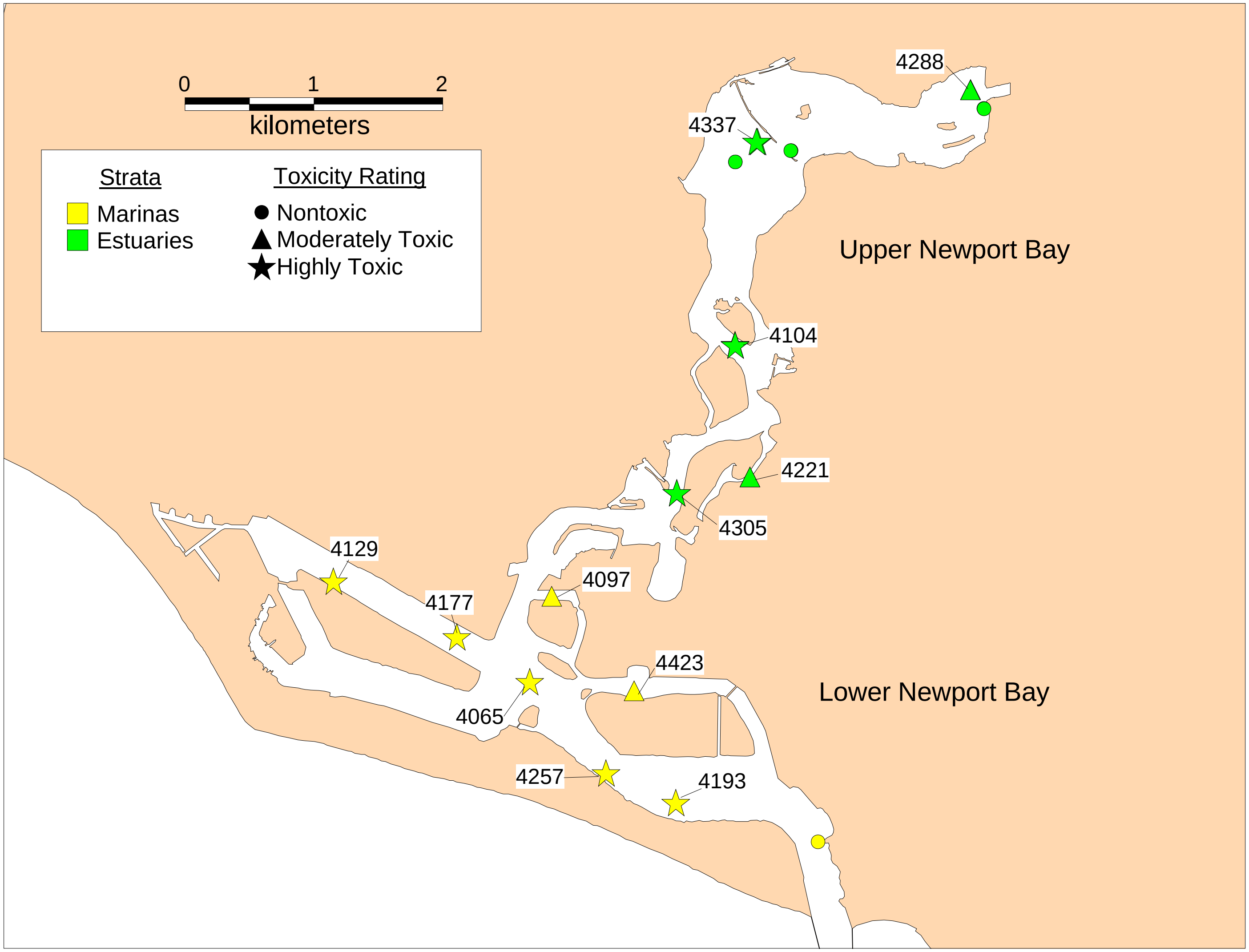

Figure IV-4. Map of sediment toxicity results for Newport Bay.

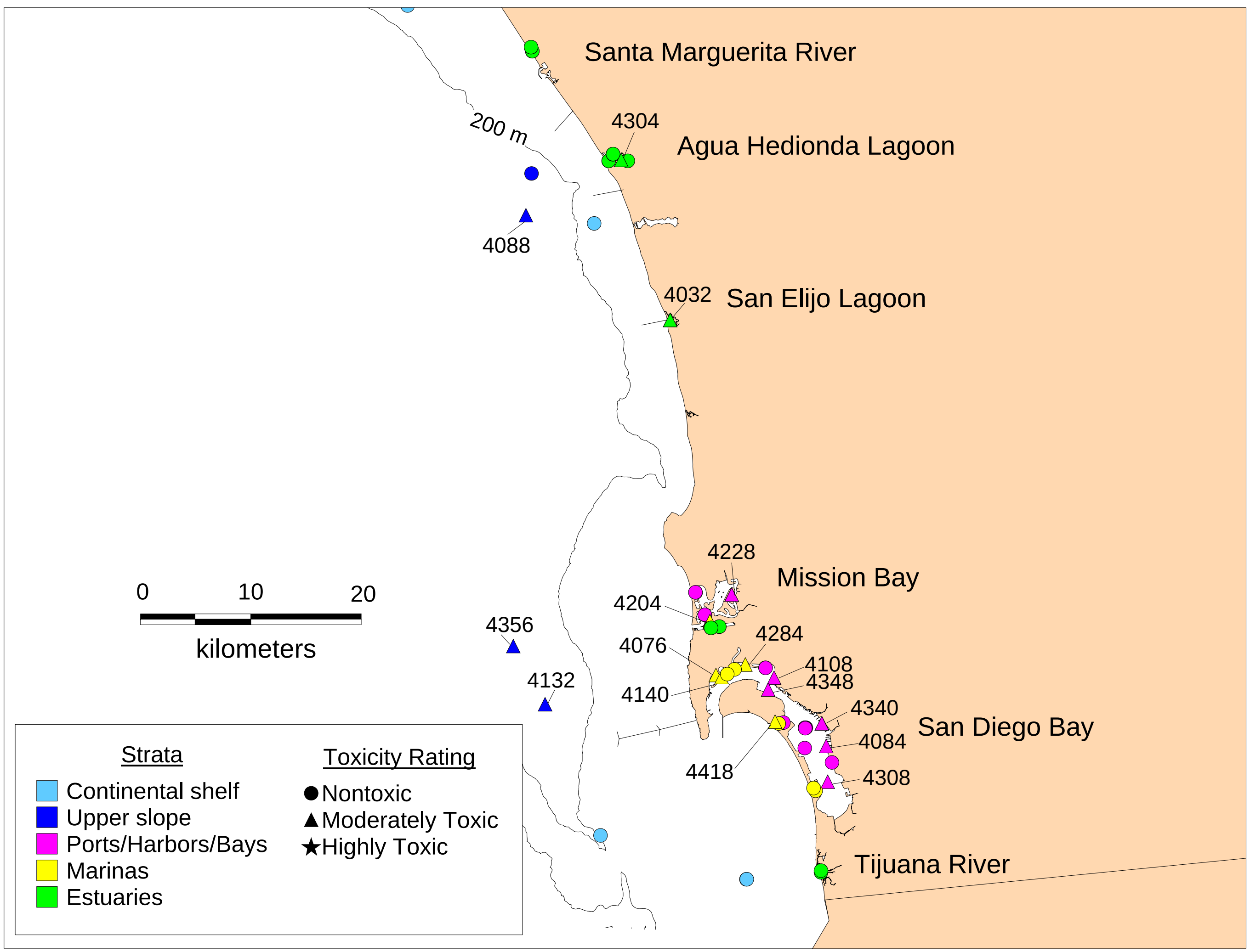

Figure IV-5. Map of sediment toxicity results for San Diego County embayments and offshore areas.

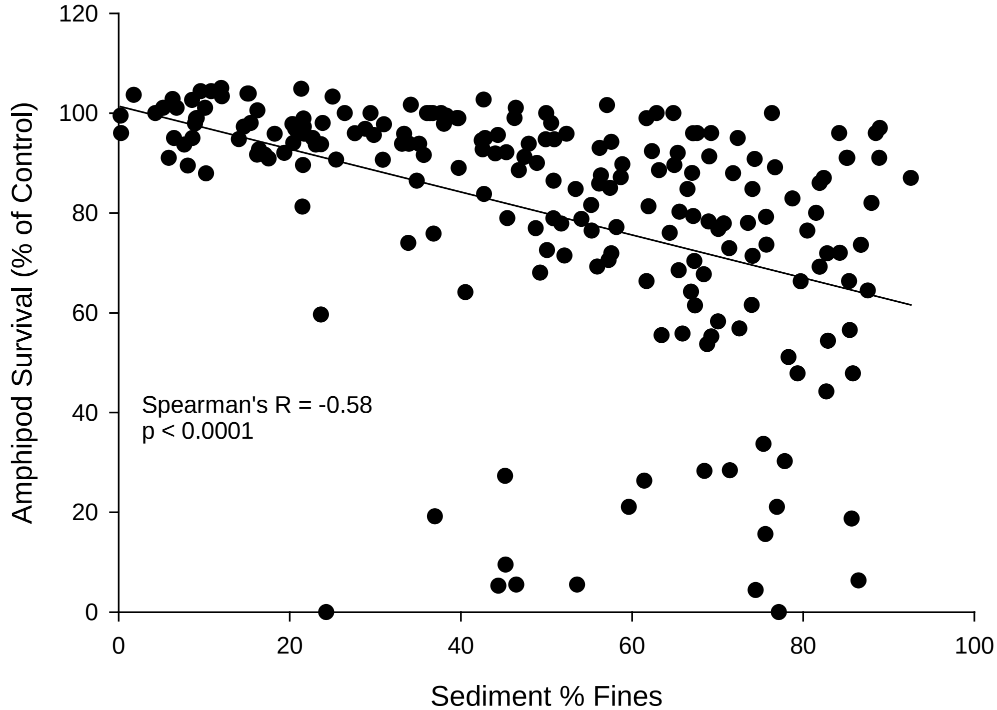

Figure IV-6. Relationship between amphipod survival and sediment fines content.

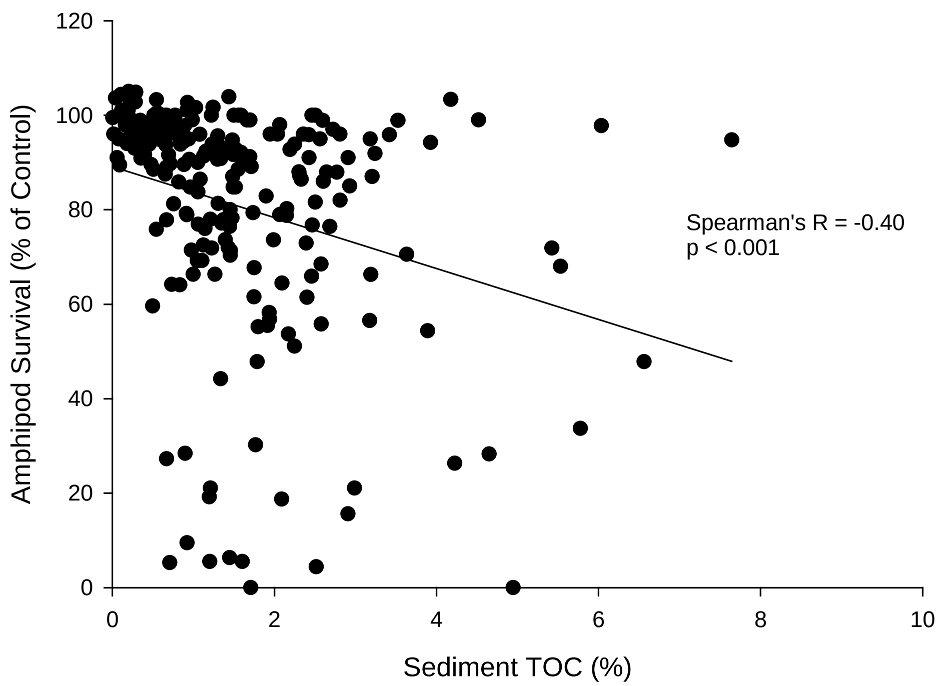

Figure IV-7. Relationship between amphipod survival and sediment total organic carbon.

V. REGIONAL ASSESSMENT OF TOXICITY

Most of the area of the SCB had no detectable sediment toxicity using the amphipod survival test. Out of a total area of 9,575 km^2 sampled for sediment toxicity, 7,807 km^2, or 82.9%, of the SCB had nontoxic sediments (Table V-1). Toxic sediments in the SCB were estimated to be present over 1,768 km^2. Almost all of the toxic area was classified as moderately toxic (17% of SCB), with only 6 km^2 (0.1% of SCB) in the highly toxic category.

The spatial extent of toxic and nontoxic sediments in the SCB reflected the conditions present in the shelf and upper slope strata, which together represented 7,937 km^2 of the SCB; none of the sediments in these two areas were classified as highly toxic. The Channel Islands stratum, the third largest region in the survey, was estimated to contain 37 km^2 of moderately toxic sediments.

Evaluation of the area containing toxicity tends to minimize the impact of conditions in the embayments, because of the relatively small area (1% of the SCB) represented by the Marinas, Ports/Bays/Harbors and Estuaries strata. Toxic sediments in the embayments were estimated to occur over 44.5 km^2, representing just 0.5% of the SCB, but 45% of the embayment area (Table V-1).

The embayment strata had a much higher proportion of area that was toxic compared to the offshore strata (Figure V-1). Marinas had the greatest proportion of toxic sediments, with 50% of the area classified as moderately or highly toxic. The relative extent of highly toxic sediments was also greatest in the Marinas stratum; 16% of the area within Marinas was estimated to be highly toxic. The area included in the Ports/Bays/Harbors and Estuaries strata also contained a relatively high percentage of toxic sediment (44% and 41%, respectively).

Two previous regional surveys of SCB sediment toxicity have been conducted using a similar probabilistic sampling design, the 1994 Southern California Bight Pilot Project (SCBPP) (Bay 1996) and the 1998 Southern California Bight regional survey (Bay *et al.* 2000). Both of these surveys used a 10-day amphipod survival test to measure toxicity and thus provide an opportunity to describe temporal patterns in sediment toxicity. The SCBPP analyzed sediment from several mainland shelf strata (embayments and the Channel Islands were not sampled) and did not detect any toxicity. A different amphipod test species, *Ampelisca abdita*, was used in the SCBPP, however, and the apparent increase in the extent of toxicity of shelf sediments in Bight'98 and Bight'03 may be due to differential sensitivity between the species. Several studies have compared the response of these two species to field sediments and the results indicate that *E. estuarius* may be more sensitive than *A. abdita*.

The same species and a similar study area were used for both Bight'98 and Bight'03, and the results permit a comparison of toxicity spatial extent for several strata. The percent of the SCB shelf stratum classified as toxic in Bight'98 was very similar to the Bight'03 results (Figure V-2). The Bight'03 results for the Ports/Bays/Harbors and Marinas indicate an increase in the relative extent of toxicity in embayments compared to Bight'98.

A comparison of temporal changes in the area toxic in selected embayments can also be made using the Bight'98 data. Each of these previous studies analyzed at least 8 stations in either the Marinas or Ports/Bays/Harbors strata of San Pedro Bay, Newport Bay, or San Diego Bay. The area toxic in Newport Bay Marinas was quite similar between the two studies and ranged from 81% in 1998 to 88% in 2003 (Figure V-3). A smaller spatial extent of toxicity in San Pedro Bay and San Diego Bay was measured in the Bight'98 survey. The difference was most dramatic for San Diego Bay Marinas, where the toxic area increased from 0% in 1998 to 44% in 2003. A large change was also observed in San Diego Bay Ports/Bays/Harbors, where the percent of area toxic increased from 13% to 50% in 2003. Too few stations were sampled in the other embayments for Bight'98 and Bight'03 to enable a similar comparison.

Table V-1. Area of SCB sediment classified by toxicity during the Bight'03 study. All area measurements are in square kilometers.

	Not Toxic		Moderate Toxicity		High Toxicity	
Strata	Area	95% CI	Area	95% CI	Area	95% CI
Shelf (5-200 m)	4527.0	664.0	1053.1	154.4	0.0	0.0
Upper Slope (200-500 m)	2319.6	359.0	632.6	97.9	0.0	0.0
Channel Islands	906.0	36.2	37.8	3.0	0.0	0.0
Marina	7.9	1.4	5.4	0.9	2.5	0.3
Ports/Bays/Harbors	42.3	8.1	31.0	5.9	2.8	0.2
Estuaries	4.1	0.7	1.9	0.3	0.9	0.1
Total	7806.9	703.4	1761.8	158.7	6.2	0.01

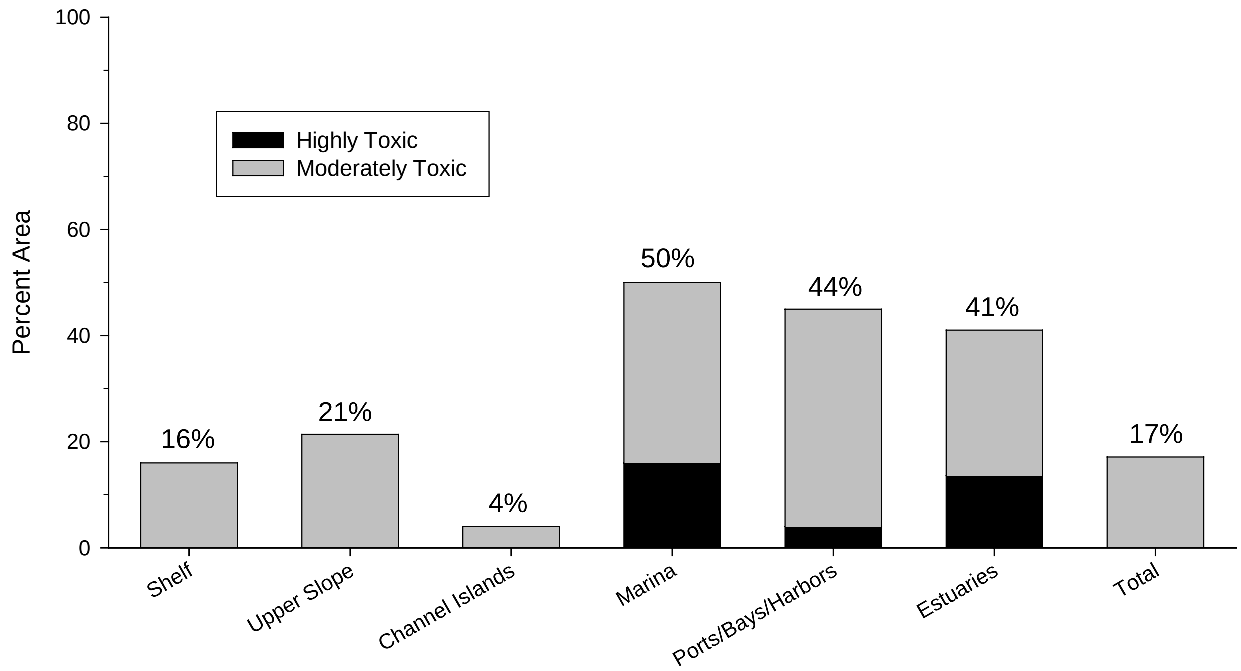

Figure V-1. Percent of area found to be toxic to amphipods. Values above each bar indicate the total percent of area toxic (high + moderate) within each stratum.

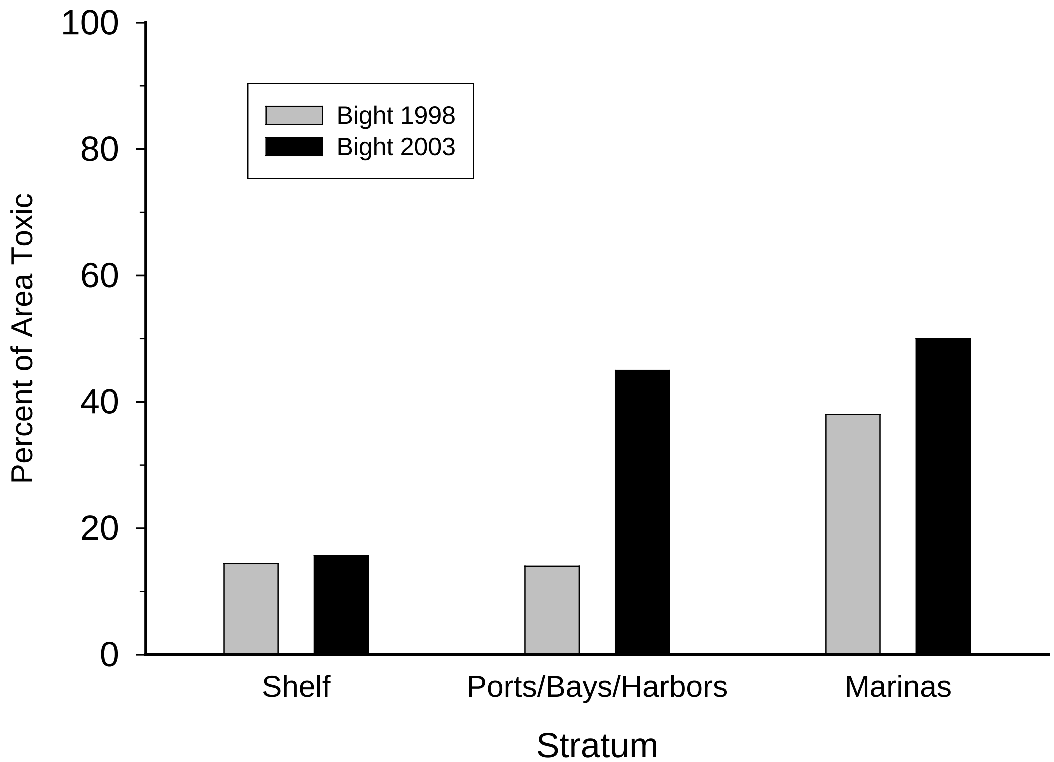

Figure V-2. Comparison of percent area toxic for selected Bight'98 and Bight'03 strata.

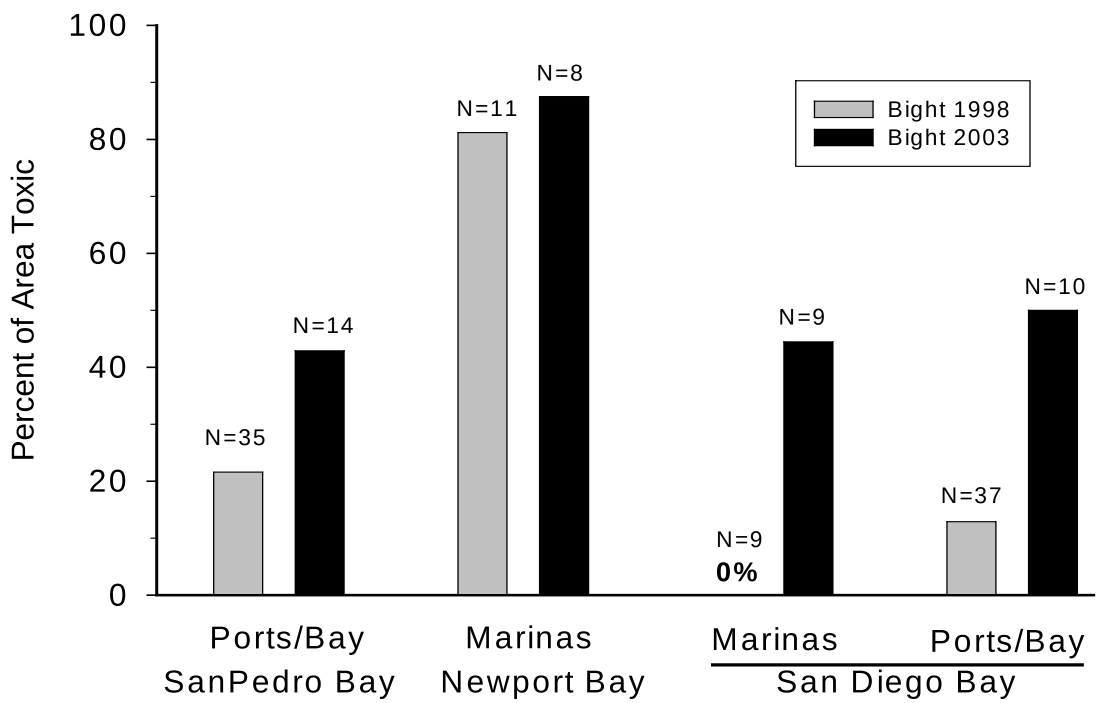

Figure V-3. Comparison of percent area toxic for selected embayments in Bight'98 and Bight'2003.

VI. DISCUSSION

Sediment toxicity was more prevalent in embayments based on the southern California regional monitoring results from the summer of 2003. Acute toxicity of surficial sediments to amphipods was two to three times more likely to occur in marinas, ports/bays/harbors, or estuaries than on the mainland shelf, upper mainland slope, or Channel Islands. In addition, highly toxic samples (>50% mortality) were only observed from embayments. This increased likelihood of sediment toxicity may be due to many factors including proximity to sources. For example, ports and marinas have a large number of potential sources that could contribute to sediment toxicity including antifouling paints on vessel hulls, discharge of petroleum hydrocarbons, shipyard and boatyard activities, among others (SSC SD 2000). Antifouling paints, in particular, are designed to retard the growth of invertebrates including crustaceans by constantly leaching pesticides such as copper (Schiff *et al.* 2004). Estuaries receive wet and dry weather runoff from our highly developed southern California watersheds that include urban and agricultural activities. These wet weather nonpoint source inputs from developed watersheds now exceed the annual mass emission of many pollutants compared to traditional point sources such as POTWs (Schiff *et al*. 2001). Dry weather mass emissions of many potential pollutants can rival wet weather discharges, especially in dry water years.

A second factor that could contribute to the toxicity of embayment areas is the lack of mixing and circulation that can ameliorate and dissipate many of the effects from sources that discharge in offshore areas. Because of our dry climates, many of the embayments in southern California are tidally mixed which limits circulation to small-scale forcing. Water column turnover in some embayments can take two weeks or more (ACTA 2001). This lack of mixing, coupled with large inputs, will lead to an accumulation of potential pollutants in the sediments that can result in toxicity. The higher proportion of fine sediments in these areas may also be related to the greater contamination and toxicity in embayments. Silts and clays tend to have a greater affinity for contaminants due to their high surface area and usually higher organic carbon content.

Others have observed the toxicity in the embayments of the SCB. Anderson *et al* (1988) also conducted a triad assessment of sediment quality in southern California inshore and offshore areas. They found some of the greatest disturbances in estuaries and harbor areas that were most protected and closest to urbanization including the Port of Los Angeles, Los Angeles River Estuary and San Diego Bay. The California Bay Protection and Toxic Cleanup Program (BPTCP) conducted an extensive investigation of bays, harbors and estuaries statewide. They consistently found sediment toxicity, as well as increased sediment chemistry and impacted infaunal communities from inshore areas near urban centers including Los Angeles, Orange, and San Diego Counties (Anderson *et al.* 2001, Fairey *et al*. 1998). A randomized design study conducted in 1994 observed sediment toxicity in 58% of the area of small bays and marinas in southern California (Anderson *et al.* 1997).

The spatial extent of sediment toxicity we observed in estuaries of the SCB exceeded the extent observed in other estuaries around the country. The national EMAP program used similar methods as Bight'03 to assess the spatial extent of sediment toxicity in estuaries and found that

6% of sediments were toxic overall (USEPA 2004). For Bight'03, sediment toxicity was estimated to extend over 41 to 50% of the embayment strata in the SCB. Some of this difference may be attributable to a difference in amphipod test species, as the EMAP studies used *Ampelisca abdita* while *Eohaustorius estuarius* was used in Bight'03. A separate series of investigations of urbanized bays and estuaries by the National Status and Trends program found a range of sediment toxicity spatial extent that includes that observed in the SCB. For example, 50% of Long Island Sound and 38% of the Hudson-Raritan estuary were toxic to amphipods (*Rhepoxynius abronius*), while less than 10% of many other bays on the Atlantic and Gulf Coasts were toxic (Long *et al*. 1996). Some of the differences in the prevalence of sediment toxicity between SCB estuaries and other regions may be due to differences in size, environmental characteristics, and study design.

The utility of sediment TIEs has increased in recent years as the methods have evolved and matured into more reliable and predictable toxicological tools. In the limited sediment TIEs conducted as part of this study, we identified polar organic compounds as the toxicants that were driving reduced survival. Organic compounds, such as pesticides from urban settings, are often abundant in discharges from developed watersheds to the marine environment. However, pesticides are not always the only compounds environmental managers need to be concerned about. For example, Bay *et al*. (2004) identified trace metals as among the constituents of concern in sediment TIEs from Newport Bay. Regardless of the specific constituent(s) of concern, sediment TIEs appear to be a useful tool for narrowing the list of potential toxicants for environmental managers to focus their efforts.

Caution should be exercised in using the toxicity results reported here as the sole basis for describing sediment quality in the SCB. Toxicity tests, like other indicators of sediment quality such as chemistry and benthic community assessment, have limitations that result in a likelihood that some errors in classification will occur. While the amphipod toxicity test is a robust method that measures an ecologically relevant response, the method may not detect some impacts because it does not include some types of toxic effects or modes of exposure. In addition, there may be undetected changes in sediment characteristics caused by sediment handling procedures that could lead to over or underestimation of the toxicity. Environmental scientists recommend the use of multiple lines of evidence when assessing sediment quality in order to utilize the strengths and minimize the weaknesses of individual methods (Chapman *et al.* 1997). Each of the stations tested for sediment toxicity was also analyzed for sediment chemistry and benthic macrofauna community composition, and the results for these parameters will be reported in future Bight'03 documents. The results from all of these lines of evidence should be used to make an assessment of sediment quality for the SCB.

VII. CONCLUSIONS

The Bight'03 sediment toxicity study is the most spatially extensive regional assessment of sediment toxicity conducted to date in the SCB. Analysis of the results by the Toxicology Committee, representing the participating laboratories and other partners, has produced the following conclusions:

- **Sediment toxicity was not widespread in most of the SCB.**
  There was no detectable toxicity in 83% of the SCB. When toxicity was detected, it most often consisted of a moderate response (50-82% amphipod survival). Less than 1% of the SCB was considered to be highly toxic (<50% amphipod survival).

- **Marina and estuary strata contained the greatest relative amount of sediment toxicity.**
  Toxicity was present in marinas and estuaries at 50% and 41% of the area, respectively. In addition, these strata contained the greatest relative extent of highly toxic sediments (16% and 13%, respectively). These findings are consistent with the results of previous studies in southern California and elsewhere, which indicate that embayments should be high priority areas for additional investigation of sources and causes of toxicity.

- **Sediment toxicity in the Slope and Channel Islands was relatively low and similar to other SCB strata.**
  This study is the first regional toxicity assessment to include slope and Channel Islands strata. The Channel Islands stratum had the lowest spatial extent of toxicity of any strata investigated (4%). The extent of toxicity in slope sediments (21%) was similar to that of the SCB as a whole.

- **The extent of sediment toxicity in the SCB has changed little over the past five years.**
  Temporal comparisons based on periodic regional surveys such as Bight'98 and Bight'03 indicated that the prevalence of sediment toxicity has remained largely stable between 1998 and 2003. We observed some increases in sediment toxicity from San Diego Bay. Method differences and a short time frame limit the confidence in these temporal comparisons, but the confidence will improve as additional surveys are conducted.

- **Limited sediment toxicity identifications indicate that organic contaminants are important contributors to sediment toxicity in some estuaries.**
  Preliminary TIE results suggest that nonpolar organics, possibly pesticides currently used in the watershed, are responsible for a majority of the toxicity to amphipods observed in the Ballona Creek and Dominguez estuaries. Additional studies are needed to verify and provide greater specificity in the results so that the information can be used to improve the management of these waterbodies.

VIII. RECOMMENDATIONS

The Bight'03 Toxicology Committee recommends the following actions in response to the results of this study:

- **Use the sediment toxicity data in combination with other sediment measurements in order to assess sediment quality in the SCB.**
  Each of the measurement types employed in Bight'03 has important strengths and limitations. Although toxicity tests integrate the effects of chemical mixtures and have an ecologically relevant endpoint, the tests may produce false negative or false positive results when attempting to classify categories of toxicity. The final assessment of sediment quality in the Bight'03 survey should be based on an integrated assessment of the sediment chemistry, toxicity, and benthic community data.

- **Sediment TIE studies should be utilized to a greater extent in future surveys.**
  Sediment TIE methods were shown to be useful in their limited application in Bight'03. The collaborative and comprehensive framework of the Bight regional survey program provides an excellent opportunity to apply and refine TIE methods, in addition to providing information that is critical to identifying management actions to improve sediment quality in bay and estuary areas.

- **Incorporate multiple toxicity test methods in future studies.**
  No single toxicity test is able to measure all of the important toxicant exposure routes and modes of action associated with sediments. This limitation can be minimized through the use of a suite of test methods that incorporates a range of organism types, exposure durations, and measures both lethal and sublethal responses. Information on the performance and comparability of some of these alternate test methods is lacking for California; their incorporation into future surveys would provide a platform to learn more about their performance and correspondence with ecological impacts.

- **Refine the survey logistics to increase toxicity test performance.**
  Toxicity tests differ from most other sediment assessment tools in that the samples cannot be stored for extended periods of time. This constraint presents a challenge in a cooperative regional monitoring program where multiple agencies are collecting samples simultaneously. The result is an increased possibility of pulses in sample collection that can exceed laboratory capacity. Additional coordination between laboratory and field teams can prevent such occurrences and thus reduce the chance for test criteria deviations. If a deviation should occur, the increased planning should include contingency measures to ensure a complete and high quality data set.

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APPENDIX A. Participants in the Bight'03 Regional Monitoring Program. Participants in the Toxicology Committee are indicated by an asterisk.

AMEC Incorporated*
Aquatic Bioassay and Consulting Laboratories (ABCL)*
Channel Islands National Marine Sanctuary (CINMS)
Chevron USA Products Company
City of Long Beach
City of Los Angeles Environmental Monitoring Division (CLAEMD)*
City of Oceanside
City of Oxnard
City of San Diego*
City of Santa Barbara
City of Ventura
CRG Marine Laboratories
Encina Wastewater Authority
Granite Canyon Marine Pollution Studies Lab
Jet Propulsion Laboratory
Los Angeles Department of Water and Power (LADWP)
Los Angeles County Dept. of Beaches & Harbors
Los Angeles County Dept. of Health Services
Los Angeles County Dept. of Public Works
Los Angeles Regional Water Quality Control Board
Los Angeles County Sanitation Districts (LACSD)*
Loyola Marymount University
MBC Applied Environmental Sciences
Minerals Management Service
NES Energy, Inc.
NRG Energy, Inc.
Orange County CoastKeeper
Orange County Environmental Health Division
Orange County Public Facilities and Resources (OCPFRD)
Orange County Sanitation District (OCSD)*
Port of Long Beach
Port of Los Angeles
Port of San Diego
Reliant Corporation
San Diego Baykeeper
San Diego County Dept. of Environmental Health
San Diego Regional Water Quality Control Board (SDRWQCB)
San Elijo Joint Powers Authority
Santa Ana Regional Water Quality Control Board
Santa Barbara Health Care Services
Santa Monica Baykeeper
South Orange County Water Authority (SOCWA)
Southern California Coastal Water Research Project (SCCWRP)*
Southern California Marine Institute (SCMI)
State Water Resources Control Board (SWRCB)*
Surfrider Foundation
University of California, Los Angeles
University of California, Irvine
University of California, Riverside
University of California, San Diego
University of California, Santa Barbara
US EPA Region IX
US EPA Office of Research and Development
US Geological Survey
Vantuna Research Group
Ventura County Environmental Health Division
Ventura County Watershed Protection Division
Weston Solutions*

APPENDIX B. Test Results by Station. A summary of the toxicity test results and general characteristics of the samples is included below. The complete sediment toxicity database is available at www.sccwrp.org.

Station	Longitude (west)	Latitude (north)	Strata	Depth (m)	Location	Amphipod (%Control)	Fines (%)	TOC (%)	QA Code
4000	117.1993	32.5508	Mid-shelf (30-120 m)	34	South San Diego Shelf	104	9.6	0.11	COQX
4002	118.1025	33.7550	LA Estuaries	3	San Gabriel River Estuary	101	10.1	0.20	E
4006	118.4481	33.8604	Mid-shelf (30-120 m)	60	Santa Monica Bay	97	20.6	0.55	E
4007	120.0103	34.3627	Upper slope (200-500 m)	430	West Santa Barbara Channel	97	89.0	2.72	A
4008	117.4124	33.2288	Estuaries	1	Santa Margarita River Estuary	99	38.3	0.67	A
4010	118.2491	33.7668	Marinas-Rep 2	4	Los Angeles Harbor	80	65.5	2.58	EJ
4015	119.7417	34.3338	Mid-shelf (30-120 m)	87	East Santa Barbara Channel	100	36.7	0.51	A
4017	117.8889	33.6459	Estuaries	1	Upper Newport Bay	84	42.7	1.06	COQX
4018	118.1299	33.7554	Marinas	6	Alamitos Bay	83	78.7	1.90	CJOX
4019	119.5122	34.2310	Mid-shelf (30-120 m)	83	East Santa Barbara Channel	93	56.2	1.37	A
4020	117.2416	32.7675	Ports/Bays/Harbors	8	Mission Bay	103	8.6	0.23	A
4021	118.4828	33.9287	Mid-shelf (30-120 m)	35	Santa Monica Bay	90	21.6	0.48	E
4023	119.7127	34.3078	Outer shelf (120-200 m)	138	East Santa Barbara Channel	90	48.9	1.05	A
4026	118.1951	33.6211	Mid-shelf (30-120 m)	43	San Pedro Shelf	99	9.1	0.23	A
4027	119.9362	34.1156	Channel Islands (5-200 m)	101	Island Shelves	96	29.8	0.81	Q
4028	117.1439	32.6754	Ports/Bays/Harbors	7	San Diego Bay	105	21.3	0.29	A
4029	119.3516	34.0342	Channel Islands (5-200 m)	75	Island Shelves	95	11.8	7.65	E
4032	117.2765	33.0092	Estuaries	1	San Elijo Lagoon	76	80.5	2.69	A
4033	117.2274	32.7579	Estuaries	1	San Diego River Estuary	92	45.3	1.59	A
4034	118.1145	33.7472	LA Estuaries	5	San Gabriel River Estuary	104	15.1	0.21	EQ
4035	119.5071	34.2836	Mid-shelf (30-120 m)	71	East Santa Barbara Channel	72	84.3	1.43	A
4039	120.4556	34.2871	Upper slope (200-500 m)	420	West Santa Barbara Channel	100	76.3	2.51	A
4043	119.3549	34.2840	Inner shelf (5-30 m)	18	East Santa Barbara Channel	94	20.4	0.18	A
4048	117.3510	33.0881	Mid-shelf (30-120 m)	72	North San Diego Shelf	96	33.4	0.68	A
4049	117.3378	33.1392	Estuaries	3	Agua Hedionda Lagoon	91	30.9	0.95	E
4050	118.2622	33.7242	Ports/Bays/Harbors	26	Los Angeles Harbor	85	66.5	1.49	A
4051	119.7485	34.0754	Channel Islands (5-200 m)	92	Island Shelves	89	46.8	1.55	E
4052	117.1342	32.6232	Marinas	3	San Diego Bay	102	57.1	1.03	A
4053	118.4396	33.9713	LA Estuaries	2	Ballona Creek Estuary	0	24.3	4.95	J
4058	118.0784	33.6430	Inner shelf (5-30 m)	28	San Pedro Shelf	98	8.9	0.16	A
4059	119.9878	34.3870	Outer shelf (120-200 m)	144	West Santa Barbara Channel	95	42.8	0.94	A
4061	119.1508	34.1011	Inner shelf (5-30 m)	14	Hueneme to Dume	100	4.3	0.08	A
4065	117.9048	33.6094	Marinas	7	Newport Bay	9	45.2	0.92	J
4066	118.1171	33.7420	LA Estuaries	2	San Gabriel River Estuary	96	0.3	0.02	E
4067	119.6874	34.2302	Outer shelf (120-200 m)	134	East Santa Barbara Channel	89	39.8	0.67	A
4068	117.3411	32.5857	Outer shelf (120-200 m)	182	South San Diego Shelf	96	44.3	1.30	Q
4069	118.9169	34.0366	Inner shelf (5-30 m)	16	Hueneme to Dume	101	6.8	0.12	A
4071	120.3686	34.3442	Upper slope (200-500 m)	300	West Santa Barbara Channel	96	67.6	2.04	A
4072	117.9541	33.6366	Estuaries	1	Santa Ana River Estuary	95	6.5	0.08	E
4075	117.8834	33.6466	Estuaries	1	Upper Newport Bay	95	42.4	0.89	Q
4076	117.2305	32.7181	Marinas	4	San Diego Bay	81	61.9	1.30	Q
4079	119.5958	34.3836	Mid-shelf (30-120 m)	36	East Santa Barbara Channel	78	73.5	1.21	A

Station	Longitude (west)	Latitude (north)	Strata	Depth (m)	Location	Amphipod (%Control)	Fines (%)	TOC (%)	QA Code
4080	117.5339	33.2655	Mid-shelf (30-120 m)	63	North San Diego Shelf	92	35.7	0.69	A
4083	119.6289	34.1182	Upper slope (200-500 m)	249	East Santa Barbara Channel	88	67.0	2.30	A
4084	117.1229	32.6603	Ports/Bays/Harbors	8	San Diego Bay	66	61.7	1.00	A
4085	118.4535	33.9643	Marinas	6	Marina del Rey	85	57.4	2.93	A
4086	118.4698	33.8355	Mid-shelf (30-120 m)	93	Santa Monica Bay	81	21.5	0.75	E
4087	117.3187	33.1394	Estuaries	1	Agua Hedionda Lagoon	88	56.4	0.65	E
4088	117.4172	33.0938	Upper slope (200-500 m)	410	North San Diego Shelf	73	71.4	2.39	A
4089	118.5679	33.8480	Mid-shelf (30-120 m)	80	Santa Monica Bay	96	18.2	0.84	E
4090	118.1307	33.6596	Inner shelf (5-30 m)	29	San Pedro Shelf	98	15.4	0.33	A
4091	120.1782	34.1438	Upper slope (200-500 m)	438	West Santa Barbara Channel	91	85.1	2.91	A
4092	117.1828	32.7243	Ports/Bays/Harbors	3	San Diego Bay	97	14.6	0.39	A
4093	119.1344	34.0666	Outer shelf (120-200 m)	187	Hueneme to Dume	76	64.4	1.14	A
4096	117.5649	33.2699	Mid-shelf (30-120 m)	79	North San Diego Shelf	94	23.0	0.40	A
4097	117.9028	33.6152	Marinas	2	Newport Bay	66	85.4	1.26	A
4098	118.1687	33.7442	Ports/Bays/Harbors	11	Long Beach Harbor	78	68.9	1.48	J
4099	119.5586	34.3064	Mid-shelf (30-120 m)	72	East Santa Barbara Channel	87	82.4	1.49	A
4103	119.7068	34.2328	Outer shelf (120-200 m)	153	East Santa Barbara Channel	100	26.4	0.67	A
4104	117.8877	33.6333	Estuaries	1	Upper Newport Bay	5	46.5	1.60	JQ
4108	117.1740	32.7160	Ports/Bays/Harbors	10	San Diego Bay	62	74.0	1.75	JQ
4115	119.7012	34.0790	Channel Islands (5-200 m)	92	Island Shelves	86	34.8	2.33	E
4116	117.1443	32.6583	Ports/Bays/Harbors	4	San Diego Bay	78	51.7	0.67	A
4117	118.4439	33.9823	Marinas	5	Marina del Rey	91	85.2	1.60	A
4118	118.1026	33.7656	LA Estuaries	4	Los Alamitos Estuary	79	45.4	2.07	A
4125	119.1972	34.0411	Upper slope (200-500 m)	401	Hueneme to Dume	99	46.3	0.99	A
4129	117.9218	33.6157	Marinas	4	Newport Bay	28	71.4	0.90	J
4131	119.2249	34.1624	Marinas	6	Oxnard	92	65.3	1.29	A
4132	117.3958	32.6939	Upper slope (200-500 m)	372	South San Diego Shelf	80	65.5	2.15	A
4135	120.2824	34.3145	Upper slope (200-500 m)	400	West Santa Barbara Channel	86	81.9	2.60	A
4138	118.2794	33.7225	Marinas	12	Los Angeles Harbor	54	82.9	3.89	A
4140	117.2243	32.7168	Marinas	4	San Diego Bay	74	75.7	1.39	Q
4142	118.2059	33.7807	LA Estuaries	2	Los Angeles River Estuary	93	2.0	0.27	E
4146	118.2158	33.7456	Ports/Bays/Harbors	21	Los Angeles Harbor	99	21.6	0.34	A
4148	117.1178	32.6468	Ports/Bays/Harbors	6	San Diego Bay	97	21.7	0.61	A
4149	118.4553	33.9634	Marinas	6	Marina del Rey	68	49.3	5.53	A
4155	120.1424	34.1016	Channel Islands (5-200 m)	101	Island Shelves	79	54.1	2.15	JQ
4156	117.2126	32.7229	Marinas	8	San Diego Bay	103	42.7	0.93	J
4159	120.3374	33.9946	Channel Islands (5-200 m)	71	Island Shelves	94	35.1	1.23	EQ
4161	118.0492	33.7033	Estuaries	2	Bolsa Chica Estuary	69	55.9	1.11	Q
4162	118.1919	33.7312	Ports/Bays/Harbors	15	Long Beach Harbor	98	38.0	0.74	A
4163	119.5101	34.0788	Channel Islands (5-200 m)	134	Island Shelves	96	21.7	2.42	E
4168	117.8669	33.6498	Estuaries	1	Upper Newport Bay	71	52.1	0.98	Q
4169	118.0225	33.4185	Upper slope (200-500 m)	334	Orange Shelf	94	23.7	0.66	A
4177	117.9107	33.6130	Marinas	4	Newport Bay	6	86.5	1.45	J

Station	Longitude (west)	Latitude (north)	Strata	Depth (m)	Location	Amphipod (%Control)	Fines (%)	TOC (%)	QA Code
4178	118.2579	33.7121	Ports/Bays/Harbors	23	Los Angeles Harbor	79	67.1	1.74	A
4179	119.7701	34.1456	Upper slope (200-500 m)	355	East Santa Barbara Channel	100	62.9	2.46	A
4193	117.8924	33.6008	Marinas	4	Newport Bay	21	59.6	1.21	J
4194	118.1055	33.7536	LA Estuaries	4	San Gabriel River Estuary	101	5.2	0.11	A
4197	118.6822	34.0328	LA Estuaries	2	Malibu Lagoon	93	42.5	1.53	EJQ
4199	120.3513	34.1832	Upper slope (200-500 m)	462	West Santa Barbara Channel	96	88.5	2.81	A
4201	117.8485	33.5369	Upper slope (200-500 m)	350	Orange Shelf	55	69.3	1.80	A
4202	118.3465	33.6941	Upper slope (200-500 m)	279	Palos Verdes Shelf	98	50.6	2.06	A
4204	117.2362	32.7623	Marinas	7	Mission Bay	76	55.3	1.45	A
4206	118.2289	33.8082	LA Estuaries	4	Dominguez Channel	34	75.4	5.78	A
4209	117.4134	33.2318	Estuaries	1	Santa Margarita River Estuary	104	1.8	0.04	A
4210	118.2177	33.7527	Ports/Bays/Harbors	24	Los Angeles Harbor	85	53.4	0.96	A
4211	119.8276	34.1584	Upper slope (200-500 m)	398	East Santa Barbara Channel	96	84.2	2.36	A
4212	117.1351	32.6259	Marinas	3	San Diego Bay	90	58.9	0.71	A
4213	118.4351	33.9739	LA Estuaries	1	Ballona Creek Estuary	60	23.7	0.50	J
4221	117.8860	33.6236	Estuaries	1	Upper Newport Bay	58	70.0	1.93	Q
4228	117.2155	32.7844	Ports/Bays/Harbors	3	Mission Bay	55	63.4	1.91	A
4236	117.1693	32.6789	Marinas	7	San Diego Bay	96	67.1	1.08	ACOX
4237	119.4018	34.1272	Upper slope (200-500 m)	223	East Santa Barbara Channel	98	23.9	0.46	A
4239	120.4422	34.3397	Upper slope (200-500 m)	327	West Santa Barbara Channel	96	69.2	1.95	A
4240	117.4120	33.1284	Upper slope (200-500 m)	310	North San Diego Shelf	89	63.2	0.51	ACOX
4242	118.2242	33.7242	Ports/Bays/Harbors	16	Los Angeles Harbor	86	56.2	0.82	A
4246	118.0625	33.7174	Marinas	4	Huntington Harbor	56	65.9	2.58	A
4254	118.1786	33.5135	Upper slope (200-500 m)	452	San Pedro Shelf	100	50.0	1.56	A
4255	120.5580	34.0519	Channel Islands (5-200 m)	207	Island Shelves	95	22.7	3.18	EQ
4257	117.8984	33.6029	Marinas	4	Newport Bay	5	44.4	0.71	J
4258	118.0988	33.7593	LA Estuaries	2	San Gabriel River Estuary	97	28.8	0.23	E
4261	119.0583	34.0166	Upper slope (200-500 m)	321	Hueneme to Dume	101	46.4	0.92	A
4262	118.3958	33.8431	Marinas	10	Redondo Harbor	100	36.4	1.50	A
4263	120.2999	34.2083	Upper slope (200-500 m)	460	West Santa Barbara Channel	87	92.6	3.21	A
4264	117.2354	32.7568	Estuaries	1	San Diego River Estuary	94	57.6	3.93	A
4266	118.2773	33.7662	Ports/Bays/Harbors	14	Los Angeles Harbor	91	69.0	1.13	A
4268	117.2200	32.7187	Marinas	2	San Diego Bay	104	10.8	0.21	JQ
4270	118.2414	33.8203	LA Estuaries	4	Dominguez Channel	21	76.9	2.99	A
4272	117.3330	33.1450	Estuaries	3	Agua Hedionda Lagoon	105	12.0	0.20	EQ
4273	117.9524	33.6422	Estuaries	1	Santa Ana River Estuary	91	5.9	0.06	E
4274	118.1572	33.7286	Ports/Bays/Harbors	15	Long Beach Harbor	89	76.7	1.72	J
4276	117.2507	32.7861	Ports/Bays/Harbors	3	Mission Bay	88	71.8	2.64	A
4279	119.7183	34.2778	Upper slope (200-500 m)	192	East Santa Barbara Channel	100	64.8	1.59	A
4284	117.2021	32.7269	Marinas	3	San Diego Bay	70	67.3	1.45	Q
4288	117.8685	33.6510	Estuaries	1	Upper Newport Bay	73	50.1	1.12	Q
4295	119.8842	34.3138	Upper slope (200-500 m)	385	East Santa Barbara Channel	82	88.0	2.81	A
4297	117.8961	33.5270	Upper slope (200-500 m)	450	Orange Shelf	68	68.4	1.75	J

Station	Longitude (west)	Latitude (north)	Strata	Depth (m)	Location	Amphipod (%Control)	Fines (%)	TOC (%)	QA Code
4304	117.3250	33.1402	Estuaries	2	Agua Hedionda Lagoon	72	82.8	1.23	E
4305	117.8927	33.6227	Estuaries	5	Upper Newport Bay	5	53.6	1.20	Q
4306	118.2334	33.7383	Ports/Bays/Harbors	15	Los Angeles Harbor	51	78.3	2.25	J
4308	117.1224	32.6308	Ports/Bays/Harbors	3	San Diego Bay	79	50.8	0.92	J
4318	117.7038	33.4632	Marinas	3	Dana Point	100	36.1	0.77	A
4321	117.8799	33.5982	Marinas	7	Newport Bay	89	8.1	0.09	J
4322	118.1107	33.7503	LA Estuaries	3	San Gabriel River Estuary	92	16.2	0.40	A
4327	120.3065	34.2688	Upper slope (200-500 m)	420	West Santa Barbara Channel	91	88.9	2.43	A
4329	118.0225	33.5563	Upper slope (200-500 m)	234	San Pedro Shelf	86	50.8	1.08	A
4337	117.8863	33.6473	Estuaries	2	Upper Newport Bay	4	74.4	2.52	Q
4338	118.2078	33.7625	Ports/Bays/Harbors	15	Long Beach Harbor	48	85.8	1.79	J
4340	117.1277	32.6789	Ports/Bays/Harbors	10	San Diego Bay	54	68.8	2.17	A
4341	118.4490	33.9725	Marinas	5	Marina del Rey	95	72.4	2.56	A
4347	120.0260	34.1130	Channel Islands (5-200 m)	110	Island Shelves	91	25.4	1.30	COQX
4348	117.1797	32.7065	Ports/Bays/Harbors	12	San Diego Bay	76	36.8	0.54	Q
4351	120.3290	34.0711	Channel Islands (5-200 m)	51	Island Shelves	102	5.0		EQ
4354	118.1987	33.7487	Ports/Bays/Harbors	18	Long Beach Harbor	85	74.1	1.52	A
4356	117.4270	32.7415	Upper slope (200-500 m)	461	South San Diego Shelf	61	67.4	2.40	A
4364	117.1651	32.6793	Ports/Bays/Harbors	5	San Diego Bay	91	74.3	1.34	A
4370	118.2042	33.7317	Ports/Bays/Harbors-Rep 2	21	Long Beach Harbor	60	62.3	1.15	A
4371	119.5293	34.0534	Channel Islands (5-200 m)	78	Island Shelves	95	14.1	0.45	E
4378	118.2272	33.5465	Upper slope (200-500 m)	271	San Pedro Shelf	100	29.5	0.62	A
4386	118.1133	33.7554	Marinas	4	Alamitos Bay	95	49.9	1.48	A
4400	118.2117	33.7222	Ports/Bays/Harbors	15	Los Angeles Harbor	77	58.2	1.35	A
4404	118.0654	33.7219	Marinas	4	Huntington Harbor	95	50.9	1.29	A
4418	117.1733	32.6800	Marinas	5	San Diego Bay	71	74.1	1.46	A
4421	120.3801	33.9880	Channel Islands (5-200 m)	95	Island Shelves	94	33.1	0.84	EQ
4423	117.8960	33.6085	Marinas	3	Newport Bay	80	81.5	1.45	J
4424	118.1121	33.7512	Marinas	3	Alamitos Bay	100	37.7	1.22	A
4436	118.2287	33.8089	LA Estuaries	4	Dominguez Channel	26	61.4	4.22	A
4440	118.2063	33.7655	LA Estuaries-Rep 2	4	Los Angeles River Estuary	74	33.9	2.46	A
4446	119.0693	33.4506	Channel Islands (5-200 m)	100	Island Shelves	88	10.2	2.77	Q
4453	120.2371	33.9498	Channel Islands (5-200 m)	52	Island Shelves	95	8.6	0.28	EQ
4456	118.1136	33.7662	LA Estuaries	4	Los Alamitos Estuary	87	58.7	2.31	EQ
4481	120.1239	34.0964	Channel Islands (5-200 m)	99	Island Shelves	91	47.4	1.70	Q
4494	117.9643	33.6379	Estuaries	1	Talbert Marsh	92	19.4	0.35	E
4520	118.1013	33.7561	LA Estuaries	2	San Gabriel River Estuary	94	7.7	0.27	E
4529	119.4386	34.0468	Channel Islands (5-200 m)	84	Island Shelves	101	16.2	0.55	Q
4545	119.9578	34.1342	Channel Islands (5-200 m)	170	Island Shelves	102	34.1	1.24	JQ
4561	120.0756	33.8268	Channel Islands (5-200 m)	119	Island Shelves	98	20.3	6.04	Q
4574	119.1056	33.4574	Channel Islands (5-200 m)	168	Island Shelves	99	9.0	2.60	Q
4581	120.6096	34.1665	Channel Islands (5-200 m)	169	Island Shelves	104	15.2	1.44	EJQ
4600	118.2063	33.7738	LA Estuaries	3	Los Angeles River Estuary	79	75.7	0.91	A

Station	Longitude (west)	Latitude (north)	Strata	Depth (m)	Location	Amphipod (%Control)	Fines (%)	TOC (%)	QA Code
4613	120.2049	34.1074	Channel Islands (5-200 m)	100	Island helves	94	47.9	2.25	Q
4633	119.6560	34.0804	Channel Islands (5-200 m)	85	Island Shelves	98	31.0	0.89	COQX
4636	118.1042	33.7754	LA Estuaries	2	Los Alamitos Estuary	72	57.6	5.43	A
4657	119.4736	34.0570	Channel Islands (5-200 m)	83	Island Shelves	103	12.1	4.18	COQX
4683	118.6848	34.0328	LA Estuaries	1	Malibu Lagoon	99	39.6	4.52	J
4695	117.1281	32.5566	Estuaries	1	Tijuana River Estuary	99	0.3	0.00	A
4697	119.8807	33.9755	Channel Islands (5-200 m)	63	Island Shelves	94	33.9	0.46	Q
4788	118.2061	33.7800	LA Estuaries	3	Los Angeles River Estuary	99	39.7	1.70	A
4852	118.2284	33.8032	LA Estuaries	4	Dominguez Channel	92	17.1	1.49	A
4856	118.2063	33.7699	LA Estuaries	4	Los Angeles River Estuary	90	64.9	0.88	A
4913	119.5851	33.9625	Channel Islands (5-200 m)	100	Island Shelves	93	16.4	2.19	Q
4939	118.6814	34.0325	LA Estuaries	1	Malibu Lagoon	103	6.3	0.28	EJQ
5012	118.2364	33.8164	LA Estuaries	3	Dominguez Channel	96	52.3	3.42	A
5014	118.0843	33.7403	Estuaries	1	Anaheim Bay Estuary	64	40.5	0.83	CJQX
5108	118.2282	33.8026	LA Estuaries	4	Dominguez Channel	99	61.7	1.66	A
5735	118.4478	33.9673	LA Estuaries	3	Ballona Creek Estuary	27	45.2	0.67	A
5739	118.6819	34.0345	LA Estuaries	1	Malibu Lagoon	96	27.6	0.38	J
5767	118.4502	33.9657	LA Estuaries	4	Ballona Creek Estuary	19	37.0	1.20	A
5771	118.6846	34.0328	LA Estuaries	1	Malibu Lagoon	92	44.0	3.24	J
5787	118.4554	33.9635	LA Estuaries	2	Ballona Creek Estuary	91	17.5	0.35	A
BRI-01	118.4558	33.9829	Special-BRI	5	Marina del Rey	64	87.6	2.09	A
BRI-02	118.4551	33.9756	Special-BRI	4	Marina del Rey	74	86.7	1.99	ACOX
BRI-03	118.2663	33.7372	Special-BRI	8	Los Angeles Harbor	66	79.7	3.19	A
BRI-04	118.2500	33.7706	Special-BRI	12	Dominguez Channel	28	68.5	4.65	A
BRI-05	118.2430	33.7759	Special-BRI	6	Dominguez Channel	48	79.4	6.56	A
BRI-06	118.1898	33.7593	Special-BRI	8	Long Beach Harbor	57	85.5	3.18	ACOX
BRI-07	117.9362	33.6209	Special-BRI	2	Newport Bay	103	25.0	0.54	Q
BRI-08	117.9278	33.6120	Special-BRI	4	Newport Bay	30	77.9	1.77	A
BRI-09	117.9274	33.6110	Special-BRI	4	Newport Bay	19	85.7	2.09	A
BRI-10	117.9270	33.6144	Special-BRI	4	Newport Bay	16	75.6	2.91	A
BRI-11	117.8708	33.6499	Special-BRI	4	Upper Newport Bay	0	77.2	1.71	Q
BRI-12	117.6984	33.4607	Special-BRI	4	Dana Point	64	66.9	0.73	A
BRI-13	117.6981	33.4588	Special-BRI	5	Dana Point	44	82.7	1.34	J
BRI-14	117.6912	33.4608	Special-BRI	5	Dana Point	78	70.7	1.37	A
BRI-15	117.1945	32.7265	Special-BRI	3	San Diego Bay	77	48.7	1.06	Q
BRI-16	117.1687	32.7075	Special-BRI	5	San Diego Bay	69	81.9	1.05	A
BRI-17	117.1476	32.6932	Special-BRI	7	San Diego Bay	77	70.1	2.47	A
BRI-18	117.1458	32.6928	Special-BRI	3	San Diego Bay	71	57.3	3.63	A
BRI-19	117.1244	32.6785	Special-BRI	9	San Diego Bay	57	72.5	1.94	A
BRI-20	117.1162	32.6732	Special-BRI	7	San Diego Bay	82	55.2	2.50	ACOX

A: Acceptable data for analysis
C: Reduced number of replicates
E: Sample stored > 14 days
G: Reference test missing or outside limits
J: Minor deviation in test conditions
O: One or more replicates were identified as outliers
Q: Control did not meet replicate acceptability criterion (>or=80% in any one rep)
X: One or more replicates were excluded due to QA issues

APPENDIX C. Benthic Response Index Special Study Results

Diana L. Young, Steven M. Bay, and Ananda Ranasinghe

INTRODUCTION

The development of measures of biointegrity for benthic macrofaunal communities, and their application to monitoring data, have improved the quality and interpretability of information available to environmental managers and regulators from benthic assessments of many coastal and estuarine regions of the U.S. In southern California, the Benthic Response Index (BRI) approach, which calculates an abundance weighted pollution tolerance score for species occurring in samples (Smith *et al.* 2001), is used to assess mainland shelf benthic communities. It was developed for a regional monitoring program in 1994.

The BRI approach was extended to southern California's bays (Smith *et al.* 2003) for the subsequent regional monitoring program in 1998. The index worked well, but not as well as the index developed for the mainland shelf. The developers' primary recommendation for improving performance of the index was recalibration with additional data, including data from highly disturbed sites to better define responses across the entire range of the pollution gradient. The initial data were collected from random locations in southern California bays and harbors and, therefore, did not include sites with highly polluted sediments.

To implement this recommendation, the California State Water Resources Control Board funded a project to supplement the Bight'03 regional monitoring survey with 20 additional sites. Instead of sampling sites picked at random, the objective was to target highly polluted sites in southern California bays and harbors for benthic macrofaunal sampling to refine and recalibrate the bay BRI. This appendix presents the results of sediment toxicity tests from the sites selected for the BRI Special Study and compares them with results of sediment toxicity tests for sites selected at random for the regional monitoring survey that were sampled concurrently.

METHODS

Site Selection

The objective of site selection was to identify highly polluted sites distributed throughout southern California bays and harbors using data from previous studies. The approach was to identify sites using sediment contaminant data from projects that did not collect benthic macrofauna or collected them using sampling gear other than those used for BRI development (0.1 m^2 Van Veen grabs and 1-mm sieves).

Multiple sites were selected in each of four geographic regions identified during BRI development. The northern bays and harbors extended from Point Conception to north of Newport Bay while the southern bays and harbors extended from south of Dana Point Harbor to the international border between the U.S. and Mexico. Newport Bay, the southernmost northern bay, and Dana Point Harbor, the northernmost southern bay, were each placed alone in “overlap” categories. BRI data from the northern and southern overlap regions were used to normalize the independently developed northern and southern BRI scores to a single scale.

Sites were selected using data from three previous projects. The State of California’s Bay Protection and Toxic Cleanup Program sampled 273 sites in southern California from July 1992 to August 1997 while Bay and Brown (2003) and Bay (2004) sampled 15 and 10 sites in Newport Bay in May 2002 and September 2000, respectively. At each site, the data for several sediment contaminants (not including DDT) were integrated by calculating a mean ERM quotient (mERMq; Long and MacDonald 1998). The sites were then segregated by geographic region and arranged in order of decreasing mERMq. If amphipod toxicity data were available, they were used to select among sites with similar mERMq to increase the likelihood that benthic macrofauna at the selected sites were impacted by sediment contaminants. One site was selected despite the absence of chemical contaminant data; it was highly toxic every time it was sampled on several visits over 18 months and it was, therefore, considered desirable to include it.

Laboratory Methods

Toxicity to amphipods was determined using a 10-day survival test (U. S. Environmental Protection Agency, 1994) with *Eohaustorius estuarius*. Amphipods and negative control sediment were collected from Beaver Creek, Oregon, a non-contaminated site, and held in the laboratory at least four days, but no longer than 14 days, prior to the test. Testing was conducted in 1 L glass test containers. Sediment was added to the test containers one day prior to the start of the test. Sediment samples were thoroughly mixed and then added to the test containers to form a sediment layer approximately 2 cm deep. Filtered seawater (20 g/kg) was slowly added until a final volume of 800 ml was reached. Pipettes connected to an air source provided aeration. Sediments were allowed to equilibrate overnight. Each sample consisted of five randomly arranged replicates, along with an extra container for water quality. A negative control (test animal collection site sediment) was included with each batch of samples tested.

At the start of the test, amphipods were added randomly until a total of 20 animals per container were present. Tests were conducted at 15 °C under constant illumination. Test animals were exposed to the sediment samples for 10 days. Test containers were checked daily for air and for any dead animals or animals stuck to the surface of the water. At the end of the exposure period the sediment was screened through a 0.5 mm screen and the number of surviving amphipods was recorded.

A cadmium reference toxicity test was conducted concurrently with each sediment toxicity test. The reference toxicant test consisted of three replicates of 5 concentrations of dissolved cadmium, plus a control. No sediment was included in the reference toxicant tests. Ten amphipods were added to each replicate and exposed to the reference toxicant for four days. At the end of four days, the total number of surviving animals was recorded and the concentration causing 50% mortality (LC50) was calculated, which was then compared to a control chart prepared from the results of past reference toxicant tests. A test result within two standard deviations of the mean control chart LC50 was considered acceptable.

Samples of overlying water and interstitial water were obtained from the extra test container for measurement of initial water quality (temperature, pH, dissolved oxygen, salinity, and total ammonia). Overlying water quality was also measured at the end of the exposure period. Water quality measurements made for the reference toxicant test were similar to the sediment phase of the test.

Data Analysis

For the amphipod test, two criteria had to be satisfied in order to classify a sample as toxic: a statistically significant reduction in survival compared to the control and a minimum significant percent difference (MSD) in survival between the sample and control. Statistical significance was determined by performing a t-test between the sample and control with a 0.05 level of significance. A 90^{th} percentile % control MSD threshold was calculated using the Bight'03 dataset. The value was determined to be 83%. Samples with a significant difference from the control and a mean survival less than 83% and greater than or equal to 50% were determined to be moderately toxic. Samples with survival less than 50% of the control and significant different from the control were considered highly toxic.

RESULTS

Among the 20 BRI sediment samples collected throughout the SCB, 19 (95% of the total) showed some degree of toxicity (Table C1, Figure C1). Seven samples (35%) were classified as highly toxic (survival less than 50% of the control value and significantly different from the control), while 12 samples (60%) were classified as moderately toxic (survival less than 83% of the control and significantly different from the control).

There were five general locations from where the BRI samples were taken: San Diego Bay, Dana Point Harbor, Newport Bay, San Pedro Bay, and Marina del Rey. The most toxic sites (those classified as highly toxic) were in the Upper Newport Bay, Rhine Channel, Dominguez Channel, and in the Los Angeles Harbor. San Diego Bay, Marina del Rey, and most of the Dana Point Harbor stations were determined to be moderately toxic. One sample from Newport Bay was classified as nontoxic.

Survival for the BRI Special Study samples was usually within the range measured for random samples from each area (Figure C2). The BRI samples tended to be more toxic, however, than the means for the random samples. In San Diego Bay, the average for the Bight'03 random samples was 84% survival. The average for the BRI samples in San Diego Bay was 72%. There was one sample taken in the Dana Point Harbor for the Bight'03 study and three BRI sites. The Bight'03 site had 100% survival and the three BRI sites had an average percent survival of 62. Newport Bay had an overall Bight'03 average percent survival of 44. The BRI samples mean was 34%. The San Pedro Bay Bight'03 sites had a mean survival of 76%, while the BRI sites in San Pedro Bay had a mean survival of 50%. In the fifth area, Marina del Rey, the Bight'03 sites averaged 85% survival, and the BRI sites had an average of 69%.

DISCUSSION

The results of the BRI sample analyses were in concordance with the expectation based on historical assessments for 95% of the stations. This concordance suggests that there has been little improvement in sediment quality during the 1-10 year interval since the previous assessment.

Although the mean survival for the BRI samples tended to be lower than the random Bight'03 samples for a given embayment, the results usually fell within the range of responses for the random samples. This overlap of responses was always present when more than four stations were sampled within an embayment (Figure C2). These results indicate that a random sampling strategy can provide a reliable assessment of the range of sediment toxicity within a waterbody when there is adequate sampling intensity.

The results of this study appear to have met the goal of obtaining data from highly disturbed sites in southern California bays and harbors. The benthic community data from these additional toxic samples will be used to better define responses of benthic macrofauna across the entire range of the pollution gradient. The recalibration of the BRI using a more complete set of data should increase the robustness of the index and allow greater accuracy in the index's ability to assess the degree of benthic community impact in southern California's bays.

TABLE C1. BRI station amphipod percent survival, toxicity classification and, location.

StationID	%Control	Std. Dev.	Toxicity	Latitude	Longitude	Location
BRI-11	0	0.0	Highly Toxic	33.6499	117.8708	Upper Newport Bay
BRI-10	16	5.0		33.6144	117.9270	Newport Bay Rhine Channel
BRI-09	19	12.5		33.6110	117.9274	Newport Bay Rhine Channel
BRI-04	28	6.5		33.7706	118.2500	Dominguez Channel
BRI-08	30	19.5		33.6120	117.9278	Newport Bay Rhine Channel
BRI-13	44	8.4		33.4588	117.6981	Dana Point Harbor
BRI-05	48	10.8		33.7759	118.2430	Los Angeles Harbor
BRI-06	57	12.2	Moderately Toxic	33.7592	118.1898	Long Beach Harbor
BRI-19	57	18.5		32.6785	117.1243	San Diego Bay
BRI-12	64	10.8		33.4607	117.6984	Dana Point Harbor
BRI-01	64	5.0		33.9829	118.4558	Marina del Rey
BRI-03	66	10.8		33.7372	118.2663	Los Angeles Harbor
BRI-16	69	12.9		32.7075	117.1687	San Diego Bay
BRI-18	71	23.6		32.6928	117.1458	San Diego Bay
BRI-02	74	6.3		33.9756	118.4550	Marina del Rey
BRI-17	77	17.8		32.6932	117.1476	San Diego Bay
BRI-15	77	5.0		32.7265	117.1945	San Diego Bay
BRI-14	78	13.9		33.4608	117.6912	Dana Point Harbor
BRI-20	82	10.4		32.6732	117.1162	San Diego Bay
BRI-07	103	4.2	Non Toxic	33.6208	117.9362	Newport Bay

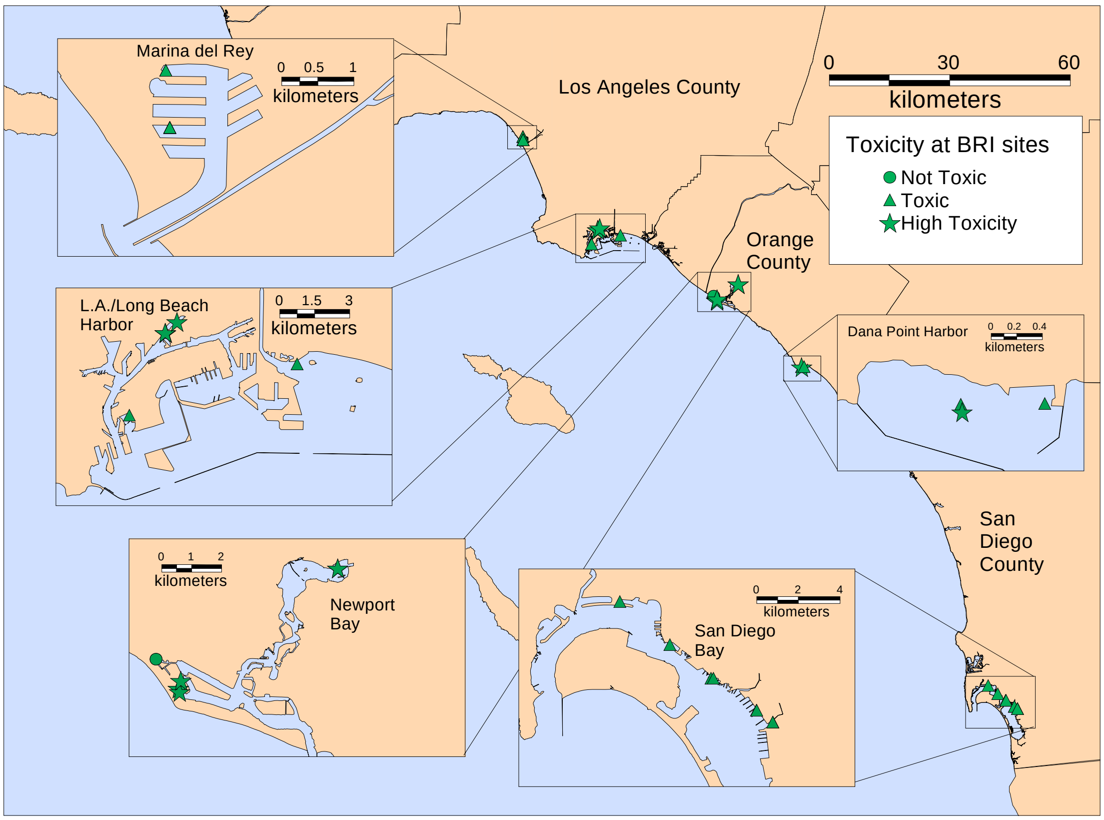

FIGURE C1. Map of the BRI stations and their toxicities.

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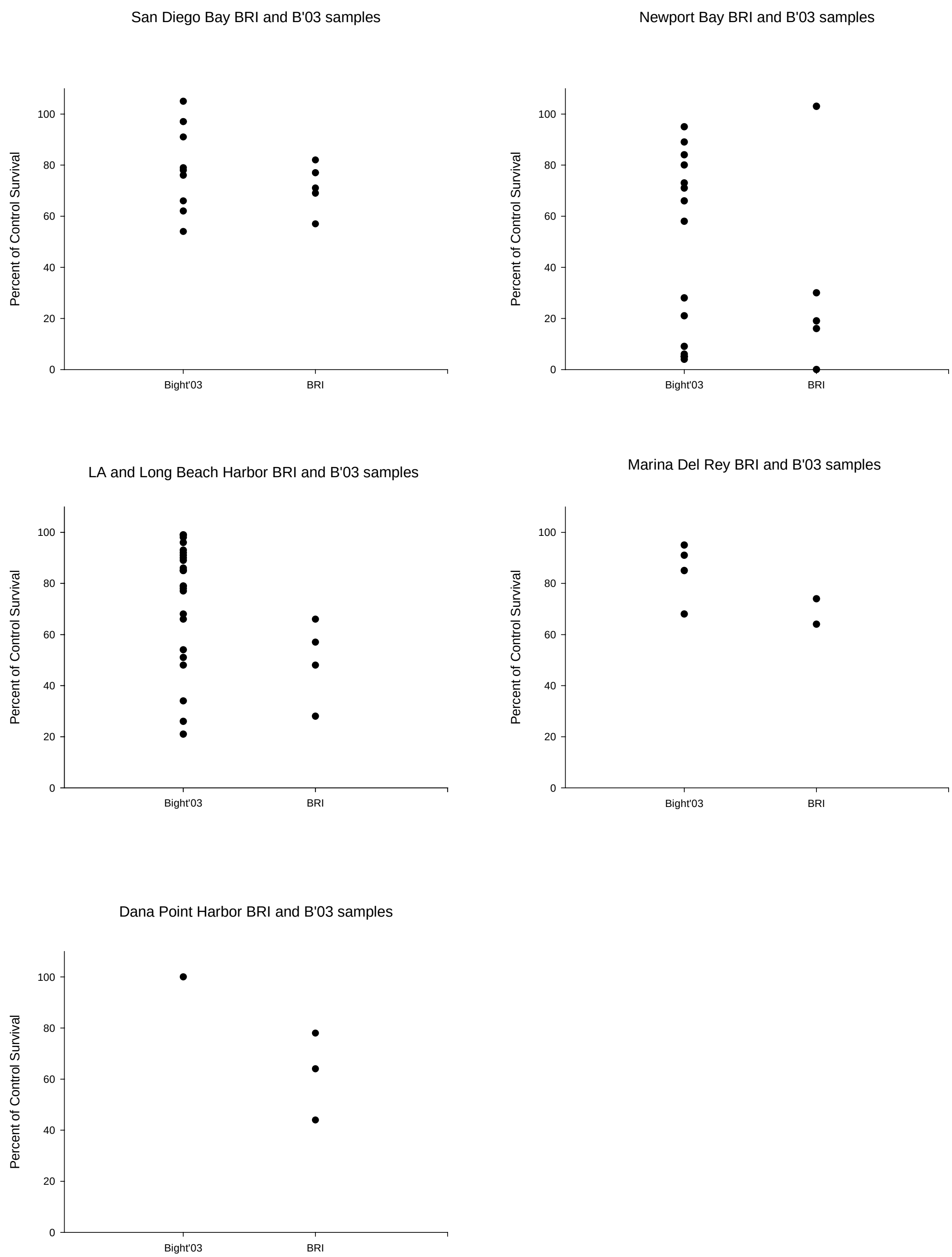

FIGURE C2. Comparisons of amphipod percent survival between Bight '03 stations, and BRI stations within each embayment.

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APPENDIX D: Toxicity Identification Evaluations Performed on Bight'03 Estuary Station Sediments and Pore Waters

Darrin Greenstein, Steven M. Bay and Diana Young

INTRODUCTION

As an adjunct project to the Bight '03 sediment toxicity project, samples from the Los Angeles Estuary strata were subjected to whole sediment and pore water toxicity identification evaluations (TIEs). The objective of this work was to determine the chemical cause of any observed toxicity within these estuaries. Information gained from this study will be used in the total maximum daily load (TMDL) calculation process. The estuaries of interest were Ballona Creek, Dominguez Channel, Los Angeles River, Malibu Creek and San Gabriel River estuaries.

METHODS

Sediment samples from estuary stations were tested for toxicity initially by either Aquatic Bioassay and Consulting Laboratories or Weston Solutions, as part of the regular Bight '03 sampling effort. These tests were performed using the amphipod, *Eohaustorius estuarius*, 10 day survival test by standard EPA methods (U.S. Environmental Protection Agency 1994). From each estuary station, a separate 2 liter sample of sediment had been collected and stored at SCCWRP. If an estuary station was found to be toxic, then a whole sediment and pore water TIE was performed by SCCWRP. A maximum of two stations per estuary was tested.

Whole sediment TIEs were performed in 250 ml beakers containing approximately 40 ml of sediment and 160 ml of 20 ppt seawater. Sediment, water and aeration was added to the beakers about 24 hrs before the animals were added. The sediment was press sieved through a 2 mm screen prior to homogenization and TIE treatment. Each beaker contained 10 *Eohaustorius* that were purchased from Northwestern Aquatic Sciences and acclimated at SCCWRP for 7 days prior to the test. The test duration was 10 days. The nominal exposure temperature was 15 °C.

Methods for conducting TIEs on whole sediments are not well established. The methods used for this study follow those that other researchers have found to work acceptably (Lebo *et al.* 1999, Burgess *et al.* 2000). For the whole sediment samples, a baseline of untreated sediment was tested both to compare against the treated sediments and to identify any changes in toxicity that may have occurred during storage, after the initial testing was conducted. Four manipulations of the whole sediment were performed. The first was addition of coconut carbon at 15% by weight to bind organic contaminants and render them non-available to the animals. The second was the addition of cation exchange resin at 20% by weight to bind cationic metals. The third treatment was addition of piperonyl butoxide (PBO) to the overlying water at 500 ug/L. PBO prevents the amphipods from metabolizing organophosphous pesticides, rendering them non-toxic. The fourth manipulation was dilution of the sediment with Yaquina Bay home sediment at 20% by weight. The dilution treatment was to verify that changes seen in the coconut carbon and cation exchange resins were not simply caused by dilution. For all treatments, a sample of amphipod home sediment was also manipulated to verify that the procedures themselves were not causing toxicity.

For the pore water treatments, sediment was centrifuged at 3000 x g for 30 minutes to extract the pore water. The pore water was pipetted from the centrifuge bottles into clean glass jars. The pore water was extracted the day before the toxicity tests were conducted.

Methods for conducting TIEs on aqueous marine samples are well established (U.S. EPA 1996). A baseline sample of untreated pore water was tested from each station, concurrently with TIE manipulated samples. On the day of pore water extraction an aliquot of each pore water sample was passed through a C-18 column to remove non-polar organic compounds. On the next day, the remaining TIE treatments were performed and 10 ml of each sample was added to 5 dram shell vialsThe remaining treatments consisted of addition of EDTA, a chelator of metals, to a final concentration of 60 mg/L, addition of sodium thiosulfate (STS), which is a reducing agent to oxidizers such as chlorine and also decreases the toxicity of some metals, to a concentration of 50 mg/L and addition of PBO to a concentration of 500 ug/L. Laboratory seawater was subjected to all of the TIE treatments to verify that the procedures were not causing toxicity.

The pore water tests also had a 10 day exposure period. On day zero, 5 *Eohaustorius* were added to each test vial. There was no aeration for the pore water test. Each day, the number of surviving animals was counted. Dead animals were not removed from the vials. The nominal exposure temperature was 15 °C.

Two of the samples had large grain size, which reduced the amount of pore water that could be extracted. For station 4053, 114 ml of pore water was extracted; to this 36 ml of laboratory seawater was added (sample was therefore 76% pore water). This provided enough volume to do all the treatments except STS. For station 4213, virtually no pore water was extracted by centrifugation. Therefore, a sediment elutriate was created for this station. The elutriate was created by placing 100 ml of sediment into each of two glass centrifuge bottles and adding 100 ml of laboratory sea water to each. As a blank, 200 ml of seawater were also added to a third bottle. All three bottles were then placed on a roller table for 16 hr. At the end of this period, the water was decanted into polycarbonate centrifuge bottles and centrifuged at 3000 x g for 30 min. This provided enough volume to do all the treatments except STS.

QA/QC

Testing for the Dominguez Channel samples was successfully completed with only one minor QA issue. All controls and blanks for the whole sediment testing had mean survival greater than 90% (Table D-1). For the pore water testing, all controls and blanks had mean survival greater than 90% except the C-18 column blank associated with station 4206 which had a mean of 80%. Both the sample and blank treated with C-18 for this station had standard deviations of 20 or more.

There were more QA issues associated with the testing of the Ballona Creek samples (Table D-1). For the whole sediment, the control for the coconut carbon had a mean survival of 80%. All other controls and blanks were greater than 90%. For the pore water, the roller table blank and EDTA blank each had mean survival of 80%. The PBO blank was considerably below acceptable control criteria with a mean survival of only 20%. The variability between replicates in the second batch was also greater than the first, with several treatments for both the whole sediment and pore water having standard deviations of 20 or more.

RESULTS

During the initial testing by various laboratories, stations from the Ballona Creek and Dominguez Channel estuaries were found to be toxic (Table D-2). None of the samples from the Los Angeles River, Malibu Creek or San Gabriel River sites were found to be toxic. Therefore, two samples each from the Ballona and Dominguez estuaries were subjected to TIE treatments.

Dominguez

For station 4270, the baseline whole sediment sample had a very similar level of toxicity to the initial sample (Figure 1). The only treatment that reduced the toxicity was the addition of coconut carbon, which increased survival to about 90%. The PBO treatment decreased survival. Some researchers have found that the addition of PBO will increase toxicity when the cause of toxicity is pyrethroid pesticides (Phillips *et al.* 2004).

For station 4206, the toxicity of the sediment was less by about a factor of two in the baseline sample than it had been in the initial testing (Figure D-2). None of the TIE treatments reduced the toxicity more than marginally. Again, the PBO treatment showed an enhancement of toxicity.

The baseline pore water sample for station 4270 exhibited strong toxicity with just over 20% of the animals surviving (Figure D-3). The STS treatment reduced toxicity somewhat, but still only about half of the animals survived. The C-18 column extraction removed nearly all of the toxicity. As with the whole sediment samples, the PBO treatment showed an enhancement of toxicity, indicating the possible presence of pyrethroid pesticides.

The baseline pore water sample from station 4206 was not toxic to the amphipods (Figure D-4). However, the PBO treatment again showed a strong increase in toxicity.

Ballona

The whole sediment baseline for station 4053 was a little less toxic than the initial testing, but still had a strong signal (Figure D-5). The cation exchange resin seemed to reduce toxicity, but had a large degree of variability making assessment of its effectiveness difficult. The carbon treatment resulted in a survival increase to nearly 100%. The PBO and dilution treatments could not be performed due to insufficient sample.

The baseline sediment sample for station 4213 had a very similar level of toxicity as the initial sample (Figure D-6). As with station 4053, the cation exchange resin removed a small portion of the toxicity and the coconut carbon removed most of it. As was observed for the Dominguez stations, the PBO treatment greatly increased toxicity. The dilution treatment could not be conducted due to insufficient sample volume.

The baseline pore water sample from station 4053 was very toxic, with no animals surviving after the 10 day exposure (Figure D-7). None of the TIE treatments that were performed had an effect. The STS sample could not be tested due to insufficient sample volume.

For station 4213, the baseline elutriate sample showed strong toxicity, with approximately 25% of the animals surviving, but also exhibited a high degree of variability (Figure D-8). Both the EDTA and C-18 extraction increased survival to about 90%. The PBO treatment had much a greater level of toxicity than the baseline, but the PBO blank sample in this batch also had no survival indicating that the treatment itself was causing toxicity. There was not enough sample to do the STS treatment.

DISCUSSION

The TIE treatments were successful in characterizing a possible cause of toxicity at all four of the stations for whole sediment and at three of the four stations for pore water. For both of the Dominguez stations, similar patterns were seen for both the whole sediment and pore water with an organic chemical suspected and more specifically, the possibility of a pyrethroid pesticide.

For the Ballona stations, there was much less agreement between the whole sediment and aqueous samples. This may be in part because of the very large grain size for these stations which led to dilution of the pore water at station 4053 and use of an elutriate for 4213. While the whole sediment for Ballona station 4053 seemed to be affected mostly by an organic chemical, with a lesser metal component, no determination could be make for the pore water. Either the contaminant of concern in the pore water was of a great enough concentration to overwhelm the TIE treatments or was caused by a contaminant for which a treatment was not performed. The sample had a sulfide odor and no treatment for sulfide was conducted, nor was sulfide measured in the sample. The other Ballona (4213) station had strong indications of an organic cause for toxicity in the whole sediment, possibly a pyrethroid pesticide, while the elutriate had indications of both organic and metals components. The fact that both EDTA and the C-18 column reduced toxicity could indicate either a mixture of organics and metals or simply metals. In previous work, we have found the C-18 column is capable of binding significant concentrations of metals (Schiff *et al.* 2002).

The possible identification of pyrethroid pesticides as a source of toxicity is new to southern California. As the commonly used organophosphorus pesticides are phased out, the use of pyrethroids is increasing. Toxicity due to synthetic pyrethroids has been identified in the Central Valley (Phillips *et al.* 2003). More work is required on the southern California sites to verify that the toxicity is being caused by pyrethroids. Currently, these compounds are not routinely analyzed in marine sediments. Other researchers have recently published methods for verification of pyrethroids as sources of toxicity in freshwater (Wheelock *et al.* 2004). These methods may also work in marine sediments, but have not yet been tested.

Table D-1. Results of QA samples tested concurrently with TIE samples. For whole sediment, QA treatments were performed on amphipod home sediment. For pore water, treatments were performed in laboratory seawater.

	Dominguez		Ballona	
Treatment	Whole Sed.	Pore Water	Whole Sed.	Pore Water
Control	98 ± 4.5	92 ± 11.5	100 ± 0.0	96 ± 8.9
Carbon	93 ± 11.5	NA	80 ± 0.0	NA
Cation	90 ± 17.3	NA	100 ± 0.0	NA
PBO	97 ± 5.8	93 ± 11.5	97 ± 5.8	20 ± 34.6
EDTA	NA	100 ± 0.0	NA	80 ± 20.0
STS	NA	100 ± 0.0	NA	NA
C-18	NA	86 ± 9.2	NA	100 ± 0.0

NA= Not applicable for that matrix or exposure.

Table D-2. Summary of initial test results from Bight 03 estuary stations.

Station	Estuary	Percent of Control Survial	TIE?	Sampling date
4053	Ballona	0	Yes	9/16/2003
4213	Ballona	59	Yes	9/16/2003
5735	Ballona	27	No TIE sample	10/6/2003
5767	Ballona	19	No TIE sample	10/6/2003
5787	Ballona	91	No TIE sample	10/6/2003
4206	Dominguez	34	Yes	8/8/2003
4270	Dominguez	21	Yes	8/8/2003
4436	Dominguez	26	No	8/8/2003
4852	Dominguez	92	No	9/17/2003
5012	Dominguez	96	No	9/17/2003
5108	Dominguez	99	No	9/17/2003
4142	Los Angeles	93	No	7/24/2003
4600	Los Angeles	79	No	9/16/2003
4788	Los Angeles	99	No	9/16/2003
4856	Los Angeles	90	No	9/17/2003
4197	Malibu	93	No	8/20/2003
4939	Malibu	103	No	8/20/2003
4683	Malibu	99	No	10/6/2003
5739	Malibu	96	No	10/2/2003
5771	Malibu	92	No	10/6/2003
4002	San Gabriel	100	No	7/29/2003
4034	San Gabriel	104	No	8/20/2003
4066	San Gabriel	96	No	7/24/2003
4194	San Gabriel	102	No	8/4/2003
4258	San Gabriel	96	No	7/29/2003
4322	San Gabriel	93	No	8/4/2003
4520	San Gabriel	93	No	7/29/2003

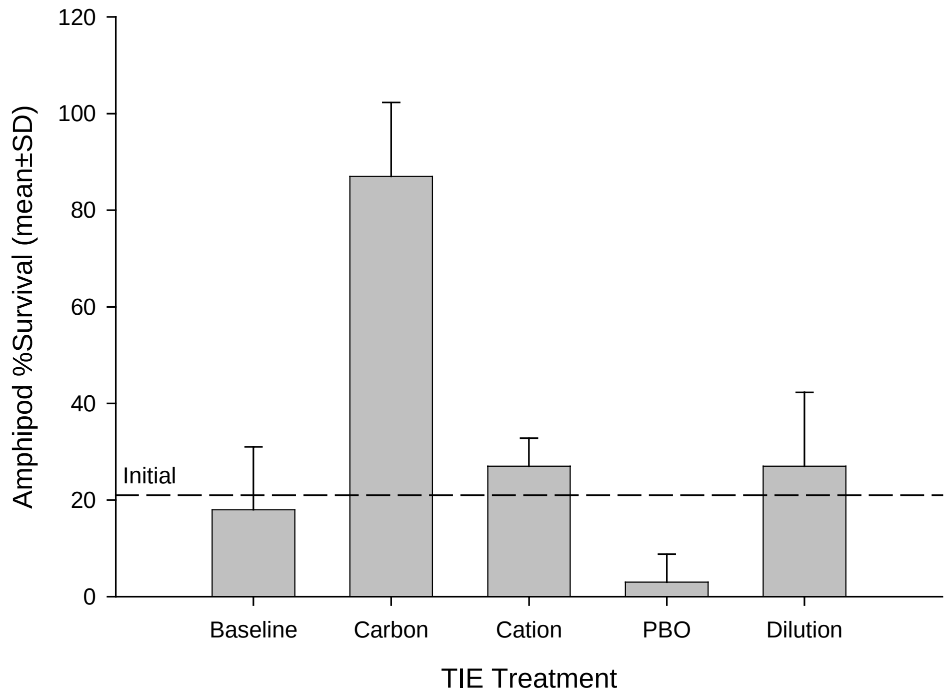

Figure D-1. Results of whole sediment TIE on Dominguez Channel station 4270.

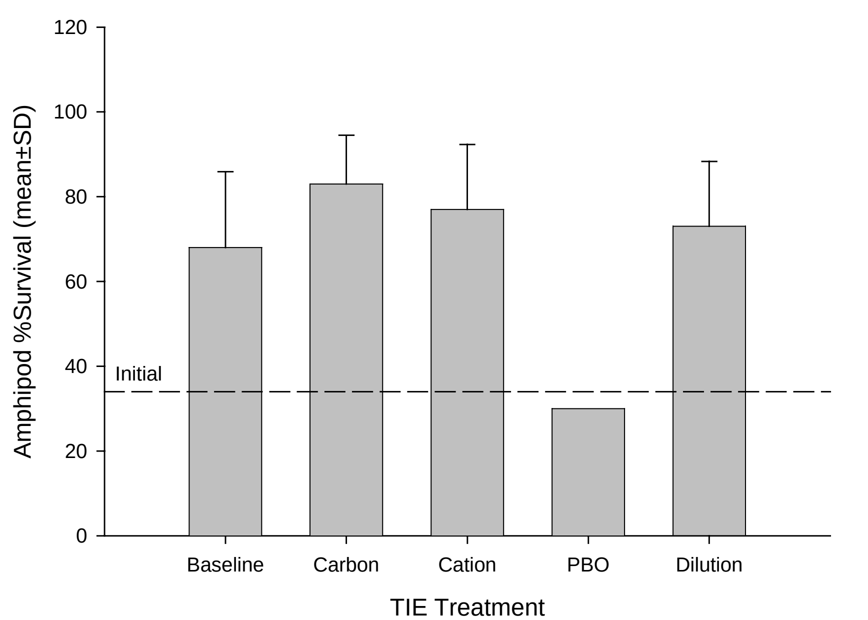

Figure D-2. Results of whole sediment TIE on Dominguez Channel station 4206.

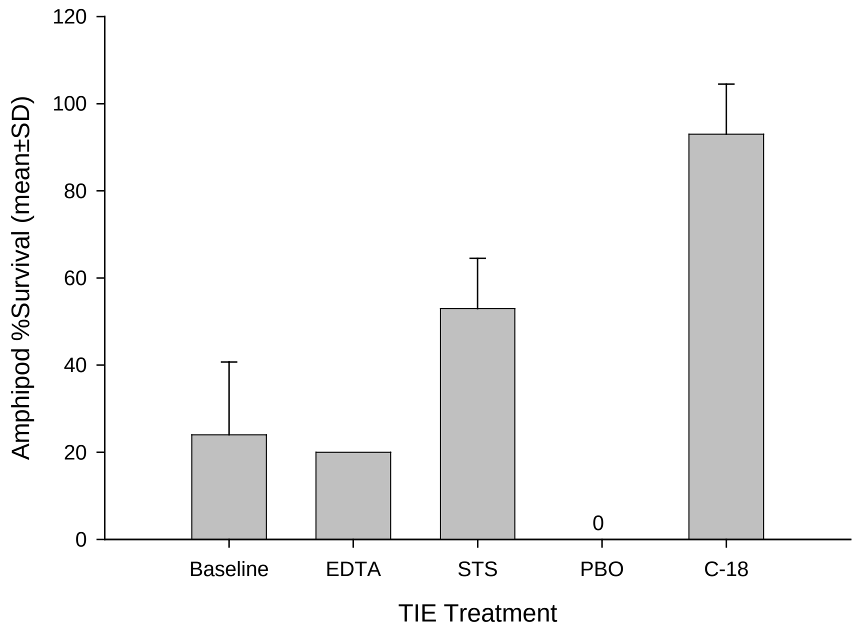

Figure D-3. Results of pore water TIE on Dominguez Channel station 4270.

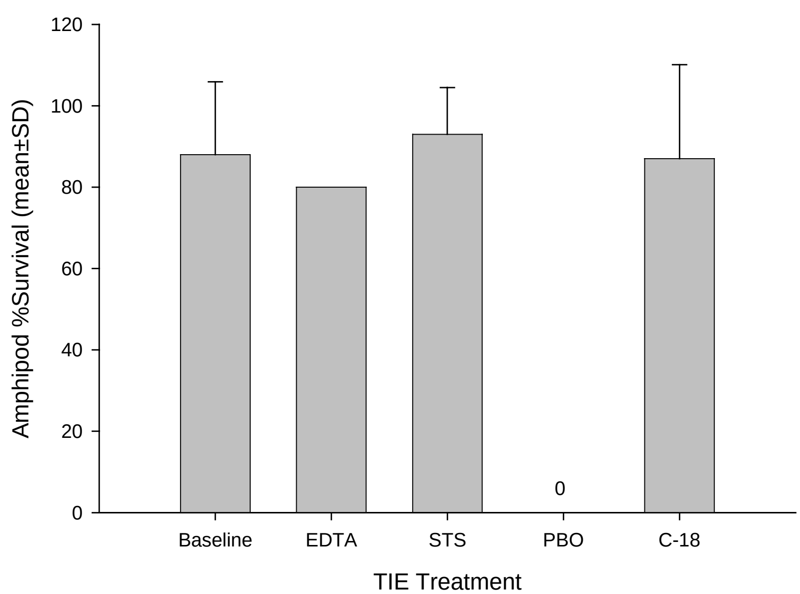

Figure D-4. Results of pore water TIE on Dominguez Channel station 4206.

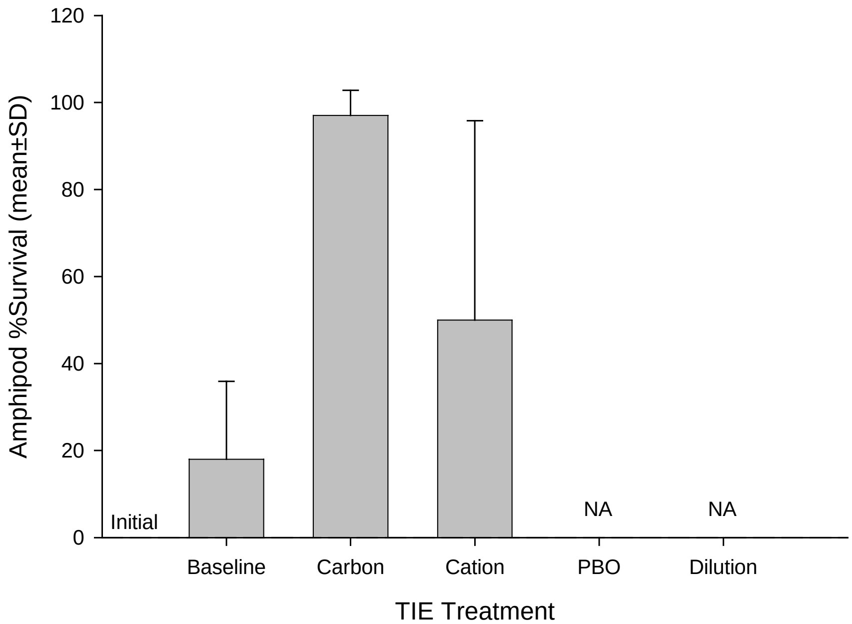

Figure D-5. Results of whole sediment TIE on Ballona station 4053. The PBO and dilution treatments were not performed due to lack of sufficient sample.

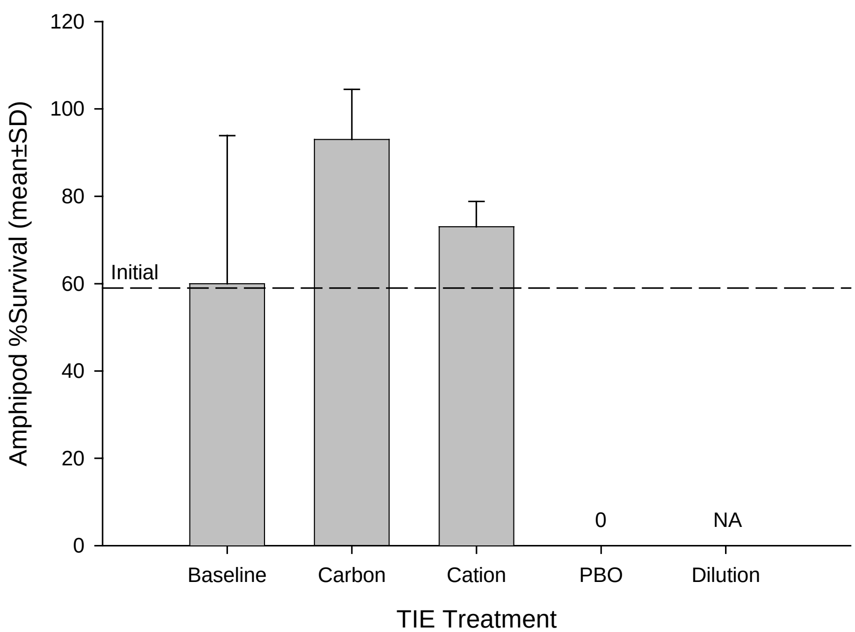

Figure D-6. Results of whole sediment TIE on Ballona station 4213. The dilution treatment was not performed due to lack of sufficient sample.

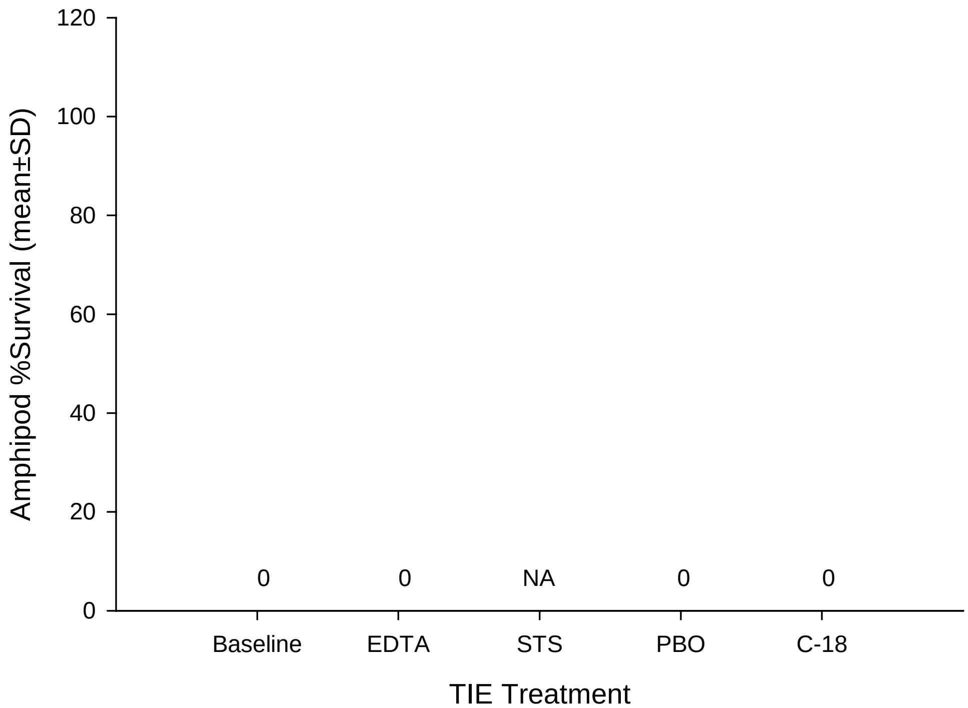

Figure D-7. Results of pore water TIE on Ballona station 4053. The STS treatment was not performed due to lack of sufficient sample.

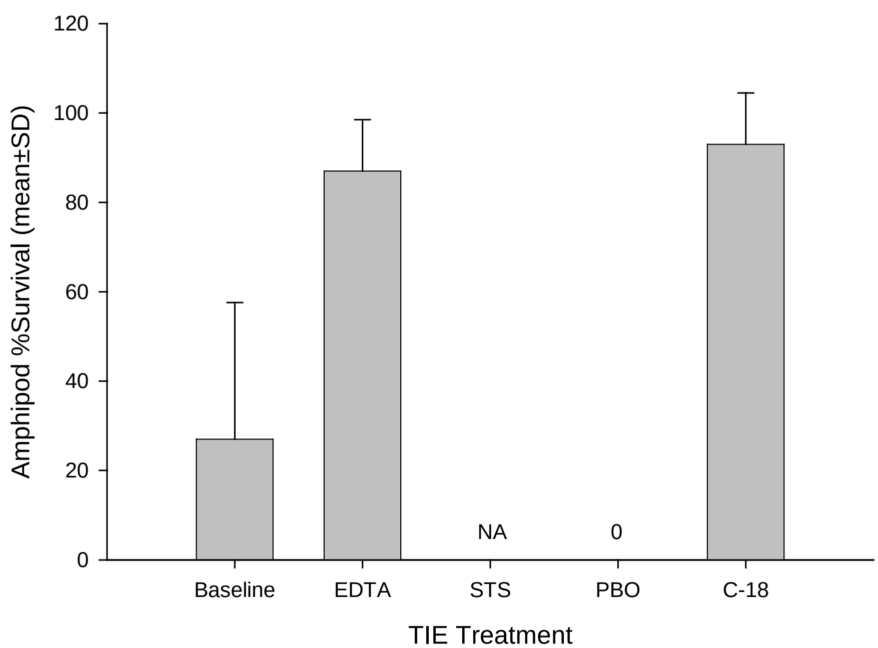

Figure D-8. Results of sediment elutriate TIE on Ballona station 4213. The STS treatment was not performed due to lack of sufficient sample.

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