Southern California Bight 1994 Pilot Project: VI. Sediment Toxicity

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Southern California Coastal Water Research Project

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FOREWORD

Although more than 10 million dollars is spent annually monitoring southern California's coastal waters, some basic questions about the ocean's condition, such as how many acres of ocean bottom are impaired, can not be answered. The principal limitation is that less than 5% of the area on the mainland shelf of the Southern California Bight (SCB) is routinely monitored. Moreover, the constituents measured, as well as the frequency and methodology by which they are measured, typically differ among monitoring programs in the SCB. These limitations reflect the predominant association of monitoring in southern California with discharge permit requirements that are focused on site-specific, single-source issues. While these programs generally collect high quality data, they are not designed to describe changes which occur on regional scales or to assess cumulative impacts from multiple sources whose fates commingle.

Recognizing the need for integrated assessment of the southern California coastal ocean, 12 governmental organizations, including the four largest municipal dischargers and the five regulators of discharge in southern California, collaborated to conduct a comprehensive regional monitoring survey in the summer of 1994. Referred to as the Southern California Bight Pilot Project (SCBPP), the monitoring survey included measures of the water quality, sediment chemistry, sediment toxicity, benthic infauna, and demersal fishes. This report summarizes the sediment toxicity portion of the study. Other reports are available on the Internet (www.sccwrp.org) or from the Southern California Coastal Water Research Project.

Participating Agencies in the SCBPP

United States Environmental Projection Agency, Office of Research and Development
United States Environmental Projection Agency, Region IX
City of Los Angeles, Environmental Monitoring Division
County Sanitation Districts of Los Angeles County
County Sanitation Districts of Orange County
City of San Diego, Metropolitan Wastewater Department
State Water Resources Control Board
Regional Water Quality Control Board, Los Angeles Region
Regional Water Quality Control Board, Santa Ana Region
Regional Water Quality Control Board, San Diego Region
Santa Monica Bay Restoration Project
Southern California Coastal Water Research Project

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EXECUTIVE SUMMARY

Most chemical contaminants entering the marine environment have an affinity for particles and tend to accumulate to elevated concentrations in sediments, creating the potential for toxicity to benthic or demersal organisms. Physical and chemical processes within sediments such as resuspension and diffusion can result in the transport of contaminants to other areas. A principal concern of the SCBPP, therefore, was the evaluation of various indicators of sediment quality that could be used to evaluate the health of benthic environments. This report presents the results of sediment toxicity tests conducted on SCBPP sediment samples.

Sediment samples were collected from 72 stations during SCBPP sampling cruises. Station locations ranged from Point Conception to the Mexican border in depths of 10-200 meters. These stations represented a subset of SCBPP sites selected for benthic chemistry analysis. Sediments were collected using a 0.1 m^2 Van Veen grab during July and August, 1994. Sediment samples were stored under refrigeration for up to four weeks before testing. Each sample was evaluated using two toxicity tests, enabling the toxicity of both sediment and interstitial water to be measured.

The toxicity of whole sediment was evaluated by measuring the survival of the tube dwelling amphipod *Ampelisca abdita* following a 10 day exposure. Interstitial (pore) water was tested for toxicity using a sea urchin embryo development test. Interstitial water was obtained by centrifuging sediment. The supernatant was diluted with seawater to produce test concentrations of 100, 50, and 25%. Embryos of the purple sea urchin (*Strongylocentrotus purpuratus)* were exposed to the test samples for 72 hours and then evaluated for the percentage of normal development using a microscope.

Amphipod survival was high in all samples tested, ranging from 80-98%. Statistically significant reductions in survival were identified for six samples. None of the 72 samples were identified as toxic, however, as amphipod survival was ≥80% of the control for all samples.

In contrast to the amphipod survival data, sea urchin embryo development was adversely affected by interstitial water from many sediment samples. Most of the 100 and 50% samples produced less than 80% of the control development in embryos, with many samples producing less than 5% normal development. Even a majority of the samples diluted to 25% interstitial water were toxic.

Many of the interstitial water samples contained elevated ammonia concentrations that were sufficient to cause embryo toxicity. The elevated ammonia concentrations were likely caused by sediment handling and storage procedures. A regression model for ammonia toxicity was applied to the data for 25% interstitial water in order to distinguish between toxicity due to ammonia and other factors. Fifteen samples were identified as having toxicity not caused by ammonia.

Nine of the 15 toxic interstitial water samples were located in the northern part of the SCB, distant from large point source waste discharges. The remaining toxic samples were located near POTW discharges in the central and southern parts of the study area.

Though limited comparable data are available, the SCBPP sediment toxicity results are generally consistent with prior research in selected areas of the SCB. Previous measurements of whole sediment toxicity at contaminated sites in Santa Monica Bay and off Palos Verdes have also shown a lack of toxicity to amphipods in 10-day tests. Ammonia toxicity has also been identified as an important factor in sea urchin embryo tests of interstitial water from southern California bays and estuaries. Previous measurements of interstitial water toxicity off Palos Verdes have also identified toxicity at stations located near a POTW discharge.

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INTRODUCTION

Evaluation of the effects of contamination on sediment quality often utilizes a multiple indicator approach, combining measures of sediment contamination, sediment toxicity, and benthic community structure. Sediment toxicity tests complement these other indicators of sediment quality by providing a measure of the joint effect of contaminant mixtures that is also sensitive to changes in biological availability. Because a biological response is measured under controlled conditions, toxicity tests can be used to examine the relationship between contamination and impacts on organisms. Using benthic community data to evaluate such relationships is often difficult, because contaminant-related changes in the benthos may be obscured by natural factors such as variations in sediment grain size or recruitment patterns.

A wide variety of sediment toxicity test methods have been developed for use in marine environments (Lamberson *et al*., 1992). The most commonly used method is a short-term lethality test where an organism (usually an amphipod) is exposed to a sample of whole sediment for 10 days. Amphipods are often used in sediment tests because these organisms appear to be among the most sensitive of benthic species to sediment contamination. They are among the first species to disappear from benthic communities impacted by pollution (Swartz *et al*. 1982). The nationwide use of amphipods in a variety of toxicity monitoring programs has also been facilitated by the development of standardized test methods (ASTM 1991).

Sediment test methods that expose marine organisms to interstitial (pore) water, sediment elutriates, or extracts are also utilized in many assessment programs. These liquid phase tests often use the early life stages of bivalves or echinoderms and are usually more sensitive to variations in sediment quality than short-term tests with amphipods (*Long et al*., 1998). Interstitial water toxicity is a particularly appropriate test phase because this portion of the sediment matrix plays is an important route of exposure for benthic organisms.

Monitoring programs in southern California rarely include sediment toxicity tests in their design. The limited studies of toxicity on the mainland shelf have examined areas of known contamination near large municipal wastewater discharge systems (Anderson *et al*. 1988, Bay *et al*. 1994, SCCWRP 1992, Swartz *et al*. 1986). Sediment toxicity in southern California’s coastal bays and harbors have been more extensively studied (Anderson *et al.* 1997, Fairey *et al*. 1998), but these areas account for a relatively small percentage of the coastal environment. As a result, we have insufficient information to evaluate sediment toxicity on a regional basis. Regional sediment quality information is needed in order to enable environmental managers to assess the relative importance of different pollutant sources and to evaluate cumulative impacts.

The Southern California Bight Pilot Project (SCBPP) was a cooperative regional monitoring survey conducted in 1994 to assess the spatial extent and magnitude of ecological disturbances on the mainland shelf of the southern California Bight (SCB). The SCBPP sampled 261 sites and measured a variety of indicators, including sediment contamination and benthic community health (SCBPP Steering Committee 1998). Sediment toxicity tests were conducted at approximately one quarter of the SCBPP sites in order to demonstrate the feasibility of the test procedures and provide initial data for use in a regional context.

The reduced sampling effort precluded addressing the entire suite of questions identified for the ecological assessment portion of the study (Bergen 1996). The objectives of the sediment toxicity portion of the study were to determine: 1) if the extent and magnitude of sediment toxicity was similar throughout geographic regions of the SCB, and 2) if variations in sediment toxicity were associated with the presence of municipal wastewater discharges from publicly owned treatment works (POTW).

METHODS

Seventy two sites were sampled on the continental shelf of the SCB from Point Conception, California to the United States-Mexico border between July 13 and August 22, 1994. (Figure 1). Sites were selected using a stratified random design, with the primary strata being geography (northern, central, and southern portions of the study area) and proximity to municipal wastewater outfalls (POTW areas). The POTW areas were delineated prior to the survey as broad regions encompassing much or all of the area monitored around ocean outfalls of the four largest POTWs with ocean discharges (Figure 2). Details of site selection are provided in Bergen (1996) and Stevens (1997).

Sediment samples were collected using a modified 0.1 m^2 Van Veen grab. Surface (top 2 cm) sediment was collected from each station with a polyethylene scoop and placed in one-liter polyethylene jars. Multiple grab samples were taken at each station to provide a minimum of three liters of sediment. An additional two liters of sediment were collected from 16 stations for use in an interlaboratory comparison study. Separate grabs were also taken to provide samples for analysis of contaminants and benthic infauna. Details of the methods used for chemical or benthic infaunal analyses are provided in Schiff and Gossett (1998) and Bergen *et al*. (1998).

Sediment samples for toxicity testing were placed on ice immediately after collection and transported to SCCWRP, where they were stored under refrigeration (3-5 °C) for up to four weeks before testing. A composite sample for each station was prepared in the laboratory by combining the contents of the storage jars in a polyethylene pail and homogenizing by hand. Subsamples of the composite were used for each toxicity test.

WHOLE SEDIMENT TOXICITY

Solid phase toxicity tests were conducted using a 10-day amphipod survival test. Samples from approximately half of the stations were tested by the Southern California Coastal Water Research Project (SCCWRP). The remaining samples were shipped on ice by overnight courier to Science Applications International Corp. (SAIC; Narragansett, Rhode Island) for analysis. A total of 10 experiments were conducted to test all of the samples. Each experiment used animals freshly collected from the field.

Both laboratories used similar test procedures (ASTM 1991). All sediment samples were passed through a 1 mm (2 mm for SAIC) mesh stainless steel screen, without adding water, to remove large debris and potential predators. The sediment passing through the screen was used in the test. A 2-cm layer of sediment was placed in the bottom of a quart-sized glass canning jar and covered with 600 ml of laboratory seawater having a salinity of 30 g/kg. A glass aeration tube was then added to ensure that all samples had acceptable dissolved oxygen concentrations. Sediment addition occurred one day before the start of the test. Five replicate jars were set up for each sediment sample and arranged randomly in the test array.

The toxicity test was started by adding 20 *Ampelisca abdita* to each jar. Amphipods were collected from tidal flats in the Pettaquamscutt (Narrow) river, a small estuary flowing into Narragansett Bay, Rhode Island. The exposure was conducted at 20 °C under constant light for 10 days. Surviving amphipods were screened from the sediment at the end of the exposure and counted to determine the percent survival.

Negative controls (collection site or nontoxic reference sediment) and reference toxicants were tested concurrently for quality assurance purposes. The type of negative control sediment varied between laboratories. SCCWRP tests used sediment from the collection site (Narrow River) as the control. Control sediment for SAIC tests was collected from the U.S. Army Corps of Engineers New England Division central Long Island Sound (LIS) reference station. Sediments from this reference station have been used as a control in many previous tests by SAIC.

Reference toxicant tests consisted of a seawater-only exposure of amphipods to sodium dodecyl sulfate (SAIC) or cadmium chloride (SCCWRP). The number surviving after 4 days was recorded and used to calculate the median lethal concentration (LC50).

INTERSTITIAL WATER TOXICITY

Interstitial (pore) water was obtained from each sediment sample and tested for toxicity using a sea urchin embryo development test. The sea urchin embryo development test is based on widely used procedures (Chapman *et al*. 1995). All interstitial water tests were conducted by SCCWRP. Five experiments were required to test all the samples.

Interstitial water was obtained by centrifuging approximately 400 ml of sediment at 3,000 x g for 30 min. The supernatant was carefully removed with a pipette and transferred to a glass jar. The salinity and pH of the interstitial water sample was measured before the sample was diluted and tested. Samples with low pH (≤7.5) were adjusted to 7.6-8.0 by addition of small amounts of a sodium hydroxide solution. Three concentrations of interstitial water (100, 50, and 25%) were prepared if sufficient sample volume was available. Laboratory seawater (0.45 µm filtered natural seawater from Redondo Beach, California) was used to prepare dilutions. Three replicates of each concentration were prepared and 10 ml were placed into 22 ml glass scintillation vials. The test containers were randomly distributed within each experiment.

Toxicity tests were initiated within eight hours of interstitial water collection. Purple sea urchins (*Strongylocentrotus*. *purpuratus)* were collected from northern Santa Monica Bay, California, in the spring and held in laboratory culture until used for SCBPP tests. Gametes were obtained by injecting sea urchins with potassium chloride; the eggs were fertilized, and then 250 embryos were added to each vial. The exposures were conducted at 15 °C for 72 hours under a 12 hr light:12 hr dark photoperiod. The salinity was approximately 33 g/kg.

Formalin (1 ml of a borax buffered full strength solution) was added to the test chambers after 72 hr to preserve the samples for later microscopic examination (generally within 2 months of the experiment). The preserved samples were examined at a magnification of 100 x and approximately 100 embryos were evaluated for abnormal development. Purple sea urchin embryos usually attain the pluteus stage after 72 hours. Abnormal development is usually expressed as a delay in developmental rate or by the presence of pathological conditions (e.g., dead cells, abnormal gut development, irregular cell division).

Reference toxicant (copper chloride) and negative control samples were tested concurrently for quality assurance purposes. The control consisted of laboratory seawater that had been passed through the centrifugation process.

WATER QUALITY

Initial and final water quality measurements were made during each toxicity test. These measurements consisted of temperature, dissolved oxygen (DO), pH, salinity, and total ammonia.

SAIC tests. Temperature was measured daily using a thermometer placed in a water-filled test chamber set in the waterbath used for exposures. Salinity of selected test chambers was measured with a hand-held Reichert-Jung refractometer. DO was measured with an Orion DO meter (model 820) and DO electrode (Orion 97-08). Measurements of pH were made using an Orion pH meter (250A) and electrode (91-57). Total ammonia was measured spectrophotometrically using the salicylate-hypochlorite method (Bower and Holm-Hansen 1980). Unionized ammonia concentration was calculated using information obtained from Hampton (1977) and Whitfield (1974).

SCCWRP tests. An Omega model PR-13 resistance temperature detector (RTD) connected to a DP41 meter was used to monitor temperature at hourly intervals. The RTD was placed in a water-filled chamber located adjacent to the experiment. DO was measured using a Microelectrodes, Inc., model OM-4 meter and MI-730 electrode. An Orion model 290A meter and 91-57 electrode was used for pH measurements. Salinity was calculated from conductivity measurements made using an Orion model 124 meter and 012210 conductivity cell. Total ammonia was measured using an Orion 9512 electrode connected to a Corning model 150 specific ion meter. The concentration of unionized ammonia (NH_3) was calculated using the same procedure described for SAIC.

INTERLABORATORY COMPARISONS

Two interlaboratory comparison studies were conducted to document test reproducibility and comparability of the results to other EMAP data. The first comparison involved SCCWRP and SAIC. Laboratory splits of 16 SCBPP sediment samples were prepared and analyzed by each laboratory using the *A. abdita* survival test. The split samples were tested at the same time as all other SCBPP samples.

The second interlaboratory comparison investigated comparability of the results with another EMAP program, the Southern California Bays and Estuaries Pilot Project. The Southern California Bays and Estuaries Pilot Project conducted sediment assessments in lagoons, estuaries, and marinas located in Orange and San Diego Counties (SWRCB *et al*. 1997). This interlaboratory comparison was conducted in September, 1994 and involved SCCWRP and the California Department of Fish and Game Marine Pollution Studies Laboratory (MPSL; Monterey, California), the laboratory which measured sediment toxicity during the Southern California Bays and Estuaries Pilot Project. Sediment from six stations were collected during the Southern California Bays and Estuaries Pilot Project, split, and shipped to SCCWRP and MPSL. The samples were obtained from Newport Bay, Aqua Hedionda Lagoon, and Oceanside Harbor (Appendix 2). Testing schedules were coordinated between each laboratory so that the samples were stored for similar lengths of time.

Amphipod survival and purple sea urchin embryo development tests were conducted on each sample by SCCWRP and MPSL. Both laboratories conducted the *A. abdita* survival test. In addition, MPSL also conducted 10-day survival tests with another amphipod species, *Rhepoxynius abronius*. The interstitial water test varied significantly in two respects between laboratories. First, MPSL interstitial water samples were stored for one day before tests were initiated. A longer embryo exposure time (96 hours instead of 72 hours) was also used by MPSL.

DATA ANALYSIS

Toxicity data were summarized for each station by calculating the mean and standard deviation of percent amphipod survival or percent normal embryo development among replicates. The sample mean was divided by the respective control mean for the experiment to express the response (survival or normal development) as a percentage of the control response. This normalization procedure reduced variation due to changes in control performance between experiments and facilitated the comparison of results between experiments.

Statistically significant test responses were determined by calculating *t* tests between each sample and the control. A statistically significant result was indicated by a *t* value corresponding to a probability of 0.05 or less. Samples were not identified as toxic based solely on *t* test results. Rather, a threshold of a 20% response relative to the control also had to be attained to identify reliably toxic samples (i.e., only samples having ≤ 80% of the control value were identified as toxic). These criteria have been established by EPA for other EMAP projects (USEPA 1994). Analysis of prior *A. abdita* data by SAIC shows that the use of the 20% response criterion results in about a 90% power to detect a statistically significant difference in survival. (SAIC 1994). SCBPP embryo development samples showing at least a 20% response were significantly different from the control more than 80% of the time.

LOGISTICS AND QUALITY ASSURANCE

LOGISTICS

Amphipod survival tests were successfully conducted on 71 of the 72 samples collected. The remaining sample contained less than one liter of sediment, an insufficient amount for both bulk sediment and interstitial water testing.

Sea urchin embryo development tests were conducted on 50% interstitial water from all SCBPP sediment toxicity samples collected. An insufficient interstitial water volume was obtained from a few samples to permit testing at concentrations of 100% and 50%, however. A total of 69 and 71 stations were tested at 100% and 25%, respectively.

QUALITY ASSURANCE/QUALITY CONTROL

Mean control survival was 91% for all amphipod tests (range: 84-97%) and water quality parameters (DO, pH, salinity, and temperature) were usually within acceptable limits (Table 1). The overlying water ammonia concentration was elevated for many samples (Figure 3). Ammonia concentrations in seawater are usually less than 0.1 mg/L. Individual water quality data for the amphipod tests are listed in Appendix 3.

All sea urchin embryo experiments had acceptable control development (80-89%, mean=85%), temperature, salinity, and DO values (Table 2). Many of the samples had a relatively low pH (≤ 7.5) immediately after centrifugation; these were adjusted to pH 7.6-8.0 with a dilute sodium hydroxide solution before testing. Total ammonia concentration was elevated in many of the samples (Figure 4). No adjustments to the ammonia concentrations were made before testing. Water quality data for individual interstitial water samples are listed in Appendix 4.

Most of the toxicity tests met the criteria established in the SCBPP Quality Assurance Plan. Reference toxicant results for the two types of tests indicated that the test organisms were of similar sensitivity between experiments conducted by each laboratory. Data from SCCWRP and SAIC experiments were checked for accuracy before addition to SCBPP data base files. In addition, a subset of statistical analyses (*t* tests) were independently checked to verify the results.

Two of the amphipod survival tests conducted by SAIC had mean control survival values below the test acceptability criterion of 85%. Control survival in one test was 84%, only slightly below the criterion; Since all SCBPP samples in this experiment had high survival, the samples were not retested. More than 20% of the control amphipods died in the second experiment in question. The data from this experiment were discarded and the test repeated. Retesting resulted in several samples being stored >30 days and tested with less than the desired five replicates (Appendix 5). Percent survival data for the retested samples were similar to those for other stations and this event did not appear to influence the results.

INTERLABORATORY COMPARISONS

SCCWRP-SAIC. Amphipod survival results produced by SCCWRP and SAIC for 16 split SCBPP sediment samples were similar (Figure 5). All samples were classified as nontoxic by both laboratories. Nearly identical survival values were reported by each lab for seven samples.

A slightly higher survival percentage was reported by SAIC for eight samples. This discrepancy was partly due to normalization of the data to the control response. Because control survival of the SAIC amphipods was relatively low in one experiment, normalization of the data increased the survival percentage for some test samples by a relatively large amount. Different control sediment types were used by each laboratory.

SCCWRP-MPSL. A greater range of amphipod survival test responses was obtained with split samples tested by SCCWRP and MPSL. *Ampelisca abdita* test results from each lab were in agreement for five of the six samples regarding their classification as either toxic or nontoxic (Figure 6). Normalized survival percentages were similar for the four samples classified by both laboratories as nontoxic. A large variation in survival percentage was present for the toxic sample (station 85013; Rhine Channel in Newport Bay), however.

Results for another widely used amphipod test species, *Rhepoxynius abronius*, were also provided by MPSL. There was a similar level of agreement in site classifications when data from the different species were used. Site classifications based on *Rhepoxynius abronius* data agreed with *Ampelisca abdita* results from SCCWRP or MPSL for four or five stations, respectively (Figure 6). There were no consistent trends in sensitivity between species.

Greater variability between laboratories was obtained for the interstitial water toxicity results. Using 80% of the control response as a criterion, MPSL and SCCWRP classified three or four of the six samples similarly, depending upon interstitial water concentration. SCCWRP results usually showed much greater responses to the samples when tested at the 50% and 100% concentrations (Table 3). At 25% interstitial water, MPSL and SCCWRP classified four of six samples similarly (3 nontoxic and 1 toxic; Figure 7). SCCWRP tests of 25% interstitial water samples were relatively more sensitive than MPSL for two samples (stations 85013 and 85015), while MPSL results for station 95015 were much more sensitive.

Variations in interstitial water quality measurements were also present between laboratories (Table 4). The average pH of water samples was about 0.1 units higher in SCCWRP samples. Initial pH was about 0.3 units lower and final pH about 0.3 units higher in SCCWRP samples. Some variations in pH may have occurred as a result of initial pH adjustments made at SCCWRP (MPSL did not adjust pH). Total ammonia concentrations were elevated above seawater values in interstitial water samples analyzed by both laboratories, but measured values were always higher in SCCWRP samples. Variations in pH and total ammonia concentration increased the concentration of unionized ammonia present in SCCWRP samples. As a result, unionized ammonia concentrations were usually 2-3 times higher in SCCWRP samples (Table 4).

Unionized ammonia concentrations were sufficient to cause the toxic effects in all SCCWRP samples showing reduced embryo development. The concentration of unionized ammonia in most of the 50% and 25% MPSL samples was below the levels likely to cause substantial toxicity (about 0.05 mg/L), indicating that the reduced embryo development seen in some samples was probably due to other factors.

MPSL used the same reference toxicant (copper chloride) as SCCWRP, enabling an additional comparison of test sensitivity. Typical reference toxicant results (EC50s) for MPSL ranged from 10-28 µg/L. MPSL reference toxicant data were similar to SCCWRP values, which ranged from 10-23 µg/L.

TOXICITY ASSESSMENT

SEDIMENT

Amphipod survival was high in all samples tested, ranging from 80-98% (Appendix 5). Statistically significant reductions in survival were identified for six samples. None of the 71 samples were identified as toxic, however, as amphipod survival was >80% of the control for all samples (Figure 8).

No trends were evident when the survival data were examined by region or POTW area. Survival values in the north region (no large sewage discharges) were similar to those in the more highly urbanized central and south regions. Sediment from sites located in POTW monitoring areas produced similar survival percentages compared to other locations.

INTERSTITIAL WATER

In contrast to the amphipod survival test data, sea urchin embryo development was affected by interstitial water from many sediment samples. Most of the 100% interstitial water samples produced less than 50% normal development in embryos (Figure 9), with many samples containing less than 5% normal embryos. Even a majority of the samples diluted to 25% interstitial water produced substantial effects on embryo development (Figure 10). Effects on embryo development were produced by the 25% interstitial water samples from all three geographic regions and did not appear to have any relationship to POTW areas (Figure 10).

The interstitial water dilutions produced a typical dose-response pattern of effect for most samples (i.e., greater effects were produced by higher sample concentrations). Embryos from only a single replicate were examined for samples having a greater interstitial water concentration than a group from the same station which produced less than 5% normal development (e.g., a single replicate was examined for 100 and 50% samples from station 1049 since the 25% sample produced 0% normal development). Embryo development data for individual samples are listed in Appendix 6.

Many of the interstitial water samples contained elevated ammonia concentrations, even when diluted two- or four-fold (Figure 4). Typical total ammonia concentrations in seawater are less than 0.1 mg/L. There appeared to be a correspondence between ammonia concentration and embryo toxicity for many of the samples. Strong effects on embryo development were consistently present whenever the total ammonia concentration exceeded about 3 mg/L. A similar relationship was found when embryo toxicity was compared to the concentration of unionized ammonia (NH_3), which is generally thought to be the form toxic to marine life (Figure 11). Embryo development was always greatly reduced in samples containing >0.1 mg/L of unionized ammonia. Subsequent analyses of the interstitial water toxicity data were limited to the 25% samples in order to minimize the influence of ammonia and provide better discrimination between stations.

Three additional toxicity tests were conducted to measure the toxicity of ammonia to purple sea urchin embryos (Greenstein *et al* 1996). The results of these experiments show that sea urchin embryos are adversely affected by ammonia at concentrations above 0.06 mg/L unionized ammonia (Figure 12), which is lower than the concentration measured in many SCBPP interstitial water samples. The presence of ammonia was therefore identified as a major factor in the sea urchin embryo toxicity data.

A regression approach was used to determine if the interstitial water test results were influenced by chemical factors other than ammonia. This approach consisted of several steps. First, a logistic regression was fitted to the unionized ammonia and embryo development data for the 25% interstitial water samples (three outlier data points were excluded from the analysis). The regression model accounted for 79% of the variation in the data. Next, the 99% confidence interval was calculated for the regression and compared to the toxicity data (Figure 13). In the final step, the 25% interstitial water samples were classified into the following three groups based on their ammonia concentration and toxicity relative to the lower bound of the 99% CI:

> Indeterminate: samples containing ≥0.08 mg/L unionized ammonia and <10% normal development. Toxicity from factors other than ammonia could not be evaluated because ammonia concentrations were high enough to mask any additional response.
>
> Nontoxic: samples with a percent normal development greater than that predicted from the lower 99% confidence limit of the ammonia regression. Any toxicity in these samples could be attributed to the presence of ammonia.
>
> Toxic: samples containing <0.08 mg/L unionized ammonia and a percent normal development below the 99% CI of the ammonia regression. These samples showed an effect greater than that expected solely from the presence of ammonia.

This procedure was able to evaluate (as toxic or nontoxic) 53 of the 71 samples tested (Figure 13). The remaining samples were classified as indeterminate because of high ammonia concentration.

Fifteen samples were classified as toxic. The measured percent normal for these samples usually differed from the predicted value by at least 10% (Appendix 7). Most of the samples classified as nontoxic had percent normal values within the 99% confidence interval based on ammonia concentration. There were a few samples with percent normal development values greater than would be expected based on the unionized ammonia concentration.

A majority of the samples identified as toxic were located in the northern region (Figure 14). The two samples with the greatest interstitial water effect from factors other than ammonia were located in the northern region. All of the five sites identified as toxic in the central region were located in Santa Monica Bay, with four of these located within the POTW area (Figure 15). The remaining toxic site was located in the southern region, within the POTW area off of Point Loma (Figure 16).

DISCUSSION

SCB SEDIMENT QUALITY

Whole sediment. Toxicity tests using survival of the amphipod, *Ampelisca abdita*, provide the most reliable measure of SCBPP sediment quality since the test is standardized, uses an ecologically relevant exposure method, and measures a clearly adverse response (mortality). The amphipod test results indicated good sediment quality at all sites tested. While sediment from some sites caused a statistically significant increase in amphipod mortality relative to the control, none of the effects were sufficiently large to meet the criterion established for toxicity (≥20% mortality).

Comparisons with previous data are difficult since most SCBPP stations were located in areas not previously tested for sediment toxicity. Prior studies have used different amphipod species and examined sediment only from stations near sewage outfalls in Orange County, off PV, and in Santa Monica Bay (Anderson *et al*. 1988, Bay *et al*. 1994, SCCWRP 1992). No significant mortality was measured when the amphipod, *Rhepoxynius abronius* was exposed to sediment from five stations off PV (Bay *et al*. 1994). Exposure to sediment from a station nearest the PV outfall system reduced *R. abronius* survival by 15%, similar to the 10% reduction measured for the nearby SCBPP station (1267). SCBPP results are also consistent with research by Swartz *et al*. (1986) that documented a reduction in PV sediment toxicity between 1980 and 1983.

Prior amphipod toxicity tests conducted on sediments collected near the Orange County and Santa Monica Bay outfall systems also agree with SCBPP results. Research conducted by SCCWRP using the amphipod, *Grandidierella japonica*, document an improvement in sediment quality in Santa Monica Bay following the termination of sewage sludge disposal in 1987 (SCCWRP 1992). Santa Monica Bay sediment samples collected in 1989 from several stations along the 100 meter depth contour did not produce statistically significant effects on *G. japonica* survival or growth. Similarly, no significant effect on *G. japonica* survival was produced by sediment collected near the Orange County Sanitation Districts outfall (Anderson *et al*. 1988).

Interstitial water. While sediment toxicity tests with amphipods provide ecologically relevant data, these tests do not measure sublethal effects. Interstitial water toxicity tests using sea urchin embryos were included in the SCBPP to provide a more sensitive measure of sediment quality. While adverse effects on sea urchin embryo development were produced by many interstitial water samples, most of the effects were produced by elevated ammonia concentrations.

Ammonia toxicity in this study was treated as an interference, rather than a consequence of anthropogenic activity, for several reasons. First, increased interstitial water ammonia did not arise directly from POTW discharges, but was the product of natural metabolic processes in the sediment. Second, sea urchin embryos are relatively sensitive to ammonia (Bay *et al*. 1993) and may not provide a meaningful assessment of sediment toxicity for benthic organisms that are more tolerant to this compound (Kohn *et al.* 1994). Finally, recent SCCWRP research indicates that storage and homogenization of SCBPP samples probably increased interstitial water ammonia concentrations, creating a toxicity artifact unrelated to actual sediment quality (Greenstein *et al* 1996). Ammonia has been identified as confounding factor in other sediment toxicity studies using the sea urchin embryo test (Anderson *et al* 1997, Fairey *et al* 1998).

Evidence of interstitial water toxicity from factors other than ammonia was present in 21% of the samples tested. The areal extent of toxicity was not calculated because data for a large number of stations (25%) were inconclusive as a result of ammonia interference.

The spatial distribution of toxic stations suggests the influence of both regional factors and POTW discharges. Most of the toxic samples represented stations located in the northern region (Point Dume–Point Conception), an area lacking large POTW or industrial discharges (Figure 14). There are no prior interstitial water toxicity data from this area available for comparison. All of the toxic interstitial water samples from the central and southern regions were located relatively close to POTW outfall systems in Santa Monica Bay or off Point Loma (Figures 15 and 16). Once again, no prior interstitial water toxicity data are available for these specific stations.

There is previous evidence of outfall-related interstitial water toxicity in southern California sediments, however. Interstitial water toxicity was present in sediment samples collected within 2 km of the PV outfall system and analyzed using a sea urchin fertilization test (SCCWRP 1994). The fertilization test results were not subject to the ammonia interference encountered during the SCBPP.

The differences in response observed between the amphipod and sea urchin embryo tests are not unusual. Interstitial water toxicity tests have shown a greater sensitivity and different pattern of response relative to the amphipod test in other studies (Carr *et al* 1996a, Fairey *et al* 1998, Long *et al* 1998). These differences are to be expected since different life stages and media are tested in each type of test.

COMPARISON TO OTHER AREAS

Toxicity tests have been used in other locations throughout the nation to assess sediment quality. In southern California, sediment toxicity has been evaluated in coastal bays and harbors through studies conducted by the State Water Resources Control Board and NOAA. The results of these studies show a greater incidence of sediment toxicity compared to SCBPP results. For example, in a study of eight coastal lagoons, estuaries, and marinas conducted in 1994 using similar test procedures, 53% and 51% of the area was toxic to amphipods and sea urchin embryos, respectively (Anderson *et al* 1997). Among southern California's coastal water bodies, the greatest extent of toxicity to amphipods has been reported for San Diego Bay, where 56% of the area was significantly toxic (Fairey *et al* 1998).

Toxic sediments have also been reported for a variety of locations nationwide. On average, about 11% of sediments in coastal areas (mostly estuaries) of the United States are toxic to amphipods (Long *et al* 1996).

RELATIONSHIP TO OTHER INDICATORS

Benthic infauna. Ninety three percent of the stations tested for toxicity had benthic infaunal communities that were characteristic of reference areas. This percentage is similar to that found for all SCBPP stations (Bergen *et al* 1998). The low incidence of altered benthos is in good agreement with the results of the amphipod toxicity tests, which classified all stations as nontoxic.

There was a poor correspondence between the toxicity classifications based on the interstitial water results and infaunal communities, however. All of the stations identified as toxic using the 25% interstitial water results (after adjustment for ammonia toxicity) were classified as reference using the benthic response index. Altered infaunal communities were present at four stations, all of which were classified as nontoxic to sea urchin embryos. The absence of altered infaunal communities at stations identified as toxic suggests that any differences in interstitial water quality were not of a sufficient duration or magnitude to produce substantial changes in populations of resident infauna.

Sediment chemistry. Over 90% of the stations tested for toxicity contained elevated concentrations of at least one contaminant, primarily total DDT or total PCB (Schiff and Gossett 1998), but there was little correspondence to the toxicity data. Application of the sediment quality guidelines developed by NOAA (Long *et al* 1995) identified 14 stations (20% of total) that exceeded the effects range-median (ER-M) for at least one chemical, with total DDT responsible for almost all exceedences (Table 5). Sediment concentration relative to the ER-M was not predictive of amphipod toxicity as none of the stations were classified as toxic. Interstitial water toxicity data also showed a poor correspondence with the ER-M guidelines. Exceedence of the total DDT ER-M successfully predicted toxicity in only 47% of the stations (Table 5).

A weak association between sediment contamination and interstitial water toxicity was indicated for several chemicals when the mean concentrations for toxic and nontoxic samples were compared (Table 6). The mean contaminant concentration of the toxic sample group tended to be higher for most analytes and were significantly different from the nontoxic group for arsenic, cadmium, chromium, lead, nickel, zinc, and PCB1242. The concentration differences were less than a factor of two in most cases.

The differences in response between the toxicity, benthic infauna, and sediment chemistry indicators may be due to a number of factors. One important factor is the predictive ability of the ER-Ms. An ER-M represents the median value in the distribution of effects for a chemical; these thresholds were never intended to represent values where biological effects would always be expected to occur. A recent comparison of toxicity and chemistry data by Long *et al* (1998) found that the predictive ability of ER-Ms is improved when multiple ER-M values are exceeded in a sample. Long *et al* (1998) found little difference in the incidence of toxicity between samples with zero or one ER-M exceedence; the occurrence of false negatives (toxicity without ER-M exceedence) was also reported to be as high as 60% for some test methods. Most of the SCBPP samples tested for toxicity had either zero or one ER-M exceedence, an area where the predictive ability of the ER-M is lowest.

A better relationship between chemistry and toxicity may have been found if interstitial water chemistry had been measured. The partitioning of chemicals between sediment particles and interstitial water is affected by a number of factors, such as oxidation state and the amount and type of organic carbon present. It is likely that contaminant partitioning between sediment and interstitial water varied between stations as the result of differences in sediment characteristics or laboratory handling. These differences may have obscured relationships between sediment contaminant concentrations and toxicity.

DATA COMPARABILITY

Interlaboratory comparisons conducted between SCCWRP and SAIC or MPSL provide a measure of data comparability between laboratories. Amphipod test data from the different laboratories resulted in similar classifications of split samples as toxic or nontoxic. In addition, data from MPSL suggests that the results from tests using different amphipod species are often similar.

Some split samples analyzed by SAIC were biased towards a higher survival percentage compared to SCCWRP data. This discrepancy appeared to be related to the use of different control sediments by each laboratory. Control survival was usually lower in SAIC tests, which tended to increase the percent survival value when the data were normalized to the control response.

Interlaboratory comparison results for interstitial water toxicity suggest a greater degree of variability exists between laboratories. Although four of six interstitial water samples were classified similarly by SCCWRP and MPSL, percent normal values varied for some samples and there was a consistent bias towards greater toxicity in the SCCWRP results. Variations in unionized ammonia concentrations between laboratories probably accounted for much of the variability in the results. The cause of the variation in ammonia is unknown, but may be related to differences in sediment or interstitial water handling (samples were stored for one day after centrifugation by MPSL and pH adjustments were used by SCCWRP).

It is possible that other important interstitial water constituents besides ammonia are affected by sediment handling. Variations in toxicity produced by the use of different interstitial water collection and storage methods have been reported by others (Ankley and Schubauer-Berigan 1994, Carr and Chapman 1995). Failure to account for the toxic effects of ammonia and other interstitial water constituents affected by sample handling may reduce the interand intralaboratory comparability of interstitial water toxicity data.

Sediment storage and other handling methods are also important variables in whole sediment toxicity tests. Sediment toxicity to has been shown to vary unpredictably with differences in storage time and temperature (Becker and Ginn 1995, Dillon *et al*. 1994, Malueg *et al*. 1986).

CONCLUSIONS

1. No acute sediment toxicity was detected throughout the Southern California Bight.

- No significant mortality was detected in 71 samples evaluated using a 10-day amphipod (*Ampelisca abdita*) survival test.
- These results are consistent with the limited previous data available for selected portions of the study area.
- A greater incidence of toxicity is present in southern California bays and harbors, which were not sampled in this study.

2. Evidence of sublethal toxicity was present in some areas.

- Interstitial water samples were toxic to developing sea urchin (*Strongylocentrotus purpuratus*) embryos.
- Most of the toxicity was attributable to increased ammonia concentrations resulting from sediment storage.
- Correction of the data for ammonia effects identified 15 stations with toxicity due to other interstitial water constituents.

3. The spatial pattern of interstitial water toxicity was influenced by both regional factors and proximity to POTW discharges.

- Most of the toxic stations were located in the northern region, away from large point source discharges.
- Toxic stations in the central and southern regions were located near large POTW discharges.

4. The acute toxicity data were comparable between laboratories.

- Two interlaboratory comparisons of the amphipod test were conducted and yielded similar results between laboratories.

5. Interstitial water toxicity test results were variable between laboratories.

- Much of the variation between laboratories was due to differences in water quality parameters (e.g. ammonia and pH) produced by differences in sample storage and handling conditions.

RECOMMENDATIONS

The SCBPP demonstrated that sediment toxicity tests were feasible to include in a cooperative regional monitoring program. Sediment toxicity tests were conducted on 72 samples and the results provided the first synoptic measure of sediment toxicity on the coastal shelf of the SCB. Although quality assurance objectives were met for the tests in most instances, interpretation of the data were limited by several factors. The presence of elevated ammonia concentrations in interstitial water samples limited the number of stations that could be evaluated for sublethal toxicity and may have affected the accuracy of the results. Sediment toxicity was not measured at all SCBPP stations, which resulted in a reduced data set that could be used to investigate relationships between toxicity, chemistry, and benthic infauna. Several modifications to the survey design have been identified that would enhance the usefulness of the sediment toxicity data. These are detailed below.

1. Assess temporal trends in sediment toxicity by conducting periodic surveys.

This study represented the first assessment of sediment toxicity throughout the Southern California Bight. While good sediment quality was indicated by the whole sediment test results, interstitial water toxicity was indicated in several areas. Repeating the survey on a periodic basis will provide information needed to evaluate whether sediment toxicity in the SCB is changing over time and whether changes in toxicity correspond with changes in benthic infauna or chemistry.

2. Incorporate sediment toxicity into the full sampling design in future surveys.

Sediment toxicity testing was included in only a subset of the SCBPP samples. The 1994 survey demonstrated that sediment toxicity testing was feasible to include in a cooperative regional survey program, but the interpretation of the data were limited by the reduced number of stations sampled. Inclusion of sediment toxicity at the same level of effort as sediment chemistry and benthic infauna analyses will result in a better dataset for examining relationships between toxicity and other indicators of effect.

3. Modify sample handling and interstitial water test procedures to minimize interferences.

The ecological relevance of toxicity tests is enhanced by measuring samples that accurately represent the study site. SCBPP interstitial water test results demonstrated that typical sediment storage and handling conditions can influence interstitial water composition and toxicity. Additional research is needed to identify storage and handling conditions that minimize changes in sediment chemistry and toxicity. In lieu of additional data, sediment holding times should be shortened to minimize changes during storage. The application of alternate test procedures should also be considered in future studies. The use of methods with less sensitivity to ammonia or other noncontaminant factors, such as the sea urchin fertilization test, may minimize the occurrence of artifactual results.

4. Include harbors and bays in future surveys.

Sediment toxicity is more prevalent in southern California bays and harbors than in the offshore area studied in the SCBPP. The inclusion of bays and harbors will provide a more complete assessment of sediment quality in the SCB and provide environmental managers with the information needed to identify areas of greatest concern.

5. Measure interstitial water chemistry.

Interstitial water toxicity tests are one of the most sensitive measures of sediment quality available. The relationship between sediment contamination and interstitial water toxicity is frequently uncertain because most chemical analyses do not accurately measure the exposure the organism is receiving. The concentration of contaminants in interstitial water is a more relevant measure of organism exposure and inclusion of these measurements in future studies would provide better information for identifying specific contaminants associated with interstitial water toxicity.

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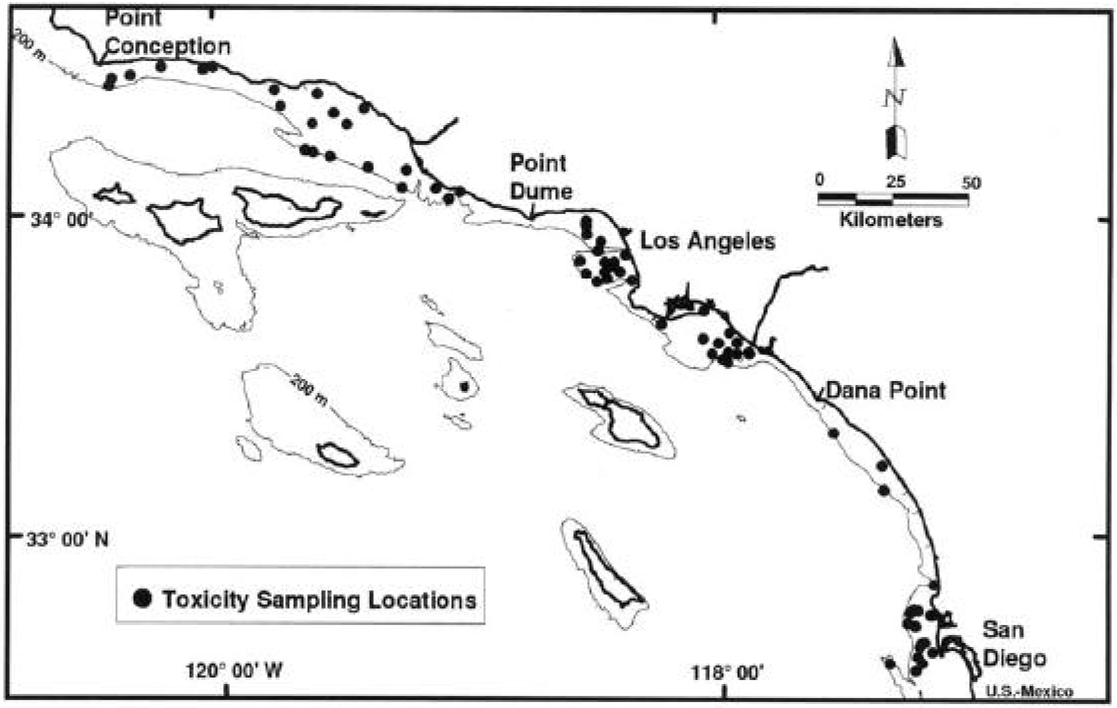

Figure 1. Location of SCBPP stations used for sediment toxicity assessment.

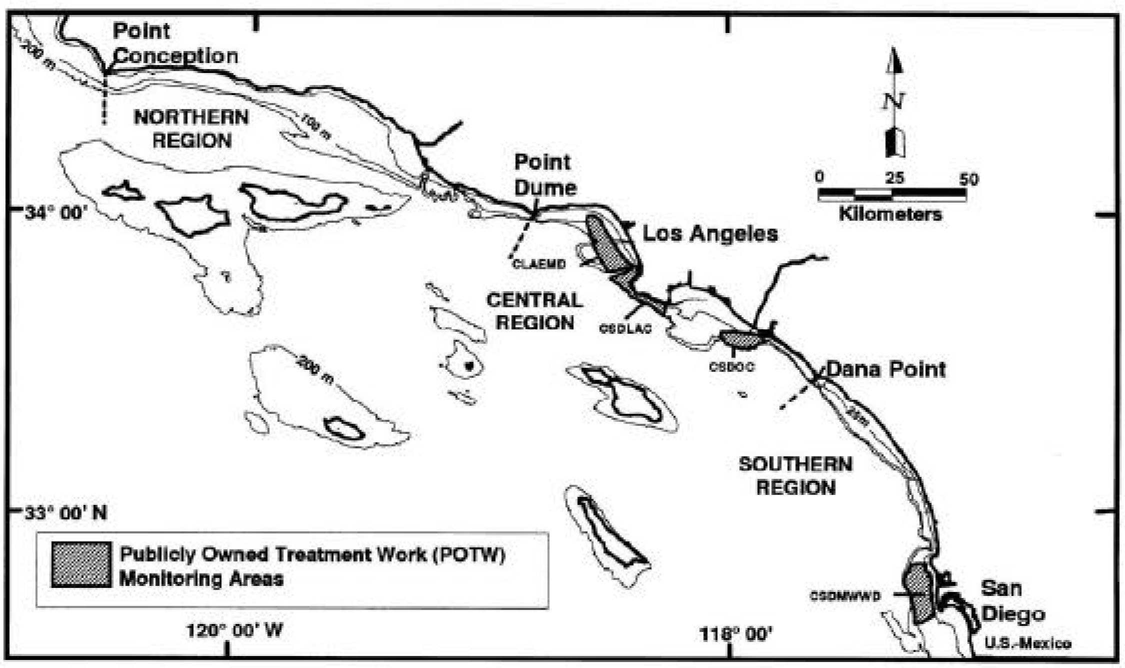

Figure 2. Distribution of subpopulations for regions and POTW monitoring areas used in sediment toxicity survey. CLAEMD = City of Los Angeles, Environmental Monitoring Division; CSDLAC = County Sanitation Districts of Los Angeles County; CSDMWWD = City of San Diego, Metropolitan Wastewater Department; CSDOC = County Sanitation Districts of Orange County.

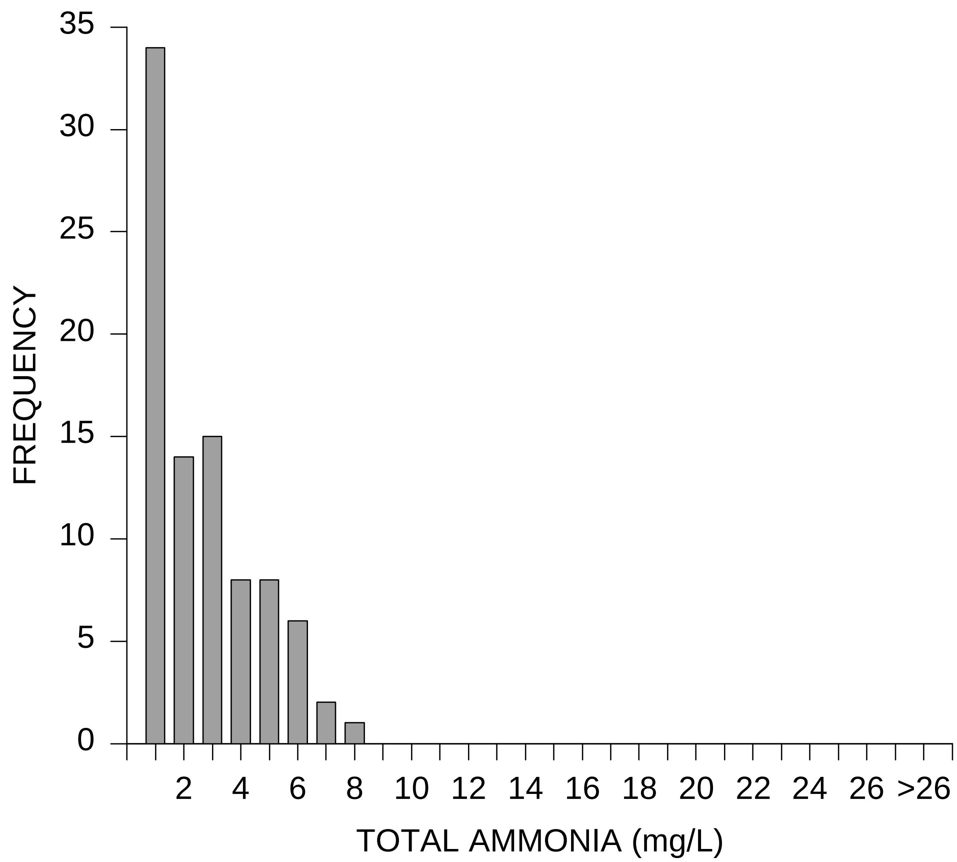

Figure 3. Overlying water ammonia concentration in amphipod toxicity tests. Labels for the x-axis indicate the maximum value for each ammonia interval.

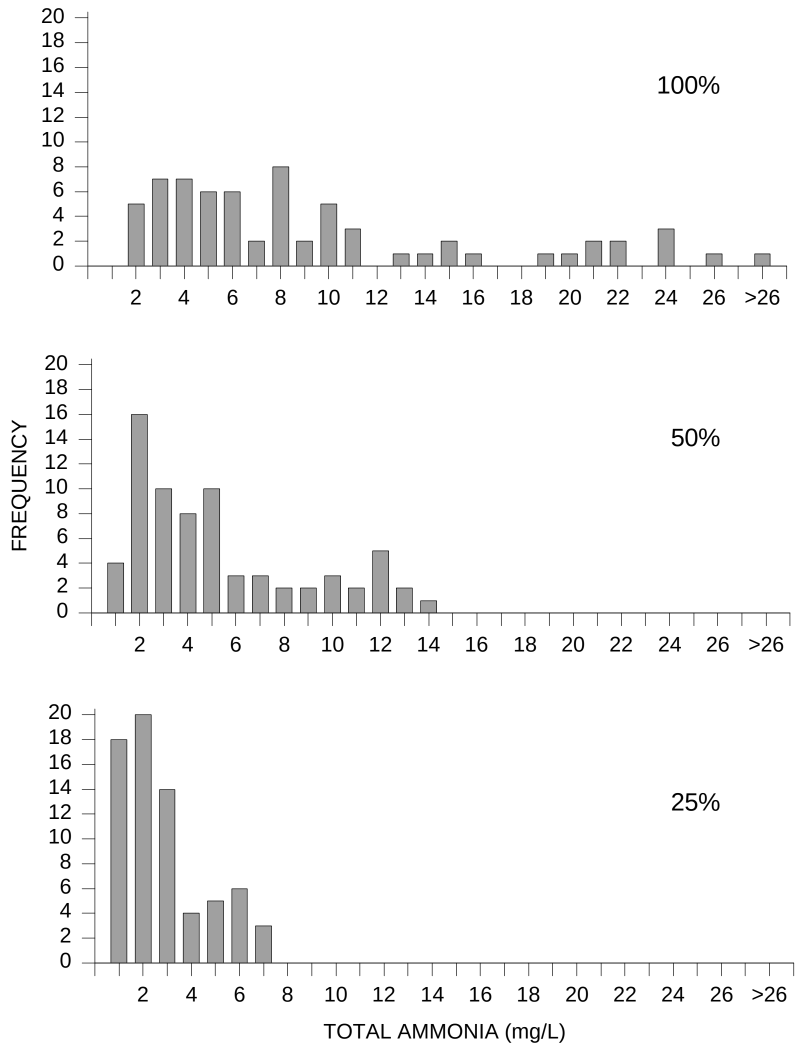

Figure 4. Ammonia concentration in interstitial water samples used in sea urchin embryo toxicity tests. Labels for x-axis indicate maximum concentration for each interval.

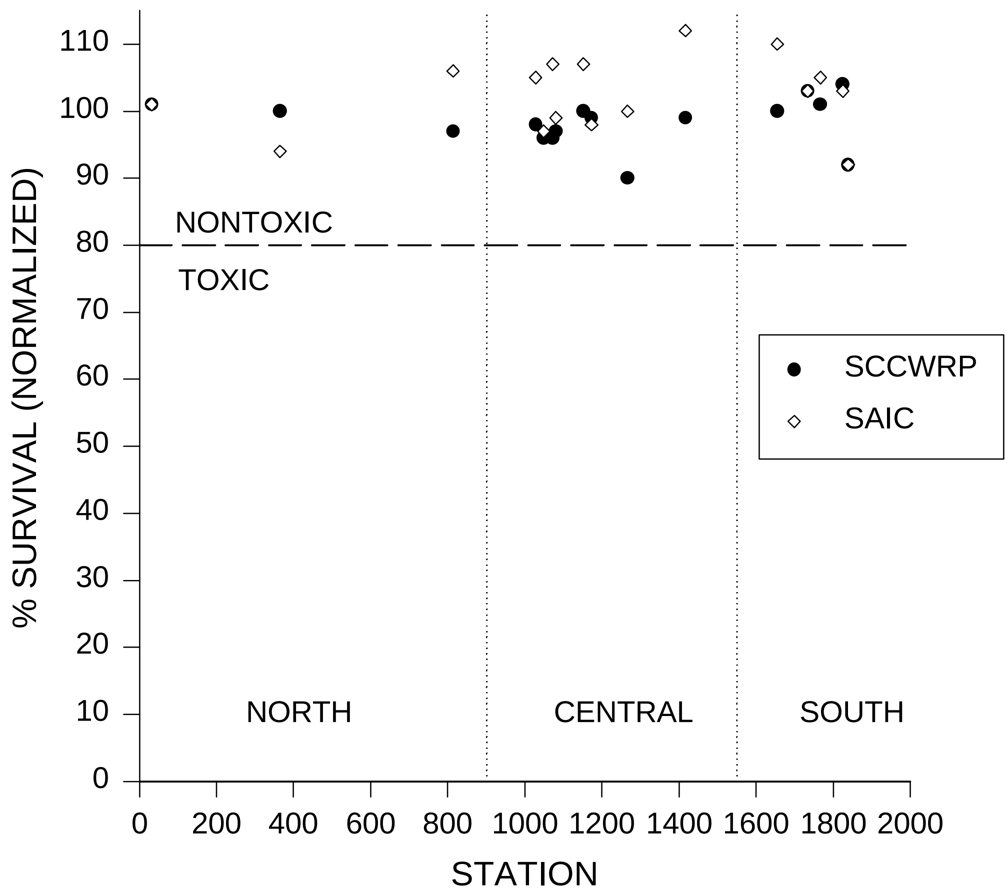

Figure 5. Comparison of Ampelisca abdita survival in interlaboratory QA tests.

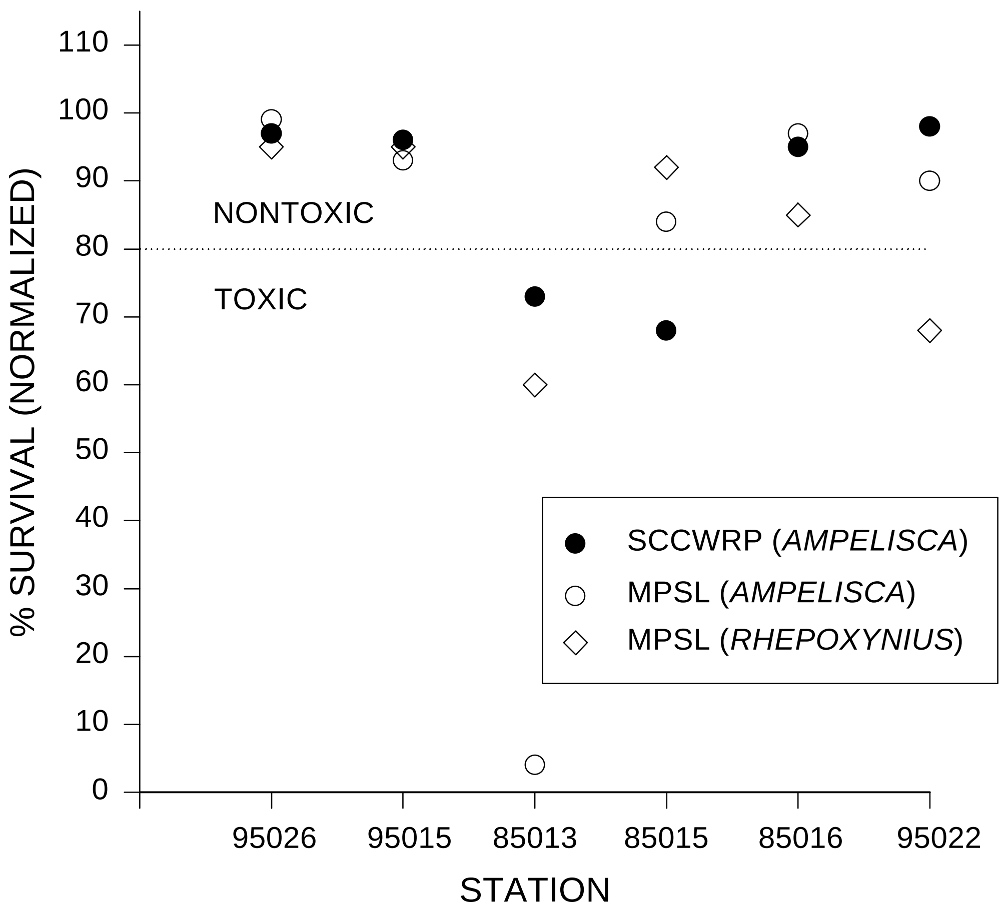

Figure 6. Comparison of amphipod survival in interlaboratory QA tests between SCBPP and California Bays and Estuaries EMAP programs.

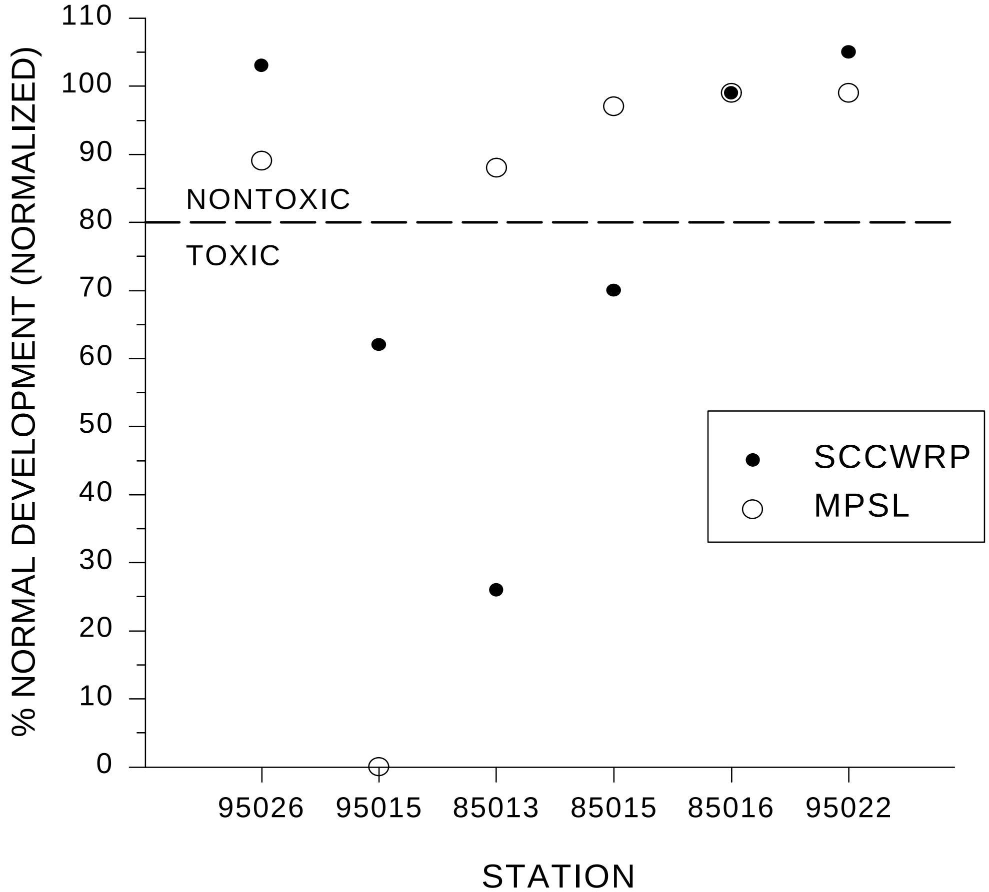

Figure 7. Comparison of Strongylocentrotus purpuratus embryo development in interlaboratory QA tests between SCBPP and California

shown.

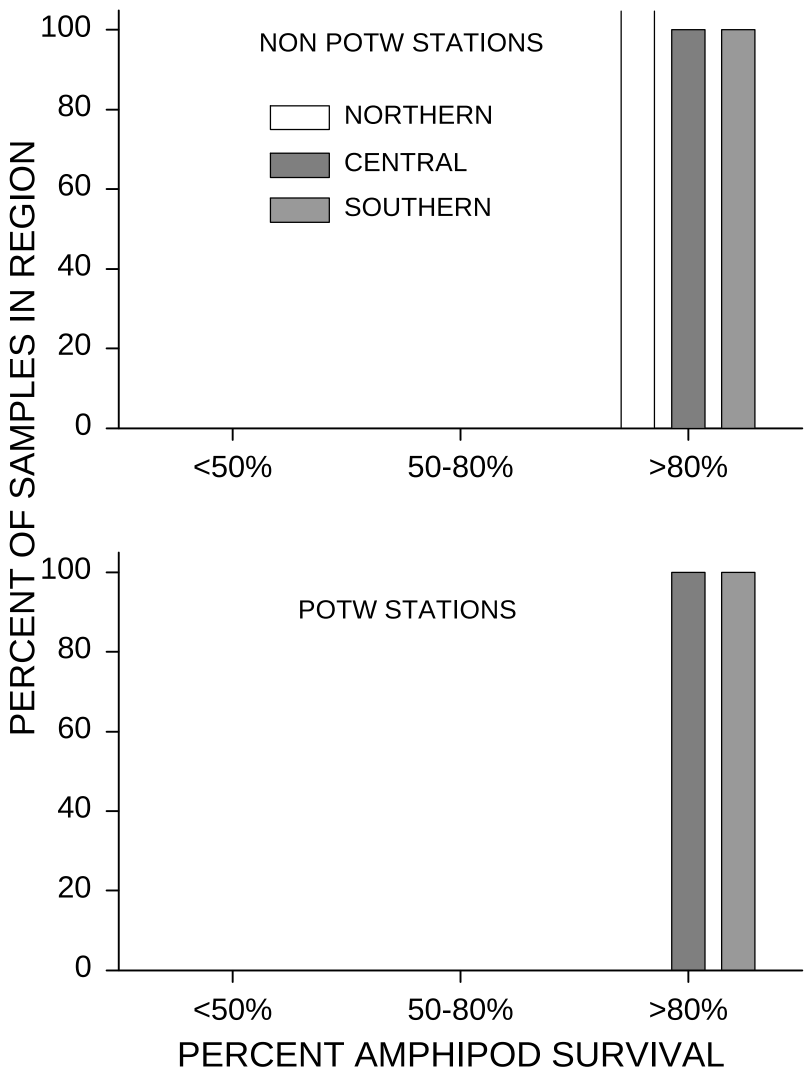

Figure 8. Amphipod toxicity test results for whole sediment for the SCBPP Survey. The results are grouped in categories corresponding to no toxicity (>80% survival), moderate toxicity (50-80% survival), and high toxicity (<50% survival).

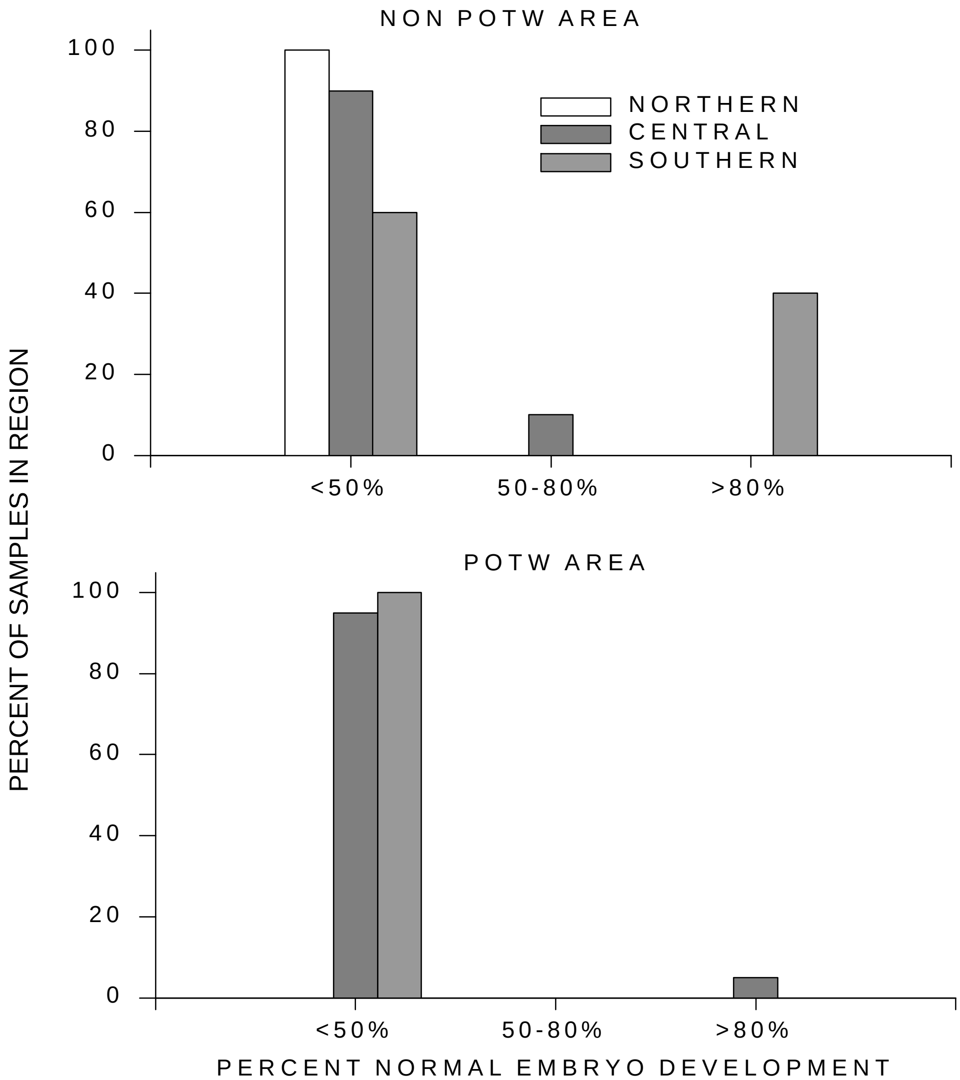

Figure 9. Purple sea urchin embryo toxicity test results for 100% interstitial water for the SCBPP Survey. The results are grouped in categories corresponding to no toxicity (>80% normal development), moderate toxicity (50-80% normal development), and high toxicity (<50% normal development).

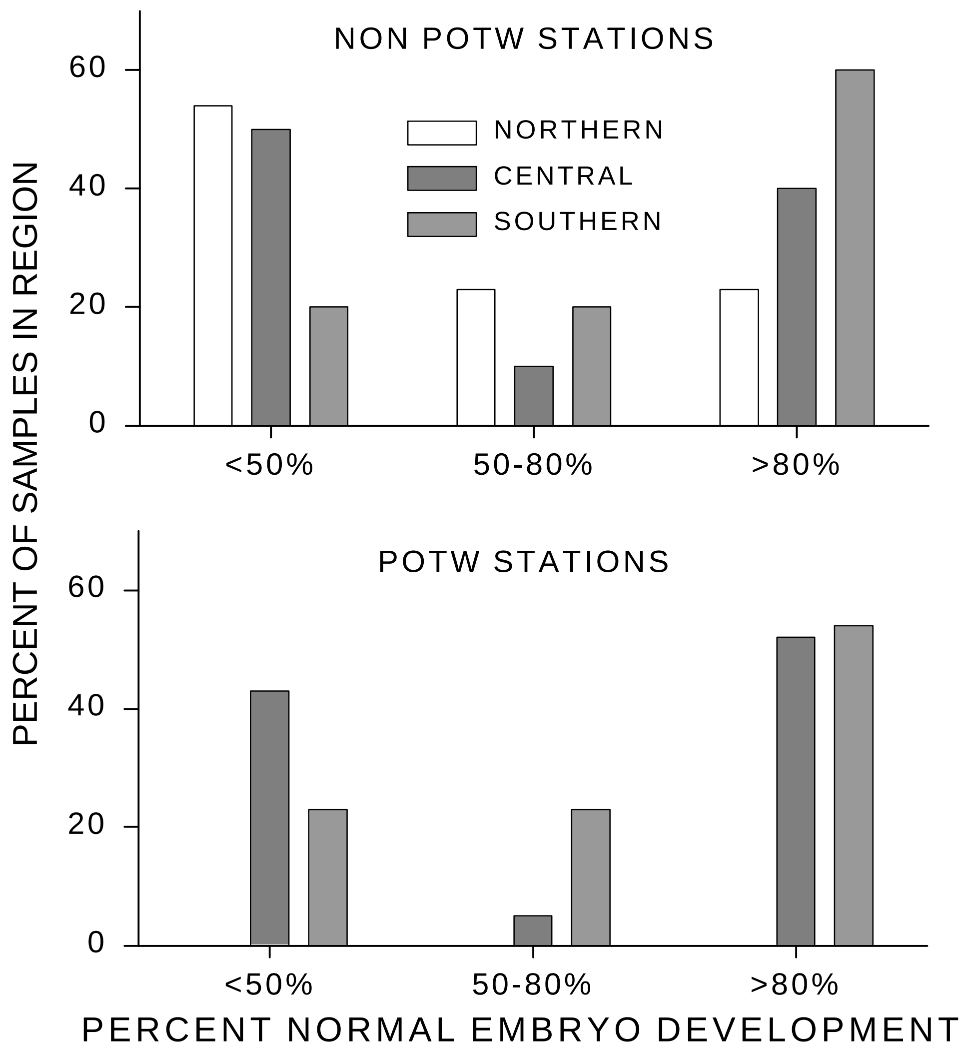

Figure 10. Purple sea urchin embryo toxicity test results for 25% interstitial water for the SCBPP Survey. The results are grouped in categories corresponding to no toxicity (>80% normal development), moderate toxicity (50-80% normal development), and high toxicity (<50% normal development).

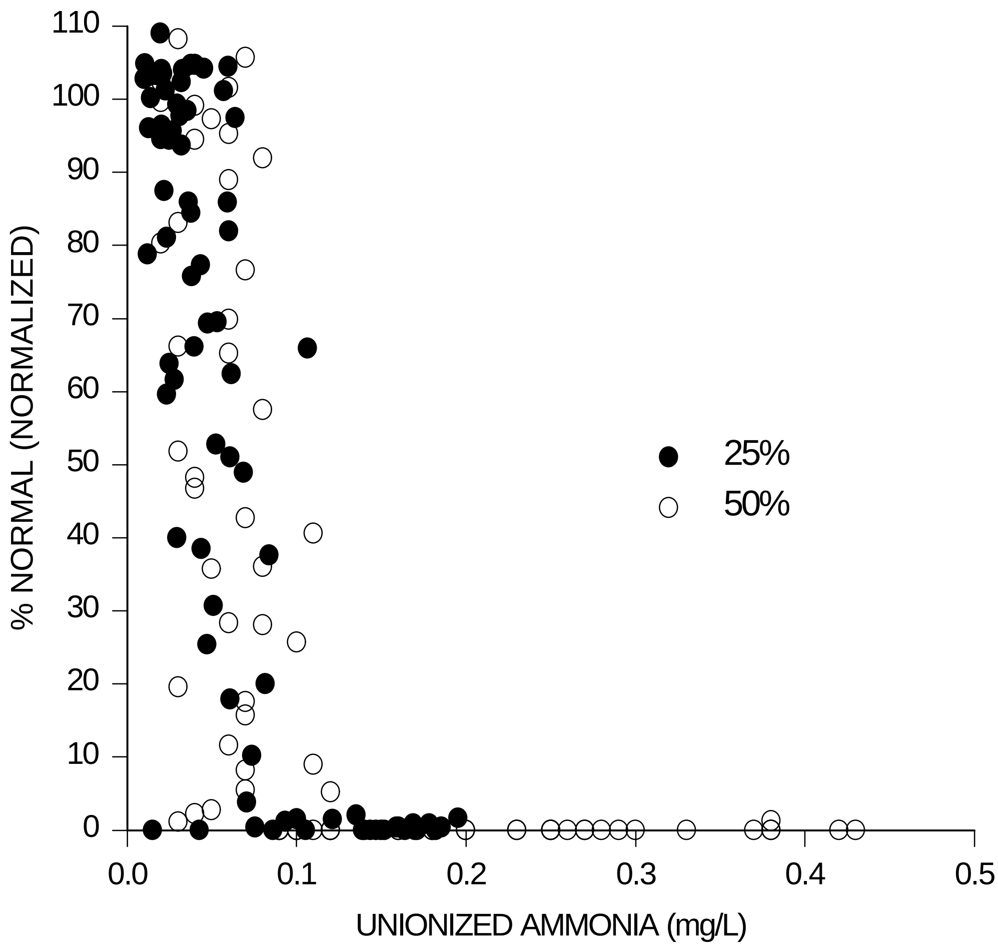

Figure 11. Relationship between sea urchin development and unionized ammonia in 25% and 50% interstitial water samples.

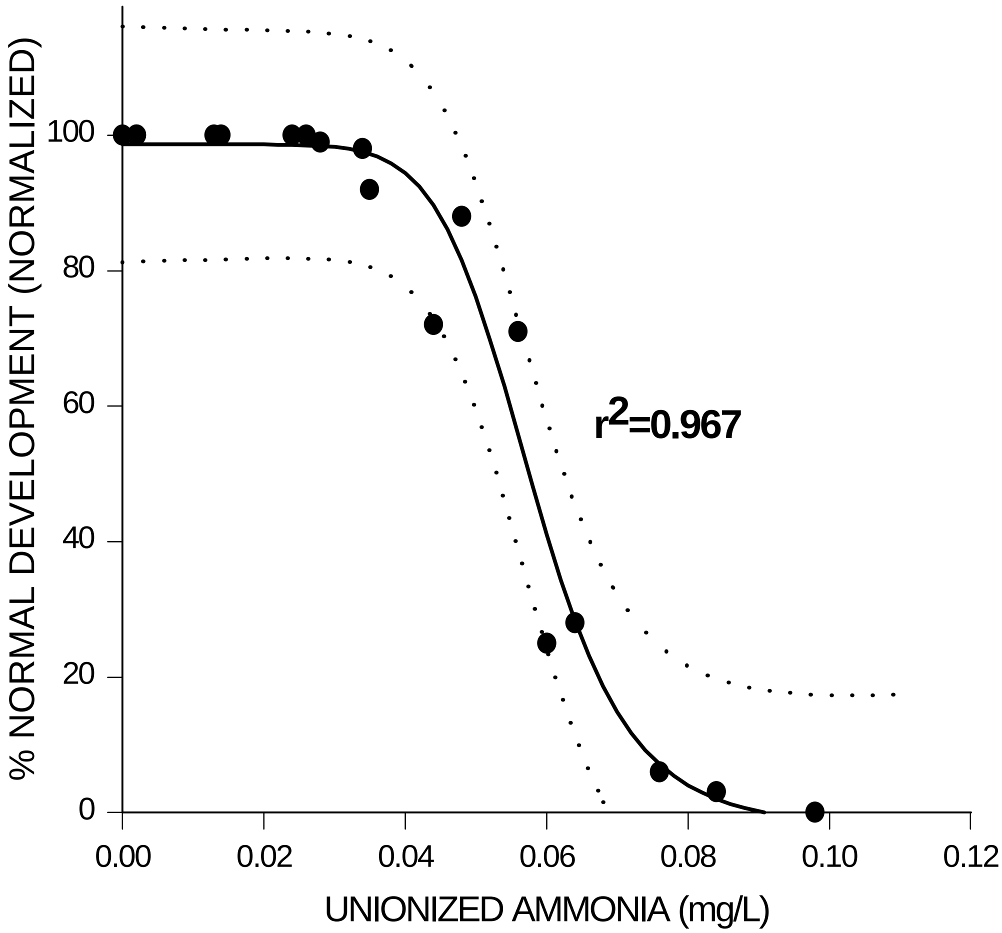

Figure 12. Response of sea urchin embryos to seawater spiked with ammonia. Lines represent predicted values ±95% confidence interval from logistic regression.

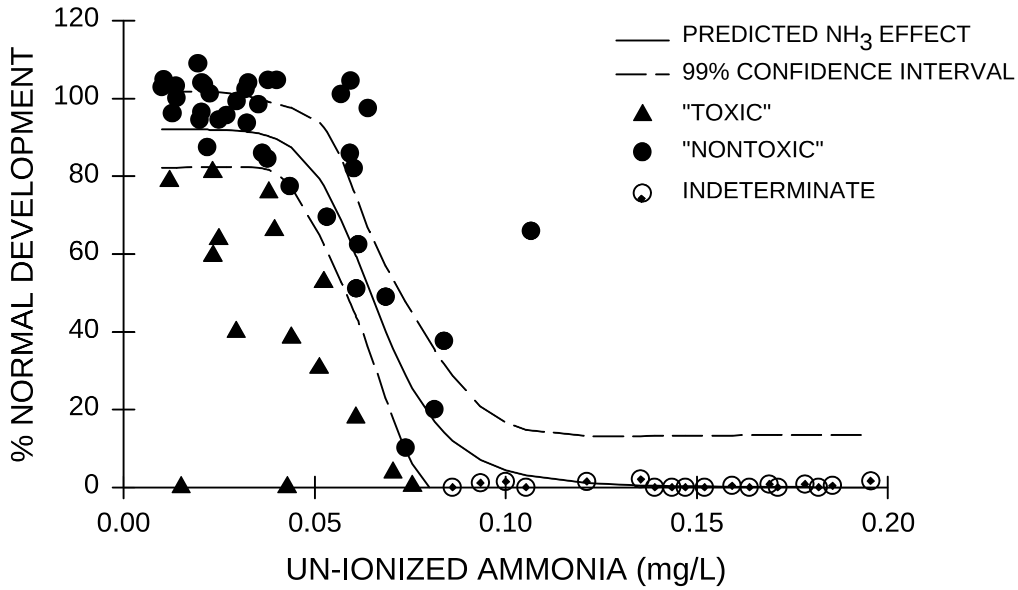

Figure 13. Classification of 25% interstitial water samples using lower 99% confidence interval (dashed line) of predicted embryo response to ammonia.

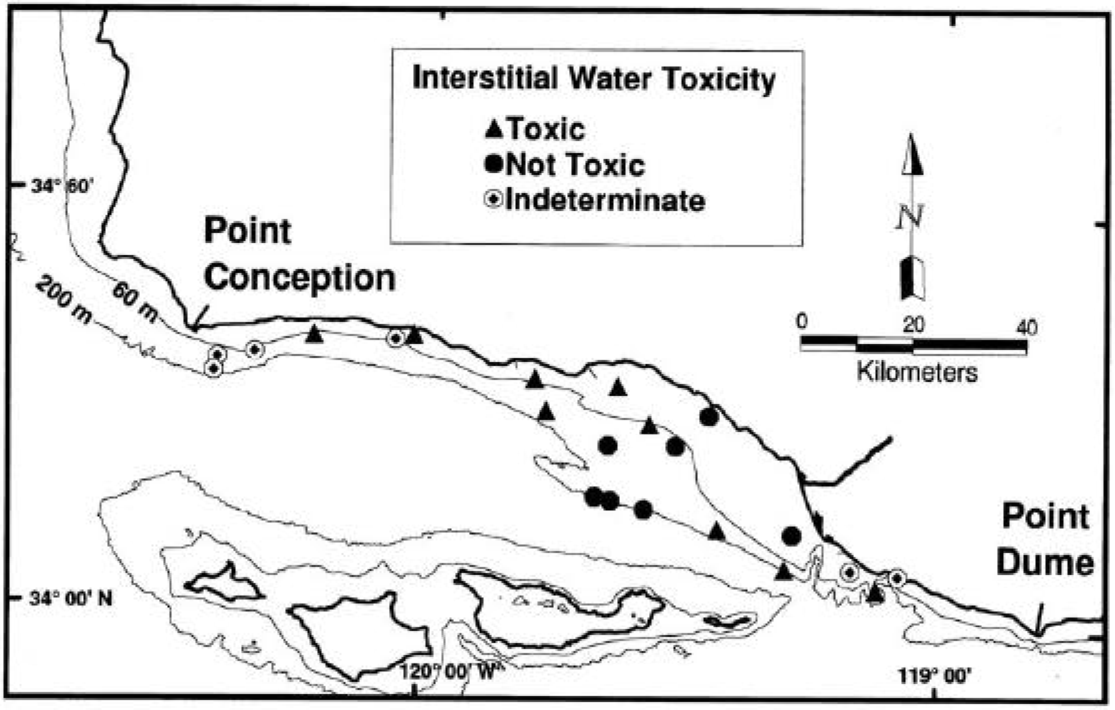

Figure 14. Location of toxic SCBPP interstitial water samples in northern region.

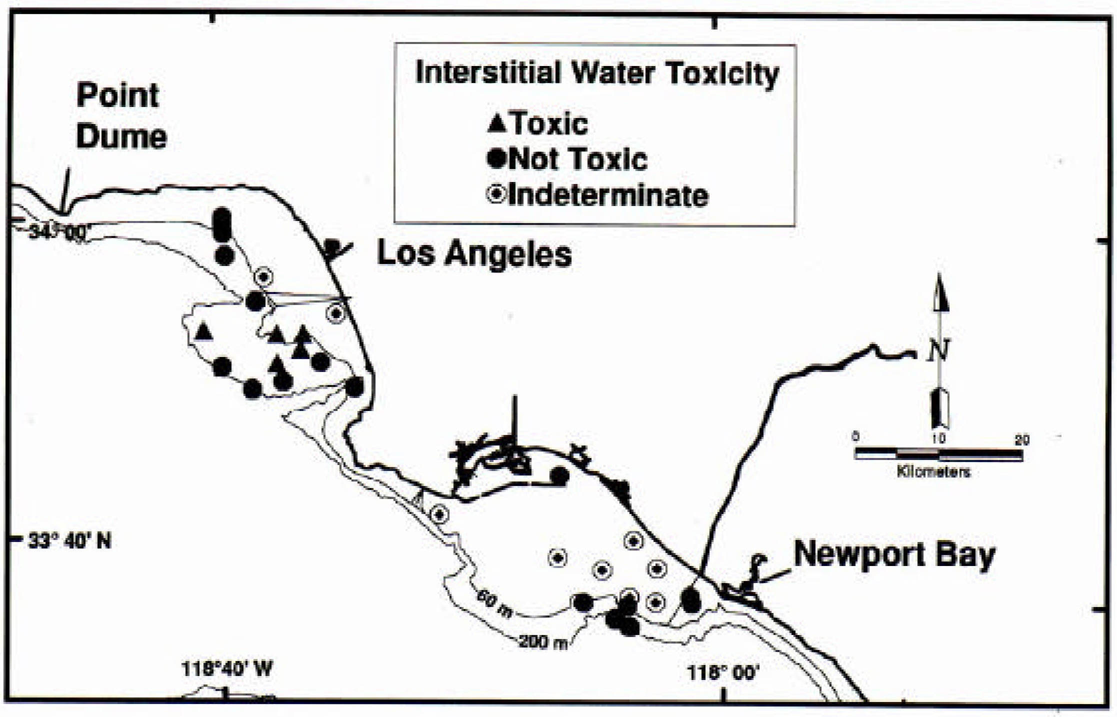

Figure 15. Location of toxic SCBPP interstitial water samples in central region.

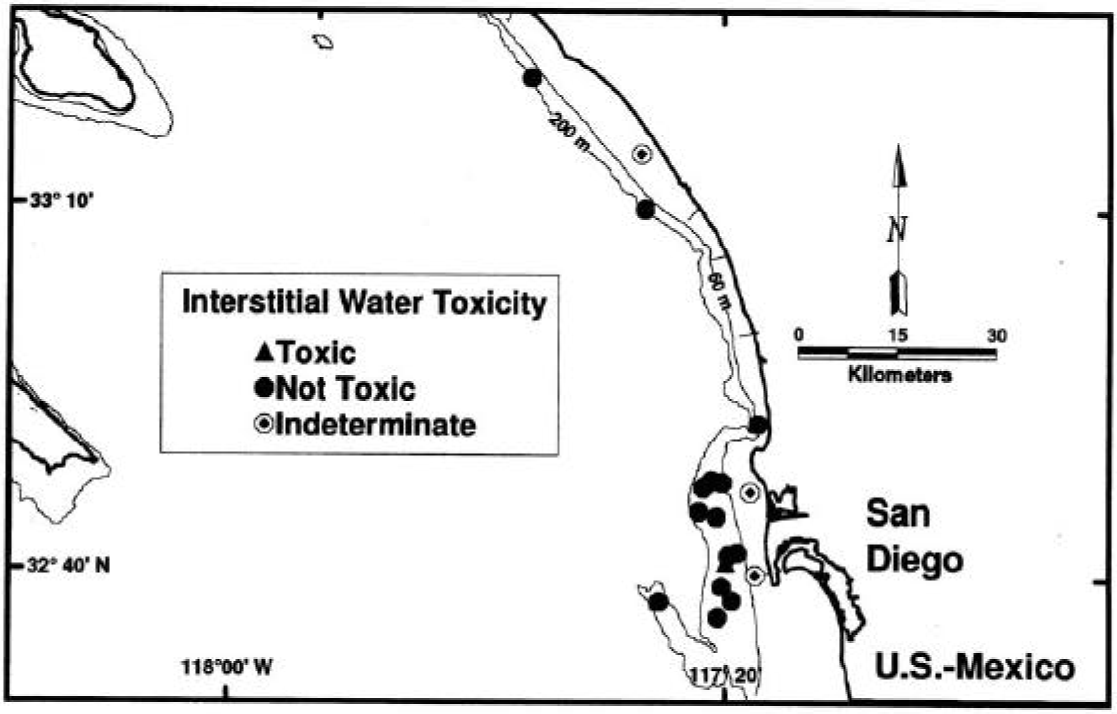

Figure 16. Location of toxic SCBPP interstitial water samples in southern region.

Table 1. Water quality measurements for amphipod survival tests. The desired rangeindicates values recommended by the test method or specified by the quality assuranceplan.

	Temperature (°C)	DO (mg/L)	pH	Salinity (g/kg)
Mean	20.0	7.4	8.09	31.1
Range	19.5-22.0	6.6-8.1	7.82-8.50	30.2-32.0
Desired range	19.0-21.0	^{3}4.8	^{3}7.6	28-32
% within range	96	100	100	100

Table 2. Water quality measurements for 100% interstitial water samples used in sea urchin embryo development tests. The desired range indicates values recommended by the test method or specified by the quality assurance plan.

	Temperature (°C)	DO (mg/L)	pH	Salinity (g/kg)
Mean	15.5	5.96	8.03	33.2
Range	15.0-15.9	3.6-7.0	7.40-8.19	30.7-34.2
Desired range	14.0-16.0	^{3}4.8	^{3}7.6	32.0-36.0
% within range	100	99	99	99

Table 3. Purple sea urchin embryo development test results for SCCWRP-MPSL interlaboratory QA tests.

	Percent of control normal development					
	100 % Interstitial water		50% Interstitial water		25% Interstitial water	
Station	MPSL	SCCWRP	MPSL	SCCWRP	MPSL	SCCWRP
85013	0	0	72	0	88	26
85015	0	0	89	0	97	70
85016	82	0	99	12	99	99
95015	0	0	0	0	0	62
95022	100	16	99	83	99	105
95026	38	0	32	36	89	103

Table 4. Water quality measurements for SCCWRP-MPSL interlaboratory QA tests. Values are the mean of initial and final measurements.

	pH		Total ammonia (mg/L)		Unionized ammonia (mg/L)	
Station	MPSL	SCCWRP	MPSL	SCCWRP	MPSL	SCCWRP
85013	8.0	8.1	3.76	7.02	0.08	0.18
85015	8.1	8.2	4.36	5.44	0.12	0.20
85016	7.8	8.0	3.48	4.22	0.05	0.12
95015	7.9	8.1	3.55	5.70	0.06	0.18
95022	7.8	8.0	1.68	1.86	0.02	0.04
95026	7.9	8.0	2.42	3.60	0.04	0.10

Table 5. Frequency of interstitial water toxicity in samples relative to exceedences in effects range median (ER-M) values.

	Number of Samples	
ER-M Exceeded	Nontoxic	Toxic
None	29	10
Nickel	0	1
Silver	1	0
Total DDT	8	5
Total PCB	1	1

Table 6. Mean concentrations of chemical constituents from sediment samples of stations designated as toxic and nontoxic.

	Mean Concentration		
Contaminant	Nontoxic	Toxic	*t* test *p* value(1 tail)
Arsenic (mg/dry kg)	4.37	6.84	0.049
Cadmium (mg/dry kg)	0.31	0.53	0.035
Copper (mg/dry kg)	15.1	19.6	0.170
Chromium (mg/dry kg)	34.8	60.5	0.021
Lead (mg/dry kg)	11.2	17.7	0.016
Mercury(mg/dry kg)	0.086	0.092	0.444
Nickel (mg/dry kg)	12.8	19.9	0.036
Silver (mg/dry kg)	0.970	0.594	0.087
Zinc (mg/dry kg)	46.6	61.7	0.032
p,p’ DDE (ng/dry g)	53.3	74.8	0.293
PCB 1242 (ng/dry g)	4.24	9.54	0.043
PCB 1254 (ng/dry g)	15.18	42.59	0.060
PCB 1260 (ng/dry g)	7.98	14.12	0.113
Total Nitrogen (%)	0.062	0.089	0.065
Total Organic Carbon (%)	0.862	1.36	0.048
Fines (%)	47.89	53.44	0.229

APPENDICES

Appendix 1. Toxicity sampling station locations and characteristics.

Station	Date	Depth (m)	Lat N	(dm)	Long W	(dm)	POTW	Region
16	8/18/94	27	34	27.16	120	1.69	No	North
32	8/18/94	62	34	26.86	120	13.38	No	North
38	8/18/94	52	34	26.65	120	3.87	No	North
115	8/18/94	63	34	24.98	120	20.21	No	North
150	8/18/94	77	34	24.35	120	24.53	No	North
228	8/18/94	49	34	23.30	119	47.31	No	North
245	8/18/94	120	34	22.95	120	24.88	No	North
252	8/17/94	42	34	22.86	119	37.60	No	North
365	8/18/94	88	34	20.26	119	45.88	No	North
366	8/17/94	21	34	20.25	119	26.81	No	North
407	8/17/94	62	34	19.29	119	33.76	No	North
474	8/21/94	70	34	17.20	119	30.64	No	North
480	8/21/94	100	34	17.09	119	38.54	No	North
670	8/20/94	208	34	12.17	119	39.92	No	North
682	8/20/94	185	34	11.83	119	38.02	No	North
708	8/21/94	198	34	11.10	119	34.16	No	North
753	8/20/94	137	34	9.34	119	25.57	No	North
758	8/16/94	18	34	9.05	119	16.78	No	North
814	8/16/94	26	34	5.74	119	9.97	No	North
815	8/16/94	190	34	5.72	119	17.56	No	North
820	8/15/94	10	34	5.33	119	4.44	No	North
846	8/16/94	63	34	3.90	119	6.93	No	North
943	8/2/94	43	34	0.39	118	35.72	Yes	Central
960	8/2/94	51	33	59.93	118	35.66	Yes	Central
993	8/2/94	60	33	59.32	118	35.55	Yes	Central
1028	7/27/94	126	33	57.95	118	35.29	Yes	Central
1049	7/27/94	55	33	56.63	118	32.21	Yes	Central
1072	8/3/94	71	33	54.99	118	32.79	Yes	Central
1081	8/4/94	15	33	54.28	118	26.44	No	Central
1106	7/20/94	84	33	52.98	118	36.86	No	Central
1108	8/9/94	58	33	52.97	118	29.83	Yes	Central
1109	8/9/94	58	33	52.95	118	31.04	Yes	Central
1126	8/9/94	84	33	52.03	118	29.15	Yes	Central
1142	7/19/94	75	33	51.14	118	27.67	Yes	Central
1148	8/9/94	100	33	51.02	118	31.04	Yes	Central
1152	7/28/94	170	33	50.67	118	35.25	No	Central
1169	7/18/94	135	33	49.80	118	30.53	Yes	Central
1173	7/19/94	60	33	49.55	118	24.97	Yes	Central
1175	7/18/94	208	33	49.24	118	32.96	No	Central
1208	7/14/94	13	33	44.04	118	8.71	No	Central
1267	7/22/94	43	33	41.35	118	18.03	Yes	Central

Appendix 1. (Continued)

Station	Date	Depth (m)	Lat N	(dm)	Long W	(dm)	POTW	Region
1306	7/14/94	13	33	39.90	118	2.76	No	Central
1332	7/15/94	32	33	38.70	118	8.72	No	Central
1348	7/13/94	16	33	38.13	118	0.91	No	Central
1355	7/13/94	33	33	37.93	118	5.18	No	Central
1401	7/13/94	22	33	36.30	117	58.29	Yes	Central
1406	7/14/94	35	33	36.20	118	3.01	Yes	Central
1415	7/13/94	33	33	35.92	118	0.98	Yes	Central
1417	7/13/94	31	33	35.89	117	58.17	Yes	Central
1418	7/14/94	84	33	35.82	118	6.59	No	Central
1426	7/14/94	45	33	35.62	118	3.15	Yes	Central
1450	7/14/94	219	33	34.81	118	4.11	Yes	Central
1469	7/13/94	162	33	34.31	118	2.94	Yes	Central
1551	7/18/94	176	33	21.33	117	39.02	No	South
1617	7/18/94	17	33	15.17	117	28.09	No	South
1655	7/18/94	196	33	10.63	117	27.68	No	South
1734	7/28/94	49	32	53.10	117	16.33	No	South
1767	7/27/94	87	32	48.30	117	20.81	Yes	South
1769	7/27/94	74	32	48.19	117	19.71	Yes	South
1770	7/27/94	94	32	47.78	117	21.58	Yes	South
1776	7/27/94	24	32	47.43	117	16.97	Yes	South
1780	7/27/94	15	32	47.05	117	16.09	Yes	South
1794	7/26/94	97	32	45.84	117	21.99	Yes	South
1797	7/22/94	85	32	45.46	117	20.27	Yes	South
1825	7/21/94	71	32	42.46	117	18.26	Yes	South
1828	7/21/94	85	32	42.24	117	19.16	Yes	South
1833	7/19/94	91	32	41.66	117	19.40	Yes	South
1839	7/15/94	42	32	40.65	117	16.48	Yes	South
1850	7/19/94	106	32	39.68	117	19.76	Yes	South
1871	7/19/94	89	32	38.52	117	18.70	Yes	South
1874	7/18/94	151	32	38.40	117	25.81	No	South
1903	7/18/94	111	32	37.16	117	20.10	Yes	South

Appendix 2. Station information for sediment samples used in SCCWRP-Marine Pollution Studies Laboratory interlaboratory comparison study.

Station	Date	Depth (m)	Lat N	(dm)	Long W	(dm)	Description
85013	9/19/94	4	33	36.72	117	55.67	Newport Bay (Rhine Channel)
85015	9/19/94	5	33	37.62	117	55.70	Newport Bay (storm drain)
85016	9/20/94	3	33	36.41	117	53.18	Newport Bay (Yachtmans Cove)
95026	9/21/94	2	33	8.75	117	19.86	Agua Hedionda Lagoon (144)
95015	9/21/94	2	33	8.71	117	20.10	Agua Hedionda Lagoon (212)
95022	9/21/94	3	33	12.73	117	23.68	Oceanside Harbor

Appendix 3. Water quality data for SCBPP amphipod tests. Values are the mean of initial and final measurements.

Station	Lab	Temperature (°C)	DO (mg/l)	Salinity (g/kg)	pH	Total Ammonia (mg/l)
0016	SAIC	20.5	7.2	31.0	8.09	3.48
0032	SCCWRP	19.6	7.5	30.9	8.24	0.65
0032	SAIC	20.5	7.2	31.0	8.10	2.16
0038	SCCWRP	19.6	7.9	30.9	8.30	0.93
0115	SAIC	20.5	7.1	31.0	8.10	7.73
0150	SAIC	20.5	7.2	30.8	8.11	5.38
0228	SCCWRP	19.6	8.0	30.9	8.26	0.22
0252	SCCWRP	19.6	8.0	31.1	8.29	0.31
0365	SCCWRP	19.6	7.5	30.9	8.27	0.23
0365	SAIC	20.5	7.1	31.0	8.02	1.02
0366	SCCWRP	19.6	8.1	30.9	8.26	0.36
0407	SAIC	20.5	7.2	31.0	8.01	0.39
0474	SCCWRP	19.6	8.1	31.1	8.27	0.13
0480	SAIC	22.0	6.9	31.5	8.05	0.71
0670	SAIC	22.0	6.8	31.3	8.05	2.82
0682	SAIC	22.0	6.9	31.3	8.09	1.86
0708	SCCWRP	19.6	8.0	31.1	8.26	2.34
0753	SCCWRP	19.6	8.0	30.7	8.28	1.63
0758	SAIC	19.5	7.1	31.0	7.91	4.17
0814	SCCWRP	19.6	7.3	30.8	8.19	4.11
0814	SAIC	19.5	7.1	30.8	7.89	5.29
0815	SAIC	19.5	7.1	31.0	7.88	3.31
0820	SCCWRP	19.6	7.5	30.8	8.30	4.82
0846	SAIC	19.5	7.0	31.0	7.84	2.12
0943	SCCWRP	19.6	7.3	30.9	8.26	0.52
0960	SAIC	19.8	7.6	32.0	7.86	3.01
0993	SCCWRP	19.6	7.2	30.9	8.23	0.90
1028	SCCWRP	20.0	7.6	30.6	8.18	0.31
1028	SAIC	19.8	7.5	32.0	7.87	0.65
1049	SCCWRP	19.6	7.4	30.9	8.34	2.93
1049	SAIC	19.8	7.3	32.0	7.91	3.52
1072	SCCWRP	19.6	7.3	31.1	8.27	1.91
1072	SAIC	19.8	7.5	32.0	7.87	1.95
1081	SCCWRP	19.6	7.4	31.0	8.50	6.98
1081	SAIC	19.8	7.3	32.0	7.88	5.43
1106	SCCWRP	19.6	7.6	31.0	8.28	1.12
1108	SAIC	19.5	7.0	31.0	7.86	2.66
1109	SCCWRP	19.6	7.2	30.9	8.20	0.50
1126	SAIC	19.5	7.1	30.8	7.82	0.59
1142	SCCWRP	20.6	7.5	30.2	8.07	0.52
1148	SAIC	20.5	7.2	31.0	7.98	0.43
1152	SCCWRP	19.6	7.2	31.0	8.28	0.42
1152	SAIC	19.8	7.2	32.0	7.87	1.40
1169	SAIC	19.8	7.3	31.8	7.97	0.56
1173	SCCWRP	20.0	7.4	30.5	8.14	3.11
1173	SAIC	19.8	7.4	31.8	8.06	2.38

(Appendix 3 continued)

Station	Lab	Temperature (°C)	DO (mg/l)	Salinity (g/kg)	pH	Total Ammonia (mg/l)
1175	SAIC	19.8	7.5	32.0	8.11	1.10
1208	SCCWRP	20.6	7.6	30.3	8.21	0.40
1267	SCCWRP	20.0	7.6	30.6	8.14	3.99
1267	SAIC	19.8	7.3	32.0	8.05	4.34
1306	SCCWRP	20.6	7.3	30.3	8.06	5.57
1332	SAIC	19.8	7.3	31.8	8.09	3.95
1348	SAIC	19.5	7.3	31.5	8.31	4.44
1355	SCCWRP	20.6	6.6	30.3	8.12	4.82
1401	SCCWRP	20.6	7.5	30.3	8.12	0.97
1406	SAIC	19.5	7.2	31.5	8.24	4.45
1415	SAIC	19.8	7.3	31.8	8.06	6.30
1417	SCCWRP	20.6	7.5	30.3	8.17	0.64
1417	SAIC	19.5	7.3	31.8	8.16	1.54
1418	SCCWRP	20.6	7.5	30.4	8.15	0.76
1426	SCCWRP	20.6	7.4	30.3	8.10	1.06
1450	SAIC	19.5	7.3	31.5	8.15	0.54
1469	SCCWRP	20.6	7.7	30.5	8.16	0.30
1551	SCCWRP	20.6	7.5	30.4	8.10	1.54
1617	SCCWRP	20.6	7.1	30.2	8.01	5.33
1655	SCCWRP	20.6	7.6	30.3	8.14	0.34
1655	SAIC	19.5	7.3	31.8	8.20	0.44
1734	SCCWRP	20.0	7.7	30.6	8.22	2.08
1734	SAIC	19.8	7.6	32.0	7.92	3.37
1767	SCCWRP	20.0	7.6	30.6	8.14	0.40
1767	SAIC	19.8	7.4	32.0	7.86	1.80
1769	SCCWRP	20.0	7.7	30.6	8.20	0.54
1770	SCCWRP	20.0	7.7	30.4	8.18	0.70
1776	SAIC	19.8	7.3	32.0	7.92	4.13
1780	SCCWRP	20.0	7.6	30.4	8.16	5.83
1794	SAIC	19.8	7.6	32.0	7.88	1.35
1797	SCCWRP	20.0	7.5	30.4	8.13	0.65
1825	SCCWRP	20.0	7.5	30.6	8.11	0.96
1825	SAIC	19.8	7.2	32.0	7.86	2.36
1828	SAIC	19.8	7.5	32.0	7.87	2.66
1833	SAIC	19.8	7.6	32.0	7.88	2.59
1839	SCCWRP	20.0	7.4	30.5	8.10	2.01
1839	SAIC	19.8	7.3	32.0	8.01	2.39
1850	SAIC	19.8	7.1	32.0	7.88	2.22
1871	SCCWRP	20.0	7.5	30.6	8.14	1.19
1874	SAIC	19.8	7.4	32.0	8.02	2.55
1903	SCCWRP	20.0	7.6	30.5	8.16	0.69

Appendix 4. Water quality data for SCBPP sea urchin embryo tests. Values are the mean of initial and final measurements.

	100%					50%		25%	
Station	Temperature (C)	DO (mg/l)	Salinity (g/kg)	pH	Total Ammonia (mg/l)	pH	Total Ammonia (mg/l)	pH	Total Ammonia (mg/l)
00160	15.7	6.1	33.5	8.14	7.41	8.17	3.66	8.11	1.79
00320	15.7	6.5	33.6	8.13	5.8	8.14	2.99	8.12	1.43
00380	15.3	6.4	33.2	8.19	13.1	8.23	6.44	8.16	2.88
01150	15.7	6.1	33.8	8.16	20.05	8.16	9.98	8.13	4.8
01500	15.7	6.5	33.6	8.15	12.6	8.13	6.51	8.11	3.43
02280	15.3	6.5	33.4	8.09	2.41	8.13	1.12	8.1	0.53
02450	a	a	a	a	a	8.25	8.57	8.21	4.08
02520	15.3	6.2	33.3	8.1	4.05	8.14	1.89	8.12	0.86
03650	15.7	7	33.6	8.13	1.95	8.12	1.07	8.11	0.78
03660	15.3	6.6	33.3	8.12	4.76	8.16	2.28	8.13	1.04
04070	15.7	6.6	33.5	8.05	1.55	8.07	0.76	8.07	0.45
04740	15.3	6.3	33.5	8.08	1.7	8.11	0.81	8.09	0.37
04800	15.3	6.6	33.4	8.05	2.5	8.14	1.12	8.11	0.49
06700	15.3	6.9	34	8.05	4.8	8.16	2.31	8.11	1.01
06820	15.3	6.6	33.9	8.08	2.04	8.15	0.94	8.11	0.43
07080	15.3	6.3	34.1	8.1	10.01	8.15	4.67	8.11	2.11
07530	15.3	6.3	33.8	8.07	7.01	8.13	3.26	8.1	1.58
07580	15.7	5	33.2	8.05	9.77	8.12	4.91	8.09	2.54
08140	15.7	5.9	33.3	8.12	15.65	8.14	7.78	8.09	3.66
08150	15.7	6.7	34.2	8.15	7.58	8.14	3.81	8.12	2
08200	15.8	6.7	30.7	7.4	15	8.19	6.13	8.13	2.73
08460	15.7	6.4	33.1	8.11	7.49	8.11	3.78	8.09	1.82
09430	15.9	5.9	32.9	7.97	3.27	8.02	1.71	8.02	0.86
09600	15.9	5.9	33	8.02	5.62	8.05	2.85	8.04	1.39
09930	15.9	6.1	33	8.01	4.78	8.05	2.34	8.05	1.47
10280	15.9	5.9	33.5	7.97	3.26	8.03	1.73	8.04	0.9
10490	15.9	5.8	33.1	7.91	20.1	8.12	10.95	8.08	5.94
10720	15.9	6.4	33	8.13	8.93	8.08	4.85	8.06	3.08
10810	15.9	6.1	32.9	7.84	20	8.07	10.33	8.06	5.16
11060	15.7	6.6	33.8	8.11	3.78	8.12	1.88	8.09	1.3
11080	15.7	6.3	33.6	8.13	9.97	8.14	5.1	8.1	2.44
11090	15.7	5.8	33.9	8.09	10.73	8.1	5.42	8.08	2.75
11260	15.7	6.2	33.8	8.02	3.27	8.05	1.71	8.04	1.13
11420	15.7	5.8	33.4	7.99	6.16	8.05	4.42	8.03	1.41
11480	15.7	5.9	33.5	8.02	2.8	8.05	1.36	8.06	0.82
11520	15.9	5.9	33.5	7.98	3.01	8.03	1.6	8.02	0.99
11690	15.7	5.7	33.7	7.89	2.85	7.99	1.48	8	0.81
11730	15.7	5.8	33.3	8.01	10.46	8.05	4.94	8.04	2.72
11750	15.7	6	33.8	7.9	1.8	8	1.05	8.01	0.55
12080	15	5.7	32.5	8.04	4.88	8.07	2.48	8.06	1.22

Appendix 4. (contintued)

	100%					50%		25%	
Station	Temperature (C)	DO (mg/l)	Salinity (g/kg)	pH	Total Ammonia (mg/l)	pH	Total Ammonia (mg/l)	pH	Total Ammonia (mg/l)
12670	15.7	5.8	33.1	8.1	21.35	8.15	11.76	8.12	5.64
13060	15	6.3	[a]	8.04	[a]	8.13	11.85	8.1	6
13320	15.7	5.9	33.2	7.93	23.6	8.13	12.62	8.06	6.11
13480	15	5.1	32.4	8.09	28.2	8.14	13.05	8.08	6.52
13550	15	4.8	32.3	8.13	25.45	8.14	12.85	8.1	6.56
14010	15	5	32.7	8.12	14.4	8.13	7.25	8.11	3.5
14060	15	4.5	32.9	8.11	23.3	8.14	11.5	8.08	5.61
14150	15	3.6	32.8	8.06	23.9	8.11	11.5	8.08	5.83
14170	15	5.6	32.7	8.1	7.5	8.1	3.43	8.09	1.99
14180	15	7	32.8	8.14	7.4	8.13	3.58	8.1	2.01
14260	15	5.7	33	8.11	9.42	8.11	4.47	8.07	2.3
14500	15	5.9	33.4	8.03	2.39	8.05	1.13	8.05	0.8
14690	15	5.7	33.3	8.08	2.72	8.08	1.32	8.08	0.69
15510	15	5.2	33.3	7.95	[b]	8.02	[b]	8.06	[b]
16170	15	6.5	32	8.13	20.05	8.16	8.97	8.12	4.4
16550	15	5.1	33.4	8	1.48	8.03	0.66	8.02	0.45
17340	15.7	5.7	33.4	7.95	7.89	8.02	4.19	8.02	2.08
17670	15.9	5.9	33.2	8.02	4.27	8.09	2.28	8.08	1.15
17690	15.9	6	33.1	8.04	8.66	8.12	4.16	8.1	2.08
17700	15.9	6	33.4	8.05	5.65	8.08	2.79	8.09	1.43
17760	15.9	6.3	32.9	8.05	18.55	8.11	9.5	8.08	4.93
17800	[a]	[a]	[a]	[a]	[a]	8.12	11.3	[a]	[a]
17940	15.7	5.7	33.3	7.93	3.51	8	1.82	7.99	0.9
17970	15.9	5.9	33.3	8.05	7.9	8.06	4.05	8.04	2.19
18250	15.7	5.8	33.4	7.94	6.64	8.02	3.63	8	1.77
18280	15.7	5.6	33.5	7.92	5.46	7.99	2.95	7.99	1.5
18330	15.7	5.8	33.4	7.93	5.97	8.02	3.14	8	1.61
18390	15.5	[a]	33.3	7.82	21.6	8.11	9.15	8.04	4.54
18500	15.7	5.8	33.5	7.97	9.08	8.03	4.78	8.01	2.46
18710	15.9	5.5	33.2	8.04	9.78	8.11	5.22	8.1	2.83
18740	15.7	5.9	33.7	7.94	3.42	7.96	1.88	7.96	0.9
19030	15.7	5.8	33.5	7.9	5.18	7.98	2.36	7.95	1.22

[a] Insufficient sample available for analysis at this concentration
[b] Error in data records

Appendix 5. Amphipod survival test results for SCBPP sediment samples.

Station	Lab	Mean	SD	%Control	*t* test[a]	Sediment Held (d)	QA Code[b]
0016	SAIC	90	9.4	93		22	A
0032	SCCWRP	92	4.5	101		8	A
0032	SAIC	94	5.5	97		22	A
0038	SCCWRP	93	7.6	100		15	A
0115	SAIC	92	4.5	95	*	22	A
0150	SAIC	93	10.4	96		22	A
0228	SCCWRP	93	5.7	100		15	A
0252	SCCWRP	93	7.6	100		16	A
0365	SCCWRP	91	8.2	100		8	A
0365	SAIC	91	4.2	94	*	22	A
0366	SCCWRP	92	6.7	99		16	A
0407	SAIC	94	4.2	97		22	A
0474	SCCWRP	91	12.4	98		12	A
0480	SAIC	95	3.5	100		26	J
0670	SAIC	91	6.5	96		27	J
0682	SAIC	92	4.5	97		27	J
0708	SCCWRP	90	7.9	97		12	A
0753	SCCWRP	88	6.7	95		13	A
0758	SAIC	93	2.7	104		21	A
0814	SCCWRP	88	7.6	97		10	A
0814	SAIC	94	5.5	106		21	A
0815	SAIC	93	4.5	104		21	A
0820	SCCWRP	89	9.6	98		11	A
0846	SAIC	85	7.1	96		21	A
0943	SCCWRP	88	8.7	96		24	C
0960	SAIC	85	0.0	98		17	A
0993	SCCWRP	89	2.2	98		24	A
1028	SCCWRP	91	12.4	98		16	A
1028	SAIC	91	7.4	105		23	A
1049	SCCWRP	87	10.4	96		30	A
1049	SAIC	84	8.2	97		23	A
1072	SCCWRP	87	4.5	96		23	A
1072	SAIC	93	8.7	106		16	C
1081	SCCWRP	88	8.4	97		22	A
1081	SAIC	86	7.4	99		15	A
1106	SCCWRP	91	8.9	100		37	E
1108	SAIC	91	4.2	102		28	A
1109	SCCWRP	88	7.6	97		17	A
1126	SAIC	87	7.6	98		28	A
1142	SCCWRP	97	4.5	101		17	A

Appendix 5. (Continued)

Station	Lab	Mean	SD	%Control	*t* test[a]	Sediment Held (d)	QA Code[b]
1148	SAIC	93	2.7	96	*	31	A
1152	SCCWRP	91	10.2	100		29	A
1152	SAIC	93	2.7	107		22	A
1169	SAIC	93	3.5	106		35	C
1173	SCCWRP	92	4.5	99		24	A
1173	SAIC	85	7.1	98		34	C
1175	SAIC	85	0.0	98		35	C
1208	SCCWRP	98	2.7	102		22	A
1267	SCCWRP	84	5.5	90	*	21	A
1267	SAIC	87	2.9	100		31	C
1306	SCCWRP	96	4.2	100		22	A
1332	SAIC	85	5.0	98		38	CE
1348	SAIC	93	7.6	111		20	D
1355	SCCWRP	94	4.2	98		23	A
1401	SCCWRP	98	2.7	102		23	A
1406	SAIC	88	4.5	105		19	D
1415	SAIC	90	7.1	103		40	CE
1417	SCCWRP	95	5.0	99		23	A
1417	SAIC	94	6.5	112		20	D
1418	SCCWRP	92	5.7	96		22	A
1426	SCCWRP	91	5.5	95		22	A
1450	SAIC	96	4.2	114		19	D
1469	SCCWRP	94	2.2	98		23	A
1551	SCCWRP	98	4.5	102		18	A
1617	SCCWRP	94	5.5	98		18	A
1655	SCCWRP	96	4.2	100		18	A
1655	SAIC	92	5.7	110		15	D
1734	SCCWRP	96	6.5	103		15	A
1734	SAIC	90	8.7	103		22	A
1767	SCCWRP	94	4.2	101		16	A
1767	SAIC	91	2.2	105		23	A
1769	SCCWRP	92	9.1	99		16	A
1770	SCCWRP	96	2.2	103		16	A
1776	SAIC	94	6.5	108		23	A
1780	SCCWRP	84	11.9	90		16	A
1794	SAIC	88	5.7	101		24	A
1797	SCCWRP	93	8.7	99		21	C
1825	SCCWRP	97	4.5	104		22	A
1825	SAIC	90	7.9	103		29	A
1828	SAIC	96	4.2	110		29	A
1833	SAIC	95	6.1	109		31	A

Appendix 5. (Continued)

Station	Lab	Mean	SD	%Control	*t* test[a]	Sediment Held (d)	QA Code[b]
1839	SCCWRP	86	5.5	92	*	28	A
1839	SAIC	80	8.2	92		38	CE
1850	SAIC	87	6.7	100		31	A
1871	SCCWRP	93	5.7	100		24	A
1874	SAIC	92	2.9	105		35	CE
1903	SCCWRP	85	5.0	91	*	25	A

[a] Asterisk indicates *t* test probability ≤ 0.05 for comparison with control.
[b] Control code legend: A: All QA criteria met.
C: Reduced number of replicates.
D: Control performance criteria not met.
E: Sample stored > 30 days.
J: Minor deviation in test conditions.
N: One or more replicates not evaluated.

Appendix 6. Development of sea urchin embryos following 3-day exposure to interstitial water from SCBPP sediment samples.

Station	50% Interstitial Water %Normal	SD	% of Control	*t* test[a]	25% Interstitial Water %Normal	SD	% of Control	*t* test	Sediment Held (d)	QA Code[b] (50%/25%)
0016	0	0.0	0	*	47	33.7	53		11	A/A
0032	0		0	nt	0	0.0	0	*	11	N/A
0038	0		0	nt	1	0.0	1	*	22	N/A
0115	0		0	nt	0	0.0	0	*	11	N/A
0150	0		0	nt	1	2.3	2	*	11	N/A
0228	16	14.8	20	*	0	0.0	0	*	22	A/A
0245	0		0	nt	0	0.0	0	*	22	CN/C
0252	2	1.5	3	*	53	41.3	64		23	A/A
0365	1	1.7	1	*	53	33.6	60		11	A/A
0366	36	23.0	43	*	78	4.7	94		23	A/A
0407	71	7.5	80	*	70	2.1	79	*	12	A/A
0474	83	4.9	100		88	7.4	105		19	A/A
0480	43	38.1	52		86	1.5	103		19	A/A
0670	24	8.1	28	*	83	6.1	99		20	A/A
0682	55	30.9	66		80	5.9	96		20	A/A
0708	0		0	nt	43	18.3	51	*	19	N/A
0753	0		0	nt	34	33.2	38		20	N/A
0758	0		0	nt	9	13.9	10	*	13	N/A
0814	0		0	nt	0	0.0	0	*	13	N/A
0815	0		0	nt	15	12.2	18	*	13	N/A
0820	0		0	nt	0	0.0	0	*	25	N/A
0846	0		0	nt	26	22.8	31	*	13	N/A
0943	83	10.2	97		88	2.6	104		15	A/A
0960	5	4.6	5	*	84	6.4	98		15	A/A
0993	31	19.3	36	*	89	2.0	105		15	A/A
1028	81	2.6	95		86	3.5	101		21	A/A
1049	0		0	nt	0	0.0	0	*	21	N/A
1072	0		0	nt	17	14.7	20	*	14	N/A
1081	0		0	nt	0	0.0	0	*	13	CN/C
1106	58	24.0	65		67	17.1	76		40	E/E
1108	0		0	nt	3	1.5	4	*	20	N/A
1109	0		0	nt	0	0.6	0	*	20	N/A
1126	2	1.0	2	*	35	20.5	40	*	20	A/A
1142	16	14.3	18	*	75	12.0	84		20	A/A
1148	41	15.0	47	*	72	11.2	81	*	20	A/A
1152	80	2.3	95		80	5.7	95		20	A/A
1169	79	1.5	89	*	84	4.2	95		21	A/A

Appendix 6. (Continued)

Station	50% Interstitial Water %Normal	SD	% of Control	*t* test[a]	25% Interstitial Water %Normal	SD	% of Control	*t* test	Sediment Held (d)	QA Code[b] (50%/25%)
1173	0		0	nt	44	2.9	49	*	20	N/A
1175	82	3.6	92	*	89	7.4	100		21	N/A
1208	85	2.0	106		84	2.5	104		18	A/A
1267	0		0	nt	0	0.0	0	*	17	N/A
1306	0		0	nt	1	1.2	1	*	18	CN/C
1332	0		0	nt	0	0.0	0	*	24	N/A
1348	0		0	nt	0	0.6	0	*	19	N/A
1355	0		0	nt	1	2.3	2	*	19	N/A
1401	0		0	nt	53	5.2	66	*	19	N/A
1406	1		1	nt	0	0.6	0	*	18	N/A
1415	0		0	nt	1	0.6	1	*	19	N/A
1417	21	4.9	26	*	81	1.5	101		19	A/A
1418	33	9.5	41	*	84	5.2	104		18	A/A
1426	0	0.0	0	*	78	4.0	97		18	A/A
1450	87	3.6	108		84	2.1	104		18	A/A
1469	80	10.5	99		88	3.2	109		19	A/A
1551	82	5.1	102		90	3.1	112		14	A/A
1617	0		0	nt	2	2.9	2	*	14	N/A
1655	82	11.6	102		83	3.1	103		14	A/A
1734	5	3.5	5	*	62	11.4	70	*	11	A/A
1767	41	14.7	48	*	87	2.6	102		21	A/A
1769	0	0.0	0	*	70	6.7	82	*	21	A/A
1770	8	4.6	9	*	89	1.7	105		21	A/A
1776	0		0	nt	0	0.0	0	*	21	N/A
1780	0	0.0	0	*					21	C/C
1794	68	5.7	77	*	78	2.0	87	*	13	A/A
1797	0	0.0	0	*	73	5.2	86	*	26	A/A
1825	7	7.0	8	*	69	6.6	77	*	18	A/A
1828	25	12.3	28	*	77	8.5	86	*	18	A/A
1833	14	6.0	16	*	59	11.8	66	*	20	A/A
1839	0		0	nt	1	2.3	1	*	24	CN/C
1850	0	0.0	0	*	56	0.6	62	*	20	A/A
1871	0	0.6	0	*	32	5.6	38	*	29	A/A
1874	51	42.7	58		86	4.6	96		21	A/A
1903	62	6.4	70	*	85	5.1	96		21	A/A

[a] Asterisk indicates *t* test probability ≤0.05 for comparison with control. nt indicates not enough replicates examined to perform *t* test.
[b] See Appendix 5 for definitions.

Appendix 7. Classification of 25% interstitial water samples using ammonia toxicity model.

Station	Class[a]	Mean NH_3 (mg\L)	% normal development measured	% normal development predicted
16	Toxic	0.052	53	51
32	Toxic	0.043	0	74
38	Indeterminate	0.093	1	0
115	Indeterminate	0.147	0	0
150	Indeterminate	0.100	2	0
228	Toxic	0.015	0	82
245	Indeterminate	0.152	0	0
252	Toxic	0.025	64	82
365	Toxic	0.023	60	82
366	Nontoxic	0.032	94	81
407	Toxic	0.012	79	82
474	Nontoxic	0.010	105	82
480	Nontoxic	0.014	103	82
670	Nontoxic	0.030	99	81
682	Nontoxic	0.013	96	82
708	Nontoxic	0.061	51	20
753	Toxic	0.044	38	72
758	Nontoxic	0.074	10	0
814	Indeterminate	0.105	0	0
815	Toxic	0.061	18	21
820	Indeterminate	0.086	0	0
846	Toxic	0.051	31	55
943	Nontoxic	0.021	104	82
960	Nontoxic	0.035	98	80
993	Nontoxic	0.038	105	79
1028	Nontoxic	0.023	101	82
1049	Indeterminate	0.164	0	0
1072	Nontoxic	0.081	20	0
1081	Indeterminate	0.139	0	0
1106	Toxic	0.038	76	79
1108	Toxic	0.070	4	0
1109	Toxic	0.076	0	0
1126	Toxic	0.029	40	81
1142	Nontoxic	0.038	84	79
1148	Toxic	0.023	81	82
1152	Nontoxic	0.025	95	82
1169	Nontoxic	0.020	95	82
1173	Nontoxic	0.069	49	0
1175	Nontoxic	0.014	100	82

Appendix 7. (Continued)

Station	Class[a]	Mean NH_3 (mg\L)	% normal development measured	% normal development predicted
1208	Nontoxic	0.033	104	81
1267	Indeterminate	0.182	0	0
1306	Indeterminate	0.178	1	0
1332	Indeterminate	0.171	0	0
1348	Indeterminate	0.185	0	0
1355	Indeterminate	0.196	2	0
1401	Nontoxic	0.107	66	0
1406	Indeterminate	0.159	0	0
1415	Indeterminate	0.169	1	0
1417	Nontoxic	0.057	101	35
1418	Nontoxic	0.059	104	25
1426	Nontoxic	0.064	97	11
1450	Nontoxic	0.021	104	82
1469	Nontoxic	0.020	109	82
1551	Nontoxic	b	112	
1617	Indeterminate	0.135	2	0
1655	Nontoxic	0.010	103	82
1734	Nontoxic	0.053	70	48
1767	Nontoxic	0.032	102	81
1769	Nontoxic	0.060	82	23
1770	Nontoxic	0.040	105	77
1776	Indeterminate	0.144	0	0
1794	Nontoxic	0.022	87	82
1797	Nontoxic	0.059	86	26
1825	Nontoxic	0.044	77	73
1828	Nontoxic	0.036	86	80
1833	Toxic	0.040	66	78
1839	Indeterminate	0.121	1	0
1850	Nontoxic	0.061	62	19
1871	Nontoxic	0.084	38	0
1874	Nontoxic	0.020	96	82
1903	Nontoxic	0.027	96	82

[a] Indeterminate: ammonia concentration too high to permit detection of toxicity from other factors.
Nontoxic: all effects on embryo development predicted solely by ammonia concentration.
Toxic: embryo development less than predicted on basis of ammonia concentration.

[b] Ammonia concentration unavailable for this sample.

Southern California Bight Pilot Project Reports

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