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## FINAL REPORT

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## FOREWORD

The United States Congress created the National Estuary Program in 1984, citing its concern for the "health and ecological integrity" of the nation's estuaries and estuarine resources. Narragansett Bay was selected for inclusion in the National Estuary Program in 1984 , and the Narragansett Bay Project (NBP) was established in 1985. Narragansett Bay was designated an "estuary of national significance" in 1988. Under the joint sponsorship of the U.S. Environmental Protection Agency and the Rhode Island Department of Environmental Management, the NBP's mandate is to direct a program of research and planning focussed on managing Narragansett Bay and its resources for future generations.

The NBP will develop a draft Comprehensive Conservation and Management Plan (CCMP) by December, 1991, which will recommend actions to improve and protect the Bay and its natural resources.

The NBP has established the following seven priority issues for Narragansett Bay:

- management of fisheries
- nutrients and potential for eutrophication
- impacts of toxic contaminants
- health and abundance of living resources
- health risk to consumers of contaminated seafood
- land-based impacts on water quality
- recreational uses

The NBP is taking an ecosystem/watershed approach to address these problems and has funded research that will help to improve our understanding of various aspects of these priority problems. The Project is also working to expand and coordinate existing programs among federal, state and local agencies, as well as with academic researchers, in order to apply research findings to the practical needs of managing the Bay and improving the environmental quality of its watershed.

This report represents the technical results of an investigation performed for the Narragansett Bay Project. The information in this document has been funded wholly or in part by the United States Environmental Protection Agency through Cooperative Agreement #CX812768 to the Rhode Island Department of Environmental Management. It has been subject to the Agency's and the Narragansett Bay Project's peer and administrative review and has been accepted for publication as a technical report by the Management Committee of the Narragansett Bay Project. The results and conclusions contained herein are those of the author(s), and do not necessarily represent the views or recommendations of the NBP.

# EXECUTIVE SUMMARY

The objective of this study was to characterize the sediments in Narragansett Bay in terms of acute toxicity to the amphipod *Ampelisca abdita*. Fine-grained sediments were collected from 31 sites in embayments and major rivers, and subjected to a standard 10-day sediment toxicity test using this amphipod.

Significant toxicity was found in sediments collected from Greenwich Cove, and sites in the Providence, Seekonk, and Blackstone Rivers. The highest toxicity was found in sediments collected from Field's Point. Sediments from all other stations in the Bay were considered non-toxic.

Although no sediments produced toxicity which would be considered high, there is concern that moderate, or marginal, acute toxicities may signal the potential for subtle ecological effects. It is recommended that toxicity tests be repeated on sediments from locations showing marginal toxicity, and that they be conducted using accepted static procedures. This modification would make these data comparable to those collected using *Ampelisca* from the Environmental Monitoring and Assessment Program, and the NOAA bioeffects surveys in Long Island Sound, Hudson-Raritan Estuary, and Tampa Bay.

# INTRODUCTION

Marine amphipods are frequently abundant in soft-bottom benthic communities, and often are principal components in marine food webs. They have been shown to be more sensitive to polluted sediments than some other taxa, and to be some of the first organisms to disappear from heavily impacted areas (Swartz et al., 1979; Sanders et al., 1980). Swartz and others on the west coast (Swartz et al., 1985) have developed an extensive database with the phoxocephalid amphipod Rhepoxynius abronius, and in a complementary effort, the Environmental Protection Agency's Environmental Research Laboratory in Narragansett has been developing and applying similar test procedures using the benthic ampeliscid amphipod Ampelisca abdita.

Sediment toxicity tests are the most direct measures available for estimating the bioavailability of contaminants in sediments and the potential for contaminant-induced effects in benthic communities. These tests provide information that is independent of chemical characterizations and ecological surveys (Chapman, 1988). They improve upon direct measures of contaminants because many chemicals are tightly bound to sediment particles or are chemically complexed and, thus are not biologically available (USEPA, 1990).

These toxicity tests have had many applications in both marine and freshwater environments (Swartz, 1987; Chapman, 1988) and have become an integral part of many benthic assessment programs (Swartz 1989) where they are used to establish contaminant-specific effects. The solid phase amphipod 10-day acute test has been employed in sediment assessments in Puget Sound (Dinnel, 1990), San Francisco Bay (Long et al., 1990), New York Harbor (Scott et al., 1990), and currently is being used to examine sediment toxicity in three NOAA National Status and Trends studies in the Hudson/Raritan Estuary, Long Island Sound, and

Tampa Bay (D. Wolfe, NOAA-Rockville, MD, pers. comm.). The success with which this test can identify toxic sediments has led to its adoption, along with several other amphipod species, in the joint EPA/COE guidance for dredged material permitting (EPA/COE, 1990).

A. abdita has been shown to be sensitive to a variety of anthropogenic materials in the marine environment. For example, it was the most sensitive of 11 species of fish and invertebrates tested in acute exposures to solid phase dredged material from Black Rock Harbor, Connecticut (Rogerson et al., 1985). This material was contaminated primarily with polyaromatic hydrocarbons and heavy metals. In chronic tests with this species, growth was retarded during exposure to 5 mg/l suspended Black Rock Harbor sediments. Consequently, sexual maturation was delayed and effects on the population structure were observed (Scott and Redmond, 1989). A. abdita was also sensitive to a series of sediments and sediment dilutions from New Bedford Harbor, Massachusetts, which were heavily contaminated with polychlorinated biphenyls and heavy metals (Scott et al., in prep.). This species was used in the New York Harbor and NOAA studies cited above, and is the test organism of choice for sediment toxicity testing in the EPA's Environmental Monitoring and Assessment Program. Because of its tube-dwelling habit, this species is isolated from the direct effects of many geophysical factors, such as grain size. Ampelisca prefers fine-grained sediments, and is only affected by very coarse sediments that do not have any fine material with which to build a tube.

In addition to its apparent sensitivity, A. abdita is a useful organism for toxicity tests because of its wide availability and ecological importance. This amphipod is found from the intertidal zone to depths of 60 m, ranging from Maine to south-central Florida and the eastern Gulf of Mexico (Bousfield, 1973). It also was introduced into San Francisco Bay (Nichols and Thompson, 1985). Ampelisca is euryhaline and is found at salinities as low as 15 ppt (Hyland, 1981). Optimal test salinities have been determined to be 25 ppt of greater (M.S. Redmond, Newport, OR, pers. comm.). A tube-dwelling amphipod which constructs a soft, upright membranous tube 3 to 4 cm long in surface sediments, A. abdita is a particle feeder, ingesting either surface-deposited particles or particles in suspension. Where large communities of Ampelisca are present, patches of amphipod tubes may affect benthic community structure by creating a topographically complex microhabitat and by trapping suspended material (Mills, 1967; Eckman, 1979). This amphipod also is a common food source for bottom fish (Richards, 1963)

In this study, acute toxicity tests with Ampelisca abdita were conducted to evaluate the relative toxicity of sediments from selected embayments in Narragansett Bay. Initial testing was conducted to identify highly toxic locations, which could then be examined in more detail to establish spatial gradients. Based on the initial screening, the area around the Field's Point outfalls was selected for closer examination at six stations along a gradient from east of Sassafras Point to east of Pawtuxet Neck.

## METHODS

### Sediment Collection

A series of three survey tests on a broad range of Narragansett Bay sediments were conducted, followed by one gradient test to examine sediments from the Field's Point area. Sediments for the four tests were collected from March 15 to July 26, 1989 from 32 locations within Narragansett Bay (Figure 1, Table 1). Based on consultations with Narragansett Bay Estuary Program personnel, station locations were selected to address potential concerns such as heavy recreational use, point source inputs, shoreline development, or known historical contamination. At each location,

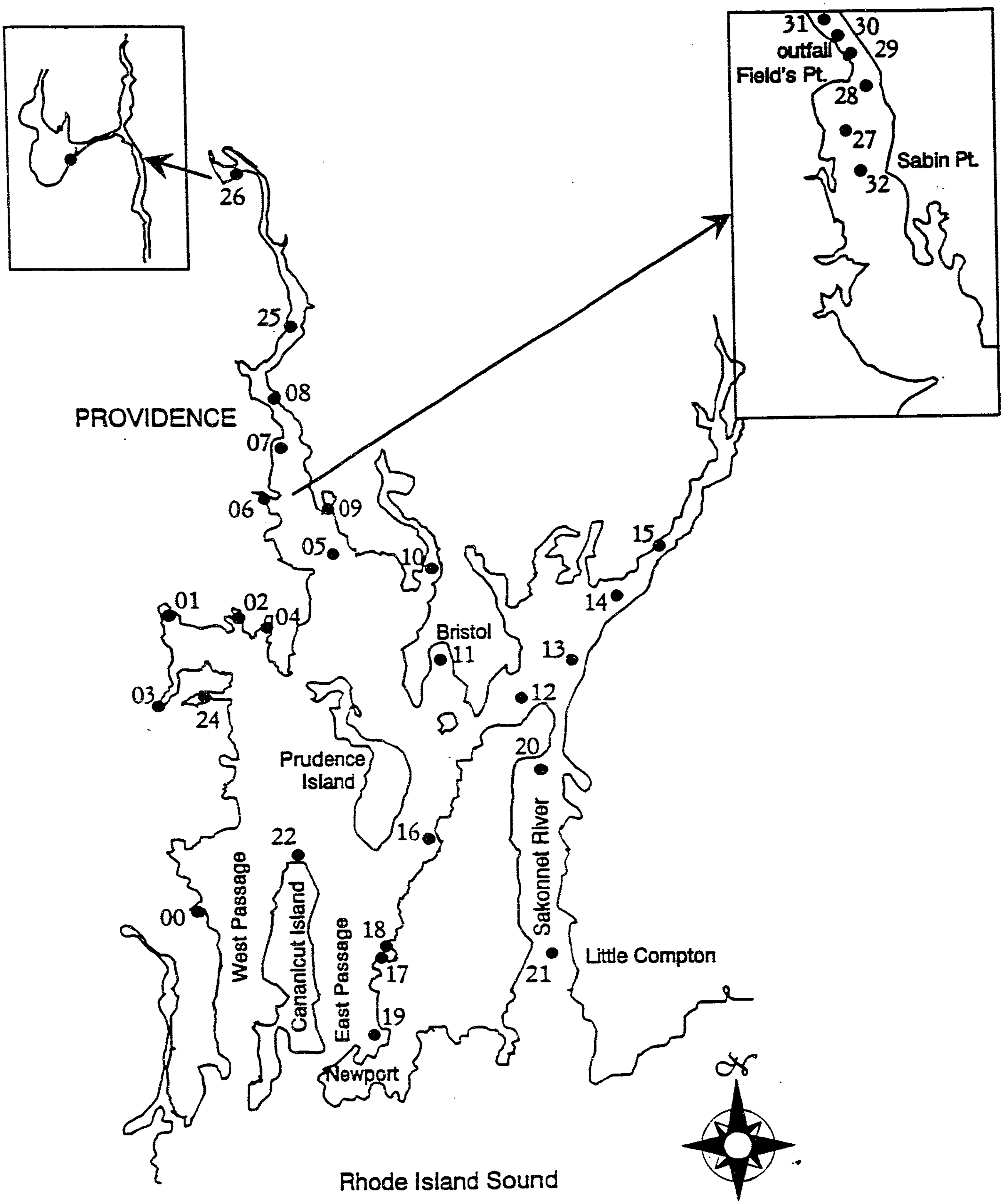


Figure 1. Sediment sampling locations in Narragansett Bay.

Table 1. Latitude and longitude of collection sites for sediments used in tests exposing <u>Ampelisca abdita</u> to Narragansett Bay sediments.

| Station # | Station location | Longitude | Latitude |
|---|---|---|---|
| 00 | Bissel Cove | $71^{\circ}25'59''$ | $41^{\circ}32'56''$ |
| 01 | Apponaug Cove | $71^{\circ}26'50''$ | $41^{\circ}41'38''$ |
| 02 | Brushneck Cove | $71^{\circ}24'29''$ | $41^{\circ}41'42''$ |
| 03 | Greenwich Cove | $71^{\circ}26'55''$ | $41^{\circ}39'14''$ |
| 04 | Warwick Cove | $71^{\circ}23'23''$ | $41^{\circ}41'40''$ |
| 05 | Providence R. Mouth | $71^{\circ}21'05''$ | $41^{\circ}43'40''$ |
| 06 | Pawtuxet Cove | $71^{\circ}23'18''$ | $41^{\circ}45'44''$ |
| 07 | Field's Point | $71^{\circ}22'49''$ | $41^{\circ}47'02''$ |
| 08 | Fox Point | $71^{\circ}23'12''$ | $41^{\circ}48'10''$ |
| 09 | Bullock Cove | $71^{\circ}21'18''$ | $41^{\circ}45'03''$ |
| 10 | Warren River | $71^{\circ}17'12''$ | $41^{\circ}43'05''$ |
| 11 | Bristol Harbor | $71^{\circ}17'05''$ | $41^{\circ}40'36''$ |
| 12 | Mount Hope Bay | $71^{\circ}14'09''$ | $41^{\circ}39'11''$ |
| 13 | Mount Hope Bay | $71^{\circ}12'25''$ | $41^{\circ}40'15''$ |
| 14 | Mount Hope Bay | $71^{\circ}10'22''$ | $41^{\circ}42'18''$ |
| 15 | Mount Hope Bay | $71^{\circ}09'00''$ | $41^{\circ}43'59''$ |
| 16 | Melville Cove | $71^{\circ}17'20''$ | $41^{\circ}35'10''$ |
| 17 | Derektor Shipyard | $71^{\circ}19'01''$ | $41^{\circ}31'37''$ |
| 18 | Coddington Cove | $71^{\circ}19'11''$ | $41^{\circ}31'21''$ |
| 19 | Newport Harbor | $71^{\circ}19'21''$ | $41^{\circ}29'02''$ |
| 20 | North Sakonnet R. | $71^{\circ}13'18''$ | $41^{\circ}37'15''$ |
| 21 | South Sakonnet R. | $71^{\circ}13'06''$ | $41^{\circ}31'23''$ |
| 22 | North Jamestown | $71^{\circ}22'09''$ | $41^{\circ}34'35''$ |
| 24 | Potowomut River | $71^{\circ}26'04''$ | $41^{\circ}39'03''$ |
| 25 | Seekonk River | $71^{\circ}22'40''$ | $41^{\circ}50'40''$ |
| 26 | Blackstone River | $71^{\circ}21'07''$ | $41^{\circ}54'11''$ |
| 27 | E.of Edgewood Yacht Club | $71^{\circ}23'01''$ | $41^{\circ}46'33''$ |
| 28 | Southeast of Field's Point | $71^{\circ}22'36''$ | $41^{\circ}47'06''$ |
| 29 | Between outfalls and Field's Point | $71^{\circ}22'57''$ | $41^{\circ}47'35''$ |
| 30 | Outfalls at Field's Point | $71^{\circ}23'20''$ | $41^{\circ}47'53''$ |
| 31 | Sassafras Point | $71^{\circ}23'30''$ | $41^{\circ}48'10''$ |
| 32 | E.of Pawtuxet Neck | $71^{\circ}22'45''$ | $41^{\circ}45'54''$ |

the sample site was chosen to represent depositional conditions, i.e., the area most likely to accumulate contaminated, toxic sediments. Sediments were collected within a 50 m radius of each station using either a Ponar or a Smith-MacIntyre grab sampler. The top two centimeters of sediment from each grab sample were thoroughly homogenized with a teflon spoon and composited, by station, in one-gallon glass jars, put on ice, returned to the laboratory and stored at 4°C until used in the toxicity tests.

A performance control sediment was used to establish that the test organisms used were consistently healthy from test to test, and, if survival is acceptable (>89 %), allowed for the comparison of absolute toxicity among different tests. The performance control sediment was collected from an uncontaminated site in central Long Island Sound (40°7.95'N and 72°52.7'W) with a Smith-MacIntyre grab sampler. The sediment was returned to the laboratory, press sieved wet through a 2-mm mesh stainless steel screen, homogenized, and stored at 4°C in glass jars until used. _A. abdita_ previously tested in sediment from this location has exhibited survival in the acceptable range (Rogerson et al., 1985; Scott and Redmond 1989; Scott et al. 1990; Ditoro et al., 1990). Chemical characterization of this sediment also shows it to be uncontaminated (Rogerson et al., 1985).

In previous work with Narragansett Bay sediments (Appendix Tables 5-8), sediment collected from a site just north of Conanicut Island did not cause significant _A. abdita_ mortality. This site ("North Jamestown"), therefore, was selected as a reference site or site control. A separate collection of North Jamestown sediment was made for this study, and was used in the first survey test along with the performance control sediment. The two sediments were not significantly different (t-test, $p < 0.05$) from each other, and thus only the North Jamestown control was included in subsequent experiments.

## Amphipod Collection and Holding

*Ampelisca* were collected from tidal flats in the Pettaquamscutt (Narrow) River, a small estuary flowing into Narragansett Bay, Rhode Island. Salinities at this site typically range between 20 and 30 ppt. Surface sediment containing the amphipods in tubes was transferred to the laboratory within one-half hour of collection, and sieved through a 0.5-mm mesh screen using laboratory seawater at ambient temperature and salinity. *Ampelisca* were collected with a dip net after flotation on the air/water interface. The amphipods were maintained in the laboratory in presieved collection site sediment and flowing filtered seawater, and acclimated to the assay temperature at the rate of 2 to 4°C per day. During acclimation, the *Ampelisca* were fed, *ad libidum*, the laboratory cultured diatom *Phaeodactylum tricornutum*.

## Exposure System

*Ampelisca* were exposed for 10 days in flowing, filtered seawater at 20°C to Narragansett Bay sediments in the solid phase, according to standard procedures (ASTM, 1990). The test endpoint was mortality. Flow-through exposures were chosen because they were the preferred method for these tests at the time. A data base on static exposures was being accumulated.

The exposure container (Figure 2) was a 900-ml glass canning jar with a one-half inch overflow hole covered with 400-micron Nitex mesh. Two hundred milliliters of control or test sediment filled the bottom of each jar, and was covered with approximately 600 ml of seawater. A tube from the delivery system described below entered a hole in the glass cover (3.5-inch diameter glass culture dish) of the exposure jar, emptying above the water surface. Air was delivered into the water column through a glass 2-Ml pipette inserted through the cover opening. Air delivery ensured acceptable dissolved oxygen concentration and circulation of the newly delivered seawater. The escape of contaminated

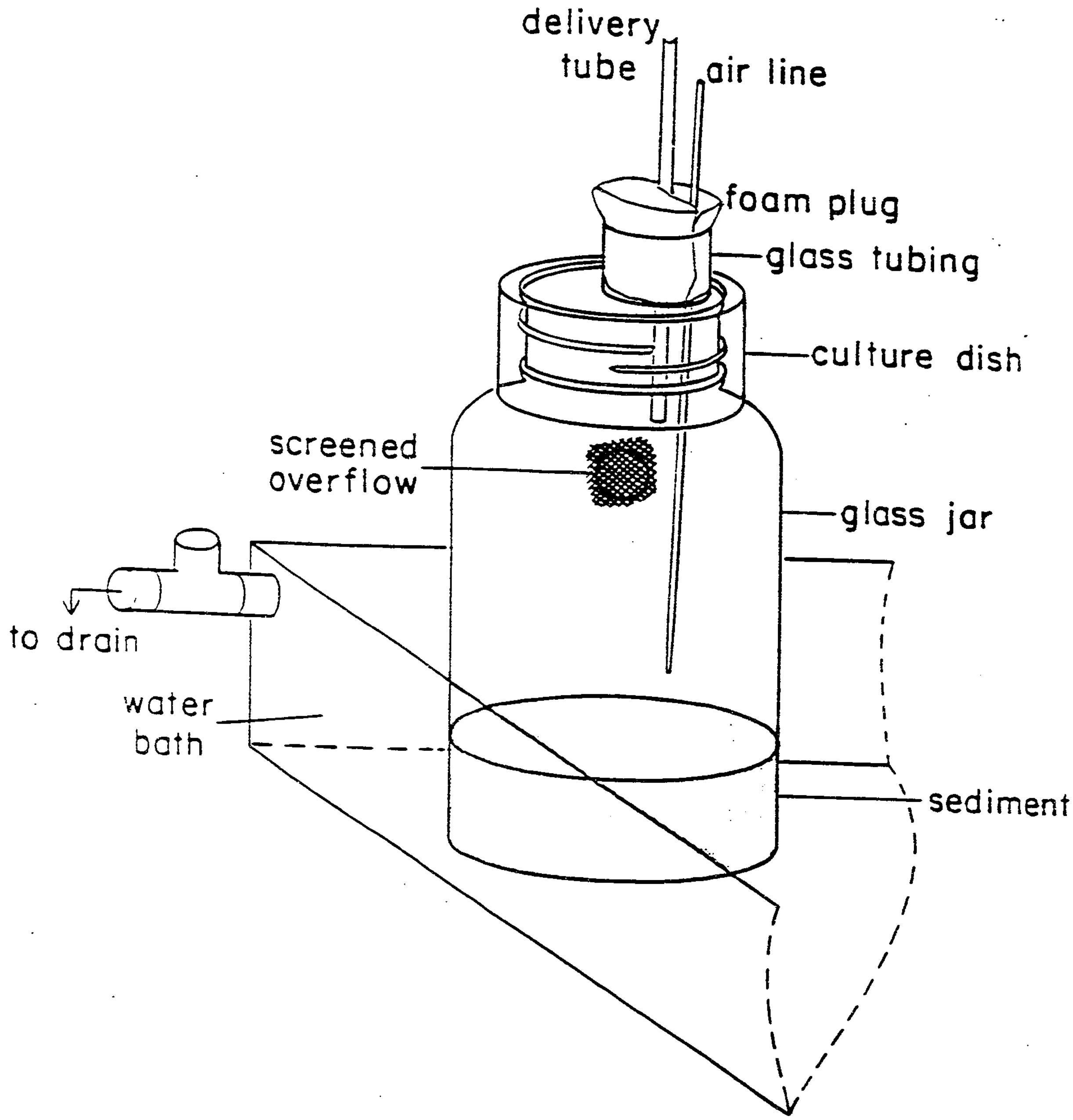


Figure 2. Exposure container for sediment toxicity tests with *Ampelisca abdita*.

aerosols was prevented by the placement of a foam plug in the cover. The water exited the screened overflow in the exposure chamber, flowed into a water bath, and then to the drain and treatment system. Additional 20°C seawater flowed to the water bath to stabilize the temperature in the exposure containers. The system used to deliver seawater to the exposure containers consisted of a mixing chamber and a distribution chamber. A predetermined, and calibrated seawater flow passed into the former, and then, intermittently via an umbrella siphon, into the latter. The distribution chamber provided for equal flows to each exposure chamber through capillary tubes and distribution tubing of equal sizes. Seawater flow rates into the mixing chamber were set to provide for approximately 10 volume replacements per day per chamber, i.e., 6 L/day/chamber.

Test Initiation

Before use in the experiment, each sediment was pressed through a 2-mm mesh stainless steel sieve to remove large debris and potential predators (Redmond and Scott, 1989), and thoroughly homogenized. The day before amphipods were added to the exposure system, sediments were added to exposure containers, and the containers filled to the overflow with filtered seawater. A petri dish attached to a glass rod was used when adding seawater to minimize disturbance of the sediment. Exposure containers were placed in the water bath overnight with air and flow-through seawater provided.

The next day, amphipods were sieved from holding containers through a 0.5-mm stainless steel screen using 20°C filtered seawater. Juvenile amphipods were distributed sequentially into 100-mL plastic beakers containing 20°C filtered seawater. Once the 30 amphipods were placed into each beaker, they were examined for dead or outsized animals, which were replaced with others from the same sieved population. The beakers were randomized, and one beaker of organisms preserved in 5% buffered formalin for later measurement using of a computerized digitizer and camera lucida device.

While the amphipods were being sorted, air and seawater delivery to the exposure containers was halted, and nitrogen gas was delivered to all chambers for one hour in an attempt to kill any indigenous amphipods in the sediments which had not already been removed. After nitrogen flushing, jars were checked and any indigenous amphipods removed. Air and water delivery were restarted, and after two hours, dissolved oxygen concentration was determined to be at saturation. Air delivery in the exposure system was again halted, and one beaker of amphipods was added to each of the exposure containers in the experiment. After one hour, the containers were checked, any amphipods not burrowed into the sediment were replaced with others from the same sieved population, and air delivery was restarted.

Test Monitoring Procedures

The flow rate of seawater entering the seawater delivery system was checked daily, and the volume delivered to each exposure container and from the flow distributor was measured before and after each test. Temperature in the water bath was monitored continuously with a temperature recorder which was checked daily against a thermometer. Salinity of the incoming seawater was measured daily with a refractometer, and dissolved oxygen was measured in the water column of each exposure container with a LG Nester oxygen meter twice during each test.

Exposure containers were checked daily and the number of individuals that were dead, moribund, on the sediment surface, and on the water surface were recorded. The number of molts and condition of the tubes constructed were also monitored. Dead amphipods and molts were removed.

Test Termination

After 10 days, the experiment was terminated and the contents of each exposure container were sieved through a 0.5-mm mesh sieve. Material retained on the sieve was preserved in 5% buffered formalin with Rose Bengal stain for later sorting, or in the case of the gradient test, examined immediately and not preserved. Recovered animals were counted, and any missing individuals were assumed to have died and decomposed during the test, and were counted as mortalities.

Data Analyses

Each sediment was tested with five replicates and 30 amphipods per replicate. In order to approximate a normal statistical distribution for ANOVA, the data were transformed. The arcsine of the square root of the proportional mortality was conducted before these analyses. The transformed mortality data were analyzed with a one-way analysis of variance followed by Duncan's multiple range test (Duncan, 1955).

## RESULTS AND DISCUSSION

Physical parameters and information on the Ampelisca used in the experiments are shown in Table 2. The salinity and temperature of the overlying seawater remained relatively constant in each test; among tests, the means of these parameters ranged from 28.8 to 30.2 ppt, and 20.0 to 21.8°C, respectively. Dissolved oxygen, measured twice per test in each exposure jar, was always greater than 93% saturation. The amphipod holding times declined with each successive test, primarily, because of the longer acclimation period required in the earlier tests. The sizes of Ampelisca at test initiation were similar for all tests. Sediment holding times were 18 days or less for all but two sediments. The holding times for the Warren River and Potowomut River sediments were 91 and 48 days, respectively.

Table 2. Physical parameters and condition of test organisms in experiments exposing <u>Ampelisca abdita</u> to Narragansett Bay sediments.

| Parameter | | Survey Test 1 | Survey Test 2 | Survey Test 3 | Gradient test |
|---|---|---|---|---|---|
| Temperature, $^{o}C^{a}$ | | 20.0±0.6(10) | 21.8±0.7(11) | 20.2±0.8(10) | 20.4±0.32(10) |
| Salinity, $^{o}/oo^{a}$ | | 29.8±0.8(11) | 28.8±0.8(11) | 30.2±0.7(10) | 30.0±0(10) |
| Volume replacements per day | | 10 | 10 | 11 [b] | 10 |
| Collection of amphipods | $^{o}C$ | 7.0 | 6.0 | 21.0 | 24.0 |
| | $^{o}/oo$ | 30.0 | 26.0 | 20.0 | 28.0 |
| Size of initial amphipods, $mm^{a}$ 4.68±0.36(30)[c] | | 3.98±0.64(30) | 4.56±0.49(60) | | 3.67±0.43(30) |
| Amphipod holding time (days) | | 14 | 8 | 4 | 3 |

a mean ± standard deviation (n)
b static for last two days of test; see text for explanation
c included some mature females

The third survey test was in its eighth day when an oil spill in Narragansett Bay necessitated the temporary shut-down of the laboratory seawater system. This test was thus conducted under static conditions during its last two days. Since exposure containers were aerated and control mortality was only 0.7% in that test, it is not likely that lack of flowing seawater during this time affected the results. In fact, this species has been used extensively in tests following ASTM (1990) procedures that call for static conditions (Scott et al., 1990; Holland et al., 1990).

Toxicity data for all 31 Narragansett Bay sites are presented in Table 3 and Appendix Tables 1-4. Mean control mortality was always less than 10% in the performance control. Except for the first test where mean mortality was 11.3%, the same was true for the North Jamestown (site) control. The following stations had sediments that caused statistically significant <u>Ampelisca</u> mortality: Fox Point, Field's Point, Greenwich Cove, Melville Cove, Mount Hope Bay 1 and 3, Sakonnet River North, Potowomut River, Seekonk River, and Blackstone River. Irregardless of the statistical significance detected with the Melville Cove, the two Mount Hope Bay, Sakonnet River North, and Potowomut River sediments, mortality at all of these sites was less than 10%, which should not be considered biologically meaningful. Control mortality at or below 10% is acceptable for this species. These statistical differences merely reflect the high precision that is often attained with this test when five replicates are used.

Sediments from the first three tests that produced mortalities significantly different from the control (either the performance control or the North Jamestown control), and were greater than 10% included all of those collected in, and north of, the Providence River, and in Greenwich Cove. The Field's Point area was selected for closer examination in the forth test. The six station sediments used in this gradient test were selected to

Table 3. Mortality in <u>Ampelisca</u> <u>abdita</u> exposed to sediments from Narragansett Bay, RI. Four test series are shown, and within each test, means followed * are significantly different from their respective control; in Test 1, a mean followed by ** is different from North Jamestown ($p < 0.05$).

| | Station | Location | % Mortality |
|---|---|---|---|
| Test 1 | Control | Long Island Sound | 2.7 |
| | 02 | Brushneck Cove | 4.0 |
| | 00 | Bissel Cove | 4.7 |
| | 05 | Providence River Mouth | 6.0 |
| | 06 | Pawtuxent Cove | 7.3 |
| | 09 | Bullock Cove | 5.7 |
| | 04 | Warwick Cove | 8.0 |
| | 22 | North Jamestown | 11.3 |
| | 01 | Apponaug Cove | 12.0 |
| | 08 | Fox Point | 13.3 * |
| | 03 | Greenwich Cove | 17.5 * |
| | 07 | Field's Point | 30.7 ** |
| Test 2 | 18 | Coddington Cove | 0.0 |
| | Control | North Jamestown | 0.7 |
| | 19 | Newport Harbor | 0.7 |
| | 13 | Mount Hope Bay 2 | 2.0 |
| | 21 | Sakonnet River South | 1.3 |
| | 15 | Mount Hope Bay 4 | 2.0 |
| | 17 | Derektor Shipyard | 2.0 |
| | 11 | Bristol Harbor | 3.3 |
| | 12 | Mount Hope Bay 1 | 2.6 * |
| | 14 | Mount Hope Bay 3 | 3.3 * |
| | 16 | Melville Cove | 4.0 * |
| | 20 | Sakonnet River North | 5.3 * |
| Test 3 | Control | North Jamestown | 0.7 |
| | 10 | Warren River | 1.3 |
| | 24 | Potowomut River | 6.0 * |
| | 25 | Seekonk River | 13.3 * |
| | 26 | Blackstone River | 12.0 * |
| Gradient | Control | North Jamestown | 6.7 |
| | 32 | East of Pawtuxent Neck | 6.7 |
| | 29 | Between outfalls and F. P. | 10.7 |
| | 28 | Southeast of Field's Point | 14.0 |
| | 27 | East of Edgewood Y.C. | 16.0 |
| | 30 | Outfalls at Field's Point | 16.7 |
| | 31 | Sassafras Point | 19.3 |

bracket the area of the outfall from the Field's Point treatment plant and the nearby combined sewer overflow. Although all sediments but one elicited average mortalities greater than 10%, there were no significant differences between the site sediments and the control sediment (Table 3) because of the higher variability among replicates. The Field's Point sediment which was very toxic (30.7% mortality) in the earlier survey test may be representative of a very limited area. Since the highest mortality in any of the tests conducted with Narragansett Bay sediments was 53%, in one Field's Point replicate in the first survey test, none of the planned LC50 tests could be conducted with these sediments.

Overall, only five of 31 sediments in Narragansett Bay exhibited toxicity which was greater than 10% and also was significantly different from controls. Further, only one sediment, that from Field's Point, caused toxicity that was greater than 25%. This level of toxicity is considered biologically significant. While there is a general lack of toxicity in these Narragansett Bay sediments, it is important to remember, however, that this is an acute toxicity test, and that even marginal toxicity (10-25% mortality) may indicate more subtle sublethal, ecological effects (Scott, 1989). A comparison of the frequency distribution of toxicity in all replicates for the Providence River and more northern sites versus all other Narragansett Bay sites clearly demonstrates that this marginal toxicity is concentrated in the river locations (Table 4). Sixty five percent of the replicates from the Providence River and sites north exhibited toxicity greater than 10%, while this level of toxicity was found in only 16% of the replicates from all other Bay sites. These data raise the concern that sublethal toxicity may be occurring in some northern areas of the Bay system, particularly in the Providence, Seekonk, and Blackstone Rivers.

The absence of sediment toxicity in most of the Narragansett Bay

Table 4. Frequency distribution of replicate mortality in *Ampelisca abdita* exposed to sediments from Narragansett Bay. The replicate data from the Long Island Sound control are not included.

| Mortality (%) | All Sites | | Providence River Sites | | All Other Bay Sites | |
|---|---|---|---|---|---|---|
| | N | % | N | % | N | % |
| 0.0-4.9 | 87 | 50.0 | 11 | 16.9 | 76 | 69.7 |
| 5.0-9.9 | 28 | 16.1 | 12 | 18.5 | 16 | 14.7 |
| 10.0-14.9 | 27 | 15.5 | 20 | 30.8 | 7 | 6.4 |
| 15.0-19.9 | 14 | 8.0 | 8 | 12.3 | 6 | 5.5 |
| 20.0-24.9 | 10 | 5.7 | 7 | 10.8 | 3 | 2.8 |
| ≤ 25 | 8 | 4.6 | 7 | 10.8 | 1 | 0.9 |
| Total N | 174 | | 65 | | 109 | |

embayments is consistent with previous tests conducted by the ERL-Narragansett for the U.S. Navy. Sediments were collected from Allen Harbor and surrounding areas, Mount View, Greenwich Bay, Potter's Cove, and North Jamestown (Munns et al. [GET]; Appendix Tables 4-8). Toxicity tests with Ampelisca using the same procedures as those described here resulted in no significant mortalities.

The overall lack of toxicity, however, does not indicate a lack of sensitivity of the test to identify contaminated sediments. Previous work with this species has established its acute sensitivity to highly contaminated sediments from Black Rock Harbor, CT (Rogerson et al. 1985, Scott and Redmond, 1989), New Bedford Harbor, MA (Scott et al., in prep.), New York-New Jersey Harbor (Scott et al., 1990), and the Calcasieu River, LA (Redmond et al. in prep.). In these studies there was a clear dose response to either a gradient of contamination or to a sediment dilution series. These sediments obviously represent contamination "hot spots" where acute toxicity would be expected.

In less contaminated urban embayments, acute toxicity of A. abdita is less predominant. For example, in San Francisco Bay, where only sediments from Oakland Harbor caused moderate, but significant, toxicity (Long et al., 1990). Similar results were found in a recently completed study examining western Long Island Sound and the Hudson Raritan sediments from NOAA Status and Trends sites. No acute toxicity was observed in sediments collected from New Haven and Bridgeport Harbors. The overall lack of toxicity observed in the Narragansett Bay sediments is consistent with what would be expected in most non-industrialized embayments.

Most of the studies described above employed an acute test under flow-through conditions. Recent studies (Word et al., 1989; Long et al., 1990) and extensive testing conducted by SAIC's

Environmental Testing Center indicate that more sensitivity in the acute test is achieved under static conditions. This increased sensitivity would be useful in assessing moderately contaminated sediments with greater reliability. Were this method used here, the moderately toxic (> 10% mortality) sediments likely would have been more clearly distinguished.

As noted above, the lack of observed acute toxicity does not mean that the benthic community is not being influenced by contaminants or other anthropogenic factors, such as organic loading. A recent survey of sediment quality in Narragansett Bay (SAIC, 1989) found many of the embayments to have altered communities, that were either azoic or dominated by surface dwelling forms. This community structure could result from one of two conditions: high organic loading (Rhoads and Germano, 1986), such as is found in Greenwich Cove; or historically contaminated sediments covered with recently deposited clean sediments. In the latter case, larger, deeper burrowing organisms would not survive in the subsurface deposits (Scott et al., 1987). One might expect this condition to become more common as point source controls become more effective in regulating contaminant inputs. In neither of the conditions described, would the test employed here have shown toxicity. In fact, some A. abdita were inhabiting many of the locations tested.

The absence of acute toxicity also does not mean that these surface sediments (top 2 cm.) do not contain contaminant concentrations that, under some conditions, could be toxic. The results do show that if contaminants are present, they are not bioavailable in concentrations high enough to be acutely toxic. It is well known that many organic compounds have high binding affinities with sediment organic carbon pools making them essentially unavailable (USEPA, 1989). Recent data on metal toxicity to A. abdita suggest that sedimentary sulfides may control metal availability in a similar manner (DiToro et al.

1990).

The Providence River, Greenwich Bay embayments and Mount Hope Bay locations sampled in the SAIC REMOTS survey were characterized as "focussing" sites for organic rich sediments which could provide the binding capacity for moderate organic contaminant concentrations. That same survey also found that many of the Greenwich Bay and other small embayments, including Potowomut Cove have very shallow oxidized zones, suggesting that the sediments may also have a large metal-sulfide binding capacity. It therefore appears that, even if contaminants are present in these sediments, expected acute toxicity would be minimal.

## CONCLUSIONS

1. The majority of sediments collected from 32 sites in Narragansett Bay did not cause significant toxicity, where mortality was greater than 10%, to Ampelisca abdita.

2. Sediments which exhibited moderate toxicity were collected from Fox Point, Field's Point, Greenwich Cove, Seekonk River, Blackstone River. Statistically significant toxicity was observed in sediments from other sites, but mortality did not exceed 10%, and was not considered biologically significant.

3. The overall absence of toxicity in Narragansett Bay is consistent with previous testing in non-industrialized embayments. Potential sediment toxicity problems are mainly concentrated in the Providence, Seekonk, and Blackstone Rivers.

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## APPENDIX

## DATA SUMMARY

Tables 5-8 for Allen Harbor
from Munns et al. (1991)

Appendix Table 1. Percent mortality of amphipods, <u>Ampelisca abdita</u>, exposed for 10 days in flowing filtered 20°C seawater to sediments from embayments surrounding Narragansett Bay, Rhode Island. Performance control sediment was from central Long Island Sound. This was the first in a series of three survey tests. Thirty amphipods were tested per replicate. Means followed by * are significantly different from the performance control; those with ** are significantly different from Jamestown North ($p < 0.05$).

| Station # | Station Location | % Mortality | Mean |
|---|---|---|---|
| Performance Control | Long Island Sound | 6.7 | 2.7 |
| | | 3.3 | |
| | | 3.3 | |
| | | 0 | |
| | | 0 | |
| 02 | Brushneck Cove | 3.3 | 4.0 |
| | | 6.7 | |
| | | 3.3 | |
| | | 6.7 | |
| | | 0 | |
| 00 | Bissel Cove | 3.3 | 4.7 |
| | | 0 | |
| | | 6.7 | |
| | | 10.0 | |
| | | 3.3 | |
| 05 | Providence River mouth | 13.3 | 6.0 |
| | | 0 | |
| | | 6.7 | |
| | | 10.0 | |
| | | 0 | |
| 06 | Pawtuxet Cove | 10.0 | 7.3 |
| | | 13.3 | |
| | | 0 | |
| | | 13.3 | |
| | | 0 | |
| 09 | Bullock Cove | 5.0 | 5.7 |
| | | 0 | |
| | | 6.7 | |
| | | 10.0 | |
| | | 6.7 | |
| 04 | Warwick Cove | 0 | 8.0 |
| | | 10.0 | |
| | | 10.0 | |
| | | 6.7 | |
| | | 13.3 | |

Appendix Table 1, continued.

| Station # | Station Location | % Mortality | Mean |
|---|---|---|---|
| 22 | North Jamestown | 10.0 | 11.3 |
| | | 20.0 | |
| | | 20.0 | |
| | | 0 | |
| | | 6.7 | |
| 01 | Apponaug Cove | 3.3 | 12.0 |
| | | 16.7 | |
| | | 16.7 | |
| | | 20.0 | |
| | | 3.3 | |
| 08 | Fox Point | 10.0 | 13.3 * |
| | | 16.7 | |
| | | 10.0 | |
| | | 16.7 | |
| | | 13.3 | |
| 03 | Greenwich Cove | 16.7 | 17.5 * |
| | | 16.7 | |
| | | 26.7 | |
| | | 10.0 | |
| 07 | Field's Point | 53.3 | 30.7 ** |
| | | 16.7 | |
| | | 36.6 | |
| | | 30.0 | |
| | | 16.7 | |

Appendix Table 2. Percent mortality of amphipods, _Ampelisca abdita_, exposed for 10 days in flowing filtered 20°C seawater to sediments from embayments surrounding Narragansett Bay, Rhode Island. This was the second in a series of three tests. Thirty amphipods were tested per replicate. Means followed by * are significantly different from the control ($p < 0.05$).

| Station # | Station Location | % Mortality | Mean |
|---|---|---|---|
| 18 | Coddington Cove | 0 | 0 |
| | | 0 | |
| | | 0 | |
| | | 0 | |
| | | 0 | |
| 22 | North Jamestown (site control) | 0 | 0.7 |
| | | 3.3 | |
| | | 0 | |
| | | 0 | |
| | | 0 | |
| 19 | Newport Harbor | 0 | 0.7 |
| | | 3.3 | |
| | | 0 | |
| | | 0 | |
| | | 0 | |
| 13 | Mount Hope Bay, second station (south of Fall River CSO) | 10.0 | 2.0 |
| | | 0 | |
| | | 0 | |
| | | 0 | |
| | | 0 | |
| 21 | South Sakonnet River | 0 | 1.3 |
| | | 0 | |
| | | 0 | |
| | | 3.3 | |
| | | 3.3 | |
| 15 | Mount Hope Bay, fourth station (Breeds Cove, Taunton River) | 0 | 2.0 |
| | | 0 | |
| | | 6.7 | |
| | | 0 | |
| | | 3.3 | |
| 17 | Derektor Shipyard | 6.7 | 2.0 |
| | | 3.3 | |
| | | 0 | |
| | | 0 | |
| | | 0 | |

Appendix Table 2, continued.

| Station # | Station Location | % Mortality | Mean |
|---|---|---|---|
| 11 | Bristol Harbor | 3.3 | 3.3 |
| | | 6.7 | |
| | | 6.7 | |
| | | 0 | |
| | | 0 | |
| 12 | Mount Hope Bay, first station (near mouth) | 3.3 | 2.6 * |
| | | 0 | |
| | | 3.3 | |
| | | 3.3 | |
| | | 3.3 | |
| 14 | Mount Hope Bay, third station (mouth of Taunton River) | 0 | 3.3 * |
| | | 3.3 | |
| | | 6.7 | |
| | | 3.3 | |
| | | 3.3 | |
| 16 | Melville Cove | 3.3 | 4.0 * |
| | | 3.3 | |
| | | 3.3 | |
| | | 6.7 | |
| | | 3.3 | |
| 20 | North Sakonnet River | 3.3 | 5.3 * |
| | | 6.7 | |
| | | 6.7 | |
| | | 3.3 | |
| | | 6.7 | |

Appendix Table 3. Percent mortality of amphipods, *Ampelisca abdita*, exposed for 10 days in flowing filtered 20°C seawater to sediments from embayments surrounding Narragansett Bay, Rhode Island. This was the third in a series of 3 tests. Thirty amphipods were tested per replicate. Means followed by * are significantly different from the control ($p < 0.05$).

| Station # | Station Location | % Mortality | Mean |
|---|---|---|---|
| 22 | North Jamestown (site control) | 0 | 0.7 |
| | | 3.3 | |
| | | 0 | |
| | | 0 | |
| | | 0 | |
| 10 | Warren River | 3.3 | 1.3 |
| | | 0 | |
| | | 0 | |
| | | 3.3 | |
| | | 0 | |
| 24 | Potowomut River | 16.7 | 6.0 * |
| | | 3.3 | |
| | | 3.3 | |
| | | 3.3 | |
| | | 3.3 | |
| 25 | Seekonk River | 20.0 | 13.3 * |
| | | 3.3 | |
| | | 10.0 | |
| | | 16.7 | |
| | | 16.7 | |
| 26 | Blackstone River | 33.3 | 12.0 * |
| | | 13.3 | |
| | | 6.7 | |
| | | 6.7 | |
| | | 0 | |

Appendix Table 4. Percent mortality of amphipods, *Ampelisca abdita*, exposed for 10 days in flowing filtered 20°C seawater to sediments from the Field's Point area in Narragansett Bay, Rhode Island. Thirty amphipods were tested per replicate. There were no significant differences between treatments ($p < 0.05$).

| Station # | Station Location | % Mortality | Mean |
|---|---|---|---|
| 22 | North Jamestown (site control) | 3.3 | 6.7 |
| | | 6.7 | |
| | | 3.3 | |
| | | 6.7 | |
| | | 13.3 | |
| 32 | East of Pawtuxet Neck | 10.0 | 6.7 |
| | | 3.3 | |
| | | 0 | |
| | | 13.3 | |
| | | 6.7 | |
| 27 | East of Edgewood Yacht Club | 13.3 | 16.0 |
| | | 23.3 | |
| | | 16.7 | |
| | | 6.7 | |
| | | 20.0 | |
| 28 | Southeast of Field's Point | 33.3 | 14.0 |
| | | 6.7 | |
| | | 13.3 | |
| | | 6.7 | |
| | | 10.0 | |
| 29 | Between outfalls and Field's Point | 30.0 | 10.7 |
| | | 6.7 | |
| | | 3.3 | |
| | | 3.3 | |
| | | 10.0 | |
| 30 | Outfalls at Field's Point | 6.7 | 16.7 |
| | | 20.0 | |
| | | 30.0 | |
| | | 13.3 | |
| | | 13.3 | |
| 31 | Sassafras Point | 23.3 | 19.3 |
| | | 23.3 | |
| | | 16.7 | |
| | | 10.0 | |
| | | 23.3 | |

Appendix Table 5. Mean percent mortality of amphipods, <u>Ampelisca abdita</u>, exposed for 10 days in flowing filtered 20°C seawater to sediments from East Allen Harbor and North Jamestown, Narragansett Bay, Rhode Island. Control sediment was from central Long Island Sound. There were five replicates tested per treatment, with 30 amphipods per replicate. There were no significant differences between treatments ($p < 0.05$).

| Station # | Station Location | %Mortality |
|---|---|---|
| control | Long Island Sound | 6.0 |
| 798018 | North Jamestown | 6.7 |
| 798019 | North Jamestown | 4.0 |
| 798020 | North Jamestown | 4.7 |
| 798021 | North Jamestown | 3.3 |
| 798022 | North Jamestown | 4.7 |
| 798039 | East Allen Harbor | 12.0 |
| 798041 | East Allen Harbor | 11.3 |
| 798042 | East Allen Harbor | 8.7 |
| 798043 | East Allen Harbor | 5.3 |
| 798044 | East Allen Harbor | 2.0 |
| 798045 | East Allen Harbor | 10.0 |

Appendix Table 6. Mean percent mortality of amphipods, *Ampelisca abdita*, exposed for 10 days in flowing filtered 20°C seawater to sediments from Allen Harbor and Greenwich Bay, Rhode Island. Control sediment was from central Long Island Sound. There were five replicates tested per treatment, with 30 amphipods per replicate. There were no significant differences between treatments ($p < 0.05$).

| Station # | Station Location | %Mortality |
|---|---|---|
| control | Long Island Sound | 6.6* |
| 798003 | Allen Harbor | 6.0 |
| 798004 | Allen Harbor | 4.6 |
| 798005 | Allen Harbor | 2.7 |
| 798011 | Allen Harbor mouth | 2.0 |
| 798012 | Allen Harbor mouth | 0 |
| 798013 | Allen Harbor mouth | 6.0 |
| 798014 | Allen Harbor mouth | 4.7 |
| 798015 | Allen Harbor mouth | 4.0 |
| 798016 | Allen Harbor mouth | 0 |
| 798024 | Greenwich Bay | 4.0 |
| 798025 | Greenwich Bay | 2.7 |

* four replicates

Appendix Table 7. Mean percent mortality of amphipods, Ampelisca abdita, exposed for 10 days in flowing filtered 20°C seawater to sediments from Allen Harbor and Greenwich Bay, Rhode Island. Control sediment was from central Long Island Sound. There were five replicates tested per treatment, with 30 amphipods per replicate. There were no significant differences between treatments ($p < 0.05$).

| Station # | Station Location | %Mortality |
|---|---|---|
| control | Long Island Sound | 2.7 |
| 798000 | Allen Harbor | 4.0 |
| 798001 | Allen Harbor | 6.0 |
| 798002 | Allen Harbor | 8.0 |
| 798006 | Allen Harbor | 8.7 |
| 798028 | Mount View | 10.7 |
| 798029 | Mount View | 2.0 |
| 798030 | Mount View | 4.7 |
| 798031 | Mount View | 2.0 |
| 798032 | Mount View | 3.3 |
| 798023 | Greenwich Bay | 10.0 |

Appendix Table 8. Mean percent mortality of amphipods, <u>Ampelisca abdita</u>, exposed for 10 days in flowing filtered 20°C seawater to sediments from Allen Harbor, Potter's Cove, and Greenwich Bay, Rhode Island. Control sediment was from central Long Island Sound. There were five replicates tested per treatment, with 30 amphipods per replicate. There were no significant differences between treatments ($p < 0.05$).

| Station # | Station Location | %Mortality |
|---|---|---|
| control | Long Island Sound | 1.3 |
| 798007 | Allen Harbor | 1.3 |
| 798026 | Greenwich Bay | 4.7 |
| 798027 | Allen Harbor | 6.0 |
| 798033 | Potter's Cove | 4.7 |
| 798034 | Potter's Cove | 2.0 |
| 798035 | Potter's Cove | 2.7 |
| 798036 | Potter's Cove | 6.7 |
| 798037 | Potter's Cove | 0 |
| 798038 | Allen Harbor | 4.7 |
| 798040 | Allen Harbor | 4.0 |