STATE OF THE COASTAL ENVIRONMENT

SEDIMENT TOXICITY

Chemical contaminants discharged into estuaries and coastal bays often attach to sediment particles and are deposited on the sea bed. In sufficiently high concentrations, these contaminant-laden sediments may pose serious threats to coastal ecosystems, the sustainability of natural resources, and human health. A national program of sediment toxicity assessment studies, begun in 1991, has provided a great deal of information on the spatial extent and severity of sediment toxicity in U.S. coastal regions. To date, the studies encompass 23 coastal bays and estuaries, and cover approximately 4,000 square kilometers.

Based on the survival tests of amphipods--a group of widely distributed crustaceans of considerable ecological importance--it can be surmised that samples representing approximately 7 percent of the total study area were toxic. More sensitive toxicity tests suggest a much wider pattern of toxicity: 39% of the study area based on the sea urchin fertilization test, and 66% based on the Microtox test, which measures the light output of a luminescent bacterium. Even though the studies performed to date are extensive, they cover only a small fraction of the total area of coastal bays, sounds, and estuaries of the United States. Data from these studies have been useful in determining the occurrence and magnitude of sediment toxicity, and in the development of management plans to clean up polluted sites and curtail sources of contamination.

The following reference format is suggested:

Hameedi, M.J., E.R. Long and M.R. Harmon. 1999 (on-line). Sediment Toxicity. In: NOAA's State of the Coast Report. Silver Spring, MD: National Oceanic and Atmospheric Administration. URL: http://state-of-coast.noaa.gov/bulletins/html/sed_15/sed.html

STATE OF THE COASTAL ENVIRONMENT

SEDIMENT TOXICITY

INTRODUCTION

Sediment contamination in U.S. coastal areas is a major environmental issue because of its potential toxic effects on biological resources and often, indirectly, on human health. A large variety of contaminants from industrial, agricultural, urban, and maritime activities are associated with sediment particulates, including bottom sediments. Of particular interest are (1) synthetic organic chemicals (chlorinated pesticides, polychlorinated biphenyls (PCBs), and industrial chemicals); (2) polycyclic aromatic hydrocarbons (PAHs), that are typically components of petroleum, coal, and pyrogenic residues, as well as biogenic and naturally occurring substances; and (3) toxic elements (e.g., arsenic, cadmium, copper, lead, mercury, zinc), all of which can be toxic at sufficiently high concentrations, even though some, like zinc, are essential for normal metabolism. The dredging and disposal of sediment from harbors and hazardous waste sites also contribute significantly to contamination in the coastal zone.

Photo 1. While the products made in petrochemical plants have many important uses, they can prove harmful to biological resources and are potentially harmful to human health when they contaminate sediments in coastal areas.

Sediment grain size, organic matter content, and chemical composition of different kinds of sediment, as well as the amount and chemical properties of contaminants, influence the levels and extent of contamination in the environment. Contaminant-laden sediments on the sea bottom may be resuspended, transported, and redeposited in areas far from the original source. Under certain conditions, contaminants may "break free" from sediments (a process known as desorption) and be released into the water, making the bottom sediments not only a sink, but also a source of contaminants.

Critical habitats and food chains supporting many estuarine fish and wildlife species involve the benthic environment (the sea bottom). Contaminants in the sediments often pose both ecological and human-health risks through degraded habitats, loss of fauna, propagation of contaminants in the coastal ecosystem, and human consumption of contaminated fish and wildlife. In many instances, fish consumption advisories are coincident with severely degraded sediments in coastal water bodies. Thus, characterizing and delineating areas of sediment contamination and toxicity are viewed as important goals of coastal resource management. This includes the analysis of trends in the environmental quality of coastal ecosystems as outlined in the 1992 National Coastal Monitoring Act (PL 102-567) and other pertinent federal legislation.

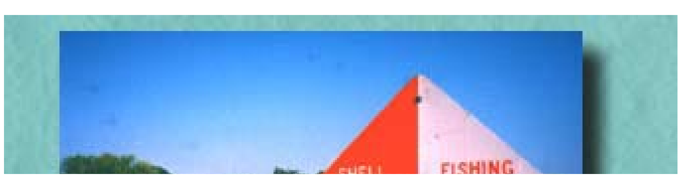


Photo 2. Shellfish tend to absorb and store (bioaccumulate) in their tissues the toxicants in their food sources. As a result, severely contaminated sediments in coastal water bodies sometimes make it necessary to close a shellfishery or to allow harvest only under certain conditions.

Resource management and regulatory agencies, such as the U.S. Environmental Protection Agency (EPA), scientific organizations such as the National Research Council, and the public at large have expressed concern over the widespread nature of sediment contamination and its associated adverse biological effects (USEPA, 1988; NRC, 1989). The EPA recently estimated that hundreds of sites in marine and estuarine waterways contain contaminants at levels high enough to cause significant adverse biological consequences (Armitage, 1995; USEPA, 1997). Some states and local governments conduct toxicity studies; however, each state or jurisdiction uses different tests and methods, making it difficult to develop a national picture of sediment toxicity. The National Oceanic and Atmospheric Administration (NOAA), as part of its environmental stewardship responsibilities, has also recognized the need to conduct research, assessment, and monitoring studies on the sources, transport, fate, and effects of contaminants on coastal resources and ecosystems (NOAA, 1996).

This essay discusses the results of NOAA's recent sediment toxicity studies, a component of the National Status and Trends (NS&T) Program for marine environmental quality. This program encompasses a broad spectrum of research and monitoring studies to evaluate sediment contamination and toxicity in U.S. coastal waters, including the long-term, nationwide monitoring of contaminant levels in sediments and bivalves; sediment toxicity assessments in specific coastal areas; the evaluation and application of biomarkers; and the development of ecological indices (NOAA, 1998).

Study Areas

The National Status and Trends Program has conducted sediment toxicity assessment studies in coastal water bodies since 1991. This essay summarizes the results from 23 estuaries and coastal embayments for which studies were completed through 1997 (Figure 1). These study areas encompass approximately 4,000 sq km. In comparison, the total surface area of the nation's estuaries and coastal water bodies, excluding the Great Lakes and those in Alaska, Hawaii, and island territories, is about 75,000 sq km (NOAA, 1990). The size of the study areas ranged from 0.3 sq km (Tijuana River) to 1,350 sq km (Galveston Bay). NOAA's sediment toxicity assessment studies do not cover offshore ocean waters.

The sites for sediment toxicity assessment studies were selected in view of the following: (1) a high level of contamination in oysters or mussels as determined by NOAA's NS&T Program; (2) the likelihood of adverse biological effects of contamination based on state and local environmental data; and (3) possible collaboration with other federal, state, and local agencies.

Photo 3. The dredging and disposal of sediment from harbors and hazardous waste sites are significant, and often controversial, coastal environmental issues.

Field Sampling

Photo 4. These researchers in Delaware Bay use a piece of equipment known as a modified Van Veen grab to collect bottom sediments for chemical analysis.

With the exception of earlier studies in Long Island Sound, the Hudson-Raritan Estuary, Tampa Bay, and San Pedro Bay, the field sampling methods for sediment toxicity discussed herein were based on a stratified-random design, i.e., sampling sites within a coastal water body were selected randomly within a subarea of interest, called a stratum. The subareas (or sampling strata) were delineated on the basis of similarity in coastal features, oceanographic conditions, or particular resource management considerations. As a result, the sampling strata were of different sizes and dimensions. Sediments were collected with a modified Van Veen or similar grab sampler at each site in amounts sufficient for chemistry and toxicity testing. Surficial sediments from the upper 2 to 3 cm of the grab sample were used to assure that measurements were made on recently deposited materials.

Contaminant Analyses

Chemical analyses measured the concentrations of about 80 chemical contaminants (Table 1) in the sediment samples (Hameedi, 1997; NOAA, 1998). These contaminants were generally grouped as chlorinated pesticides, PCBs, butyltins, PAHs, and major and trace elements.

Toxicity Tests

Toxic chemicals cause a wide range of direct and/or indirect adverse effects on biological systems, ranging from cells to ecosystems. The severity of these effects depends on the types and properties of the chemicals and the "dosage" or duration of exposure to ambient concentrations. Numerous test procedures, called bioassays, are available to investigate the adverse effects of contaminants on coastal and marine fauna, including mortality, impaired physiology, biochemical abnormalities, and behavioral aberrations.

In nearly all of NOAA's sediment toxicity assessment studies, three separate bioassays were used to measure toxicity. This ensured that a range of species and assessment end points (e.g., mortality, reproductive impairment, physiological stress) would be tested to provide a wide perspective on adverse biological effects. The bioassays were used to determine: (1) amphipod survival following a 10-day exposure to bulk (or whole) sediment; (2) successful fertilization of sea urchin (or other invertebrates) following exposure of gametes to pore water; and (3) decreased light production (indicative of metabolic stress) by a luminescent marine bacterium, *Vibrio fischeri*, when exposed to an organic extract of sediment. Details of the methods are available in the scientific literature (ASTM, 1992; Carr et al., 1996; Qureshi et al., 1998).

Photo 5. The sediments are collected for test procedures, called bioassays, that investigate the adverse effects of contaminants on coastal and marine life.

It is important to note that the toxicity bioassays used in these studies show varied biological responses and different measures of sensitivity to contaminant exposure. Acute mortality is easily interpreted and considered pertinent to population dynamics and ecosystem health; however, it is often viewed as a rather severe end point for environmental assessment purposes. Sublethal effects, such as impaired growth, reproduction, larval or embryonic development, and behavioral aberrations, are more difficult to analyze in terms of their ecological consequences. The sea urchin fertilization and bioluminescence bioassays are among the more sensitive toxicity tests. Each involves a rapid, nearly instantaneous, response to toxicants in the medium.

Toxicity assessments are based on statistically derived differences between test and control samples. For example, sediment toxicity in the amphipod test is inferred from two criteria: (1) survival is statistically lower in the test group than in the control group, and (2) mean survival in the test group is less than 80% of the control group (Thursby et al., 1997). The spatial extent of sediment toxicity is estimated as the weighted sum of an area within a stratum that shows statistically significant toxicity (Heimbuch et al., 1995).

Photo 6. In one bioassay, called the amphipod survival test, these organisms are exposed to a sediment sample for 10 days; their survival rate determines the sample's toxicity.

(top)

STATE OF THE COASTAL ENVIRONMENT
SEDIMENT TOXICITY

NATIONAL PICTURE

The toxicity assessments of bottom sediments from coastal water bodies revealed that the extent of sediment toxicity varied depending on the type of bioassay. Using cumulative data from the 23 coastal water bodies, about 7% of the studied area was toxic based on the amphipod survival test. The results of the sea urchin fertilization test and the bioluminescence test showed a much wider spatial extent of sediment toxicity: on average, 39% and 66% of the total areas studied, respectively (Table 2). The differences in toxicity among the three tests were due to their different biological end points, i.e., the specific measurements taken at the conclusion of the tests, and the presence of contaminants that may have caused such responses.

Photo 7. Severe sediment toxicity is generally found only in highly industrialized and urbanized bays, tributaries, bayous, inner harbors, and marinas.

Larger estuaries and bays, with areas equal to or greater than 250 sq km (approximately 100 sq mi), had a lower average spatial extent of sediment toxicity, 6.0%, as indicated by the amphipod survival test. In comparison, the average sediment toxicity was 10% of the total study area in estuaries and bays smaller than 250 sq km (Table 3). This was to be expected, since the relative scales of contamination from effluents, outfalls, and coastal runoff may be more pronounced in smaller bays

Table 3. Spatial extent of sediment toxicity as determined from the results of three bioassays, based on studies conducted from 1991 to 1996

	Total study area, km^2	Area showing toxicity, km^2	Percent toxic
Amphipod Survival Test			
Areas <250 km^2 (n=17)	889	90	10
Areas ≥250 km^2 (n=6)	3,263	196	6
Total (n=23)	4,152	286	7
Sea Urchin Fertilization Test			

Areas <250 km^2 (n=15)	804	187	23
Areas ≥250 km^2 (n=5)	2,913	1253	43
Total (n=20)	3717	1439	39
Microtox Test			
Areas <250 km^2 (n=10)	776	625	80
Areas ≥250 km^2 (n=6)	3263	2046	63
Total (n=16)	4039	2671	66

n=total number of study areas

The estimates indicated that the spatial extent and severity of sediment toxicity varied considerably among the study areas (Figure 2). In general, severe toxicity, as indicated by amphipod mortality, was restricted to highly industrialized and urbanized tributaries, bayous, inner harbors, and marinas (Long et al., 1996; Turgeon et al., 1998). The overall toxicity patterns can be categorized as pervasive, patchy, isolated, or slight. In areas such as Newark Bay, NJ, and San Diego Bay, CA, toxicity was apparent throughout (pervasive). In Boston Harbor, the Hudson-Raritan Estuary, and Sabine Lake, toxicity appeared to occur with no consistent pattern (patchy). In several areas, such as Tampa Bay, FL, and St. Simons Sound, GA, amphipod mortality was restricted to small channels and tributaries (isolated), although impaired sea urchin fertilization in Tampa Bay was quite widespread. In many study areas, particularly estuaries in the southeastern United States (e.g., Charleston Harbor, SC, and Pensacola Bay, FL), amphipod toxicity tests did not indicate toxic conditions. However, in these areas, results of the sea urchin fertilization test and the Microtox test indicated considerable, but highly varied, sub-lethal toxic conditions. Sediment toxicity, as inferred from decreased bioluminescence, was generally much more widespread in all of the study areas.

Photo 8. Sediment toxicity was found to be pervasive in California's San Diego Bay.

Sediment toxicity data, acquired using a similar suite of toxicity tests and a different geometric grid for field sampling, were produced by EPA as part of its Environmental Monitoring and Assessment Program for Estuaries (EMAP-E). Four broad geographic areas were studied under EMAP-E: the Virginian Province (Cape Cod, MA, to Cape Henry, VA, at the mouth of the Chesapeake Bay); the Carolinian Province (Cape Henry to Cape Canaveral, FL); the Louisianian Province (the west coast of Florida to Texas); and the Californian Province (the U.S.- Mexico border to Point Reyes, CA) (USEPA, 1993). Based on EMAP-E's amphipod mortality tests, the spatial extent of sediment toxicity in these four geographic areas was 10%, 2%, 8%, and 0%, respectively, and 7.3% collectively. These estimates are comparable to the overall average of 6.9% derived from NOAA's studies. Furthermore, EPA estimated that the extent of toxicologically significant chemical contamination in U.S. coastal waters was 6% to 12% (EPA, 1997).

(top)

STATE OF THE COASTAL ENVIRONMENT

SEDIMENT TOXICITY

REGIONAL CONTRASTS

Study areas were selected initially to estimate the extent and severity of sediment toxicity in bays and estuaries adjacent to highly urbanized areas in the northeastern and southwestern United States. During the past few years, the study areas have also included larger water bodies, such as Biscayne Bay, FL, in the Southeast and Galveston Bay, TX, in the Gulf of Mexico. Studies are currently under way in the Chesapeake Bay, Puget Sound, and Delaware Bay. Enough information is not currently available to compare large segments of the U.S. coastline (e.g., the Atlantic, Gulf of Mexico, and Pacific Coasts).

Even with limited spatial coverage and considerable variability in toxicity patterns among study areas, it is possible to infer regional contrasts from the studies completed to date. Combining results from the amphipod mortality test from study areas in the northeastern, southwestern (off the southern California coast), and southeastern United States showed that the spatial extent of sediment toxicity was quite similar, about 35%, in small, urbanized estuaries both in the Northeast and in southern California (Table 2). In contrast, southeastern estuaries, including the western Florida bays, most of which border undeveloped coastlines, farms, forests, wetlands, and limited industrial growth, showed a much lower prevalence of sediment toxicity--about 3% of the total study area. Further comparisons are not feasible due to the lack of data.

Photo 9. A Delaware state official (center) participates in the NOAA sediment toxicity study in Delaware Bay.

(top)

STATE OF THE COASTAL ENVIRONMENT

SEDIMENT TOXICITY

HOME
SITE INDEX
COVER PAGE
INTRODUCTION
NATIONAL PICTURE
CONTRASTS
CASE STUDIES
EXPERTS
COMMENTS
REFERENCES
APPENDICES
GLOSSARY
CREDITS
DOWNLOAD ESSAY

CASE STUDIES

The data from four bays--San Diego Bay, Boston Harbor, Biscayne Bay, and Charleston Harbor--are particularly interesting because they exemplify the contrasts in toxicity among the survey areas. Figures 3-6 define areas that did not show toxicity in any of the tests employed (blue); showed toxicity in the more sensitive tests but not in the amphipod survival test (green); or showed toxicity in at least the amphipod survival test (yellow).

San Diego Bay

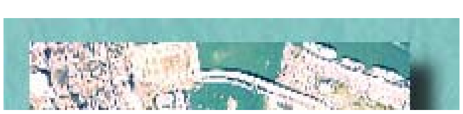
Photo 10. In San Diego Bay, sediment toxicity was severe in isolated areas, including the waters near this naval station.

Sediment toxicity was quite severe in isolated areas near a naval station, in the southern bay, and in several marinas and boat harbors (Figure 3). In both the amphipod survival test and sea urchin fertilization test, toxicity occurred throughout much of San Diego Bay. Moreover, toxicity in the amphipod tests was highly correlated with the concentration of sediment contaminants, including several chlorinated pesticides and trace metals. This study was performed in close cooperation with the California State Water Resources Control Board, which wanted to develop plans for the cleanup and remediation of toxic "hot spots." The U.S. Navy offered additional cooperation with evaluation of environmental conditions in the bay. The Navy-sponsored studies of sediment toxicity are continuing.

Boston Harbor

No clear spatial patterns in toxicity were observed among the 55 locations sampled in Boston Harbor (Figure 4). Zones in which toxicity was severe or moderate were interspersed among adjacent zones in which either slightly toxic or nontoxic conditions were apparent. Interestingly, sediments from Northwest Harbor, located nearest to the Deer Island wastewater treatment plant, did not appear to be toxic, and samples collected in the Inner Harbor, near downtown Boston, were only slightly toxic. Complex mixtures of toxicants were correlated with the results of the toxicity tests. These chemicals included PCBs and ammonia.

Biscayne Bay



Slightly or moderately toxic conditions were pervasive throughout much of Biscayne Bay, including the commercial port area of Miami (Figure 5). The amphipod survival test showed severe toxicity at one site in the northern

Photo 11. Toxic conditions were slight or moderate, yet pervasive, throughout much of Florida's Biscayne Bay. In contrast, toxicity was severe in the lower reaches of the Miami River.

basin of the bay, in much of the lower Miami River, in most of the Black Creek Canal, and in a large, plume-like area in southern Biscayne Bay off Turkey Point. Most of these sites had high concentrations of both organic and inorganic contaminants, but the area northeast of Turkey Point had very low concentrations of all of the chemicals for which analyses were performed. Therefore, it was not always possible to explain the degree of toxicity in that area in relation to the concentrations of measured contaminants.

Charleston Harbor

The amphipod survival test showed no toxicity, even in small tributaries and embayments, in this South Carolina harbor (Figure 6). Samples from strata including the Wando, Cooper, and Ashley Rivers were either not toxic in any of the three toxicity tests, or were toxic only in the sea urchin fertilization or bioluminescence test. Toxicity was not apparent in any test in the most seaward sampling stratum, near the mouth of the harbor. This study was performed in cooperation with NOAA's National Marine Fisheries Service (NMFS) and the State of South Carolina's Charleston Harbor Project (CHP). In addition to the randomly selected sampling sites, the study also included some predetermined sites that were of interest to the state's resource management agencies. NOAA's NS&T Program provided the combined data to scientists and managers at the CHP, NMFS, the U.S. Fish and Wildlife Service, and the U.S. Army Corps of Engineers. The data are being used to develop plans for dredging navigation channels and for cleaning up contaminated sites.

(top)

STATE OF THE COASTAL ENVIRONMENT

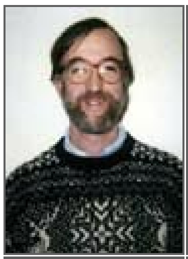
EXPERT INTERPRETATION

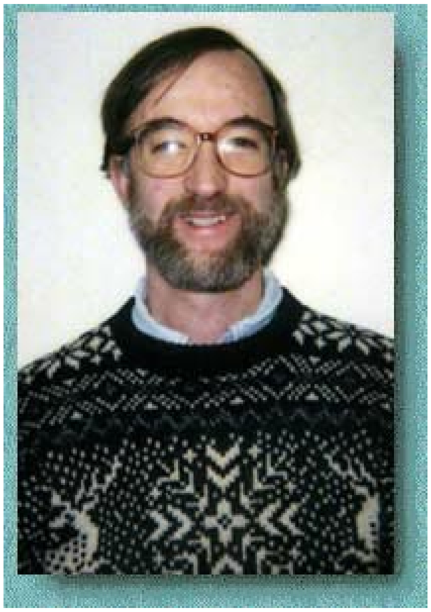
The three individuals below are experts in the topic of sediment toxicity in coastal waters. Here they voice their opinions on two questions relevant to that topic.

Question 1. Do you consider the data and information produced by NOAA's sediment toxicity studies useful in evaluating the nature and extent of contamination in coastal areas?

Question 2. Given the field sampling design and analytical methods used in these studies, what changes would you recommend to improve the scientific quality and usefulness of the data?

Experts

		
Walter Berry	**Amy Ringwood**	**Bruce Thompson**



Walter Berry

Research Biologist, National Health and Environmental Effects Laboratory, U.S. Environmental Protection Agency

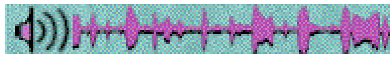
Dr. Berry is a research biologist for the United States Environmental Protection Agency in Narragansett, RI, where he has been working with contaminated sediments for the last ten years. His research has focused primarily on the bioavailability of metals in sediments. He has also worked on the development of Equilibrium Partitioning Derived Sediment Guidelines (ESGs). Dr. Berry is a member of The New England Estuarine Research Society and The Society of Environmental Toxicology and Chemistry.

Response to Question 1

Response to Question 2

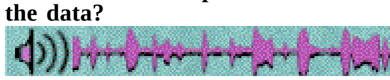
(top)

Question 1. Do you consider the data and information produced by NOAA's sediment toxicity studies useful in evaluating the nature and extent of contamination in coastal areas?

Click here for audio response

I consider the data and information produced by NOAA's sediment toxicity studies to be tremendously useful in evaluating the nature and extent of contamination in coastal areas. The analytical and bioassay techniques are state-of-the-art. The use of a probabilistic sampling design allows for estimation of the extent of contamination in a way that is not possible with many of the older data sets which concentrated on hot spots or ran transects out from hot spots. Similarly, the broad geographic scope of the NOAA monitoring allows for comparison between different areas of the country, using sediment data taken with similar methodologies. Because of its probabilistic design, the NOAA data sets can be combined with other data sets (i.e. the U.S.EPA's Environmental Monitoring and Assessment Program (EMAP)) to provide even greater coverage. One limitation to the data from the program is that it is only from surface sediments, and as such only gives a "snapshot" in time of the extent of contamination and toxicity of the sediments. Historical reconstruction, using sediment coring at even a limited number of sites, might provide some very useful information about what sediment toxicity and contamination was like at these sites in the past. This information can be used to help understand how the sediments at these sites got to their present condition, and to help predict what might happen in the sediment at these sites in the future.
(top)

Question 2. Given the field sampling design and analytical methods used in these studies, what changes would you recommend to improve the scientific quality and usefulness of the data?

Click here for audio response

One thing that I would like to see expanded in the NOAA studies is the ecological relevance of sediment toxicity. In some cases the organisms at a particular site may have developed a tolerance for the toxicants at that site, or sensitive species may have been replaced by ecologically equivalent species more tolerant of the contaminant. Even if a piece of habitat is lost, the consequences of that loss of habitat may be small if similar habitat is available nearby. If the lost habitat is unique, or used as a nursery area, or part of a migration route, or the spatial extent of the sediment toxicity is greater, the corresponding impact may be much greater. Another thing I would like to see expanded is the use of chronic tests with ecologically important species, especially amphipods. The only analytical change I would recommend is the addition of the measurement of acid volatile sulfide (AVS) and simultaneously extracted metals (SEM) to the list of parameters found in Table 1 of this essay. AVS and SEM have been helpful in interpreting the role of metals in sediment toxicity in many studies. They would, I would argue, improve the usefulness of the NOAA data set for many purposes, especially where the cause of sediment toxicity is of interest.

(top)

Amy H. Ringwood

Associate Marine Scientist
South Carolina Marine Resources Research Institute

Dr. Ringwood has worked extensively in the field of ecotoxicology for more than 15 years, conducting both laboratory and field toxicity studies with a variety of species (molluscs, echinoderms, crustaceans, etc.). Recently, she has developed expertise in cellular biomarker responses. Dr. Ringwood also works extensively developing integrated indices and identifying linkages across different levels of biological organization. She serves as an advisor tograduate and undergraduate students through her academic affiliations with University of Charleston, University of South Carolina, and the Medical University of South Carolina.

Response to Question 1

Response to Question 2

(top)

Question 1. Do you consider the data and information produced by NOAA's sediment toxicity studies useful in evaluating the nature and extent of contamination in coastal areas?

Click here for audio response

This essay summarizes the results of a suite of sediment toxicity assays (a 10-day acute toxicity assay with amphipods, and two sublethal assays based on sea urchin fertilization and Microtox bacterial assays) conducted at various coastal sites around the US. These data provide valuable information regarding sublethal as well as acute toxicity potential. The incidence and extent of acute toxicity (based on the amphipod assay) appears to be relatively rare. From my extensive experience with these as well as a variety of sediment toxicity assays, I am concerned that the final assessments rely too heavily on the amphipod assay, and may misjudge the potential ramifications of the sublethal responses. It must be appreciated that laboratory toxicity tests have some limitations, including erroneous conclusions based on false negatives and false positives. We have frequently observed no toxicity with amphipod assays for sediments from highly contaminated sites that caused a variety of types of adverse biological effects, ranging from cellular to population level stress; or toxicity with clean pristine sediments. While there may be some concern that sublethal tests are too sensitive, the amphipod assay may be too insensitive. It is important that we not be lulled into thinking that things are better than they really are simply because there is no amphipod toxicity. Long term chronic effects can have serious consequences on the sustainability of biological resources.

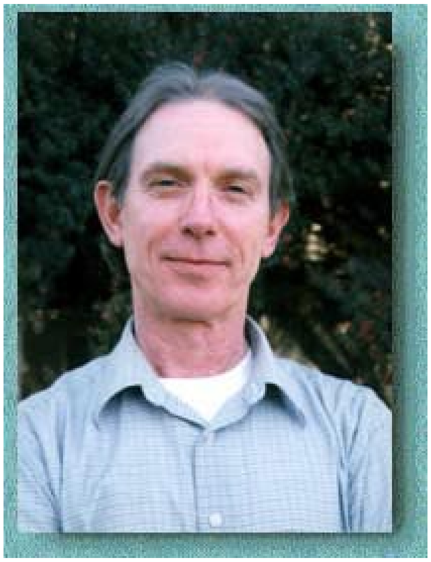
(top)

Question 2. Given the field sampling design and analytical methods used in these studies, what changes would you recommend to improve the scientific quality and usefulness of the data?

Click here for audio response
AUDIO RESPONSE UNAVAILABLE

It would be interesting to use adverse effects with any two tests as potentially indicative of toxicity, and adverse effects with all three as indicating severe toxicity, so that we are not so dependent on any one assay. Also, comparable spatial maps of the contaminants would facilitate our ability to determine correspondence between toxicity and potential exposure regimes.

(top)



Bruce Thompson

Senior Scientist, San Francisco Estuary Institute

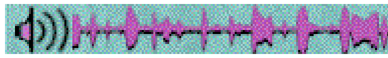
Dr. Thompson directs monitoring and research programs focused on contamination and its effects in San Francisco Bay. His research has included studies on the ecology of benthic species and communities and how they are affected by contamination. He is also involved in the development of comprehensive monitoring programs in the region. He has published numerous articles and a book chapter on his research, and is a member of the Society of Environmental Toxicologists and Chemists and the Estuarine Research Federation.

Response to Question 1

Response to Question 2

(top)

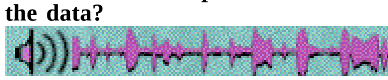
Question 1. Do you consider the data and information produced by NOAA's sediment toxicity studies useful in evaluating the nature and extent of contamination in coastal areas?

Click here for audio response

The essay provides a well written explanation of the status of sediment toxicity in the bays and estuaries of the U.S. The sources of data, methods used, and results obtained are clearly presented and appropriately qualified. The glossary is a useful feature, especially for non-technical readers. The essay describes the spatial extent of sediment toxicity based on locations sampled in the early to mid 1990s. Since sediment contamination can increase or decrease over time, the surveys will hopefully be conducted on a regular basis to track those changes. Some information was also provided about the possible sources of contaminants that could have caused the observed toxicity, such as military bases, marinas, or wastewater treatment plants. Understanding that contamination from various land-based activities can cause aquatic toxicity is an important step in controlling toxicity. Although contamination in sediments was usually measured along with the toxicity testing, the essay did not attempt to relate toxicity to specific contaminants. This is probably because sediments usually contain mixtures of many contaminants and it is not possible to know which one(s) may have caused the toxicity. Differences in the degree of toxicity were shown by several different tests at each location. Those results reflected differences in sensitivity to toxicants and indicated that the nature of the toxicity may be different for different organisms or life stages. Different contaminants may have differing modes of toxic action (e.g. narcotic, neurotoxin, etc.). Thus, it is desirable and common to base assessments on several different species and life stages.

(top)

Question 2. Given the field sampling design and analytical methods used in these studies, what changes would you recommend to improve the scientific quality and usefulness of the data?

Click here for audio response

There is no question about the quality of the data. The sampling and analyses were conducted by outstanding laboratories and should be interpreted as presented. Toxicity tests are standardized procedures that indicate the potential for ecological effects. Laboratory toxicity testing of field-collected sediments is one of the tools used in coastal assessments, along with measurements of sediment contamination, bioaccumulation by organisms, and biological community assessments. The essay is very useful in raising awareness about sediment toxicity and its possible sources. Expanded summaries of sources that are suspected of contributing to the observed toxicity could be very useful in raising awareness of the linkages between human activity and toxicity, and in prioritizing regulatory or remedial actions. Future studies might consider using organisms in the tests that may provide a stronger linkage to actual impacts in the bays and estuaries. Amphipods are common inhabitants of most bays and estuaries and provide a direct measure of potential impacts in those locations. On the other hand, toxicity to urchins, which do not normally inhabit estuaries, or luminescent bacteria, is more difficult to relate to actual environmental impacts. Perhaps a molluscan (clam), or other resident species could be used in future studies.

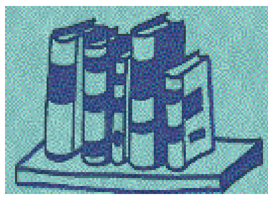
(top)

HOME
SITE INDEX
COVER PAGE
INTRODUCTION
NATIONAL PICTURE
CONTRASTS
CASE STUDIES
EXPERTS
COMMENTS
REFERENCES
APPENDICES
GLOSSARY
CREDITS
DOWNLOAD ESSAY

REFERENCES

[Text References]

[On-line References]



Text References

American Society of Testing and Materials (ASTM). 1992. Standard guide for conducting 10-day static sediment toxicity test with marine and estuarine amphipods, E1367-92. In: Annual book of standards. Philadelphia, PA: American Society of Testing and Materials.

Armitage, T.M. 1995. EPA's contaminated sediment management strategy. In: Allen, H.E. (ed.), Metal contaminated aquatic sediments. Chelsea, MI: Ann Arbor Press. pp. 273-286.

Carr, R.S., E.R. Long, H.L. Windom, D.C. Chapman, G. Thursby, G. Sloane, and D.A. Wolfe. 1996. Sediment quality assessment studies of Tampa Bay, Florida. Environmental Toxicology and Chemistry 15:1,218-1,231.

Hameedi, M.J. 1997. Strategy for monitoring the environment in the coastal zone. In: Haq, B.U., et al (eds.), Coastal zone management imperative for maritime developing nations. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Heimbuch, D., H. Wilson, J. Seibel, and S. Weisberg. 1995. R-EMAP data analysis approach for estimating the proportion of area that is subnormal. Research Triangle Park, NC: U.S. EPA. 22 pp.

Long, E.R., A. Robertson, D.A. Wolfe, J. Hameedi, and G.M. Sloane. 1996. Estimates of the spatial extent of sediment toxicity in major U.S. estuaries. Environmental Science and Technology 30:3,585-3,592.

National Oceanic and Atmospheric Administration (NOAA). 1998. The National Status and Trends Program for marine environmental quality. Silver Spring, MD: NOAA, National Ocean Service, National Centers for Coastal Ocean Science. 32 pp.

NOAA. 1996. NOAA strategic plan: A vision for 2005. Washington, DC: NOAA. 210 pp.

NOAA. 1990. Estuaries of the United States: Vital statistics of a national resource base. Rockville, MD: NOAA, National Ocean Service, Office of Ocean Resources Conservation and Assessment. 79 pp.

National Research Council (NRC). 1989. Contaminated marine sediments--assessment and remediation. Washington, DC: National Academy Press. 493 pp.

Qureshi, A.A., A.A. Bulich, and D.L. Isenberg. 1998. Microtox toxicity test systems--where they stand today. In: Wells, P.G, K. Lee, and C. Blaise (eds.), Microscale testing in aquatic toxicology. Boca Raton, FL: CRC Press. pp. 185-200.

Thursby, G.B., J. Heltshe, and K.J. Scott. 1997. Revised approach to toxicity test acceptability criteria using a statistical performance assessment. Environmental Toxicology and Chemistry 16:1,322-1,329.

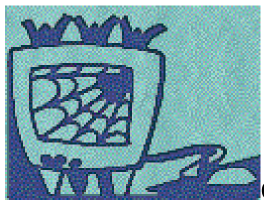
Turgeon, D.D., J. Hameedi, M.R. Harmon, E.R. Long, K.D. McMahon, and H.H. White. 1998. Sediment toxicity in U.S. coastal waters. Silver Spring, MD: NOAA, National Ocean Service, Office of Ocean Resources Conservation and Assessment. 20 pp.

U.S. Environmental Protection Agency (EPA). 1997. The incidence and severity of sediment contamination in surface waters of the United States, vol. 1: National sediment quality survey. EPA/823-R-97-006. Washington, DC: U.S. EPA, Office of Science and Technology.

U.S. EPA. 1993. EMAP project descriptions. EPA/620/R-93/009. Washington, DC: U.S. EPA, Office of Research and Development. 106 pp.

U.S. EPA. 1988. An overview of sediment quality in the United States. EPA-905-9-88-002. Washington, DC: U.S. EPA.

(top)



On-line References

The following references were accessed on the World Wide Web during 1999.

Dredged Sediments

EPA Office of Water. Dredged Materials Management Programs.

http://www.epa.gov/owow/oceans/dmmp/index.html#man

Contains information on the proper management of dredging, planning for dredging and disposal, testing dredged material, and evaluating alternative disposal options.

Management of Contaminated Sediment

EPA Office of Water. Contaminated Sediment Management Strategy.

http://www.epa.gov/OST/cs/stratndx.html

Discusses the actions needed to reduce the risks posed by contaminated sediments and the uncertainties associated with the problem; includes a summary of the extent and severity of sediment contamination.

Miscellaneous

EPA Office of Water. National Sediment Bioaccumulation Conference Proceedings: A Summary.

http://www.epa.gov/OST/cs/confprod.html

Presents the proceedings of the National Sediment Bioaccumulation Conference, which included sessions on field and laboratory methods for measuring bioaccumulation; interpretation and applications of bioaccumulation results; modeling bioavailability of sediment contaminants; food chain models and bioenergetics; human-health-based risk assessment; and ecologically based risk assessment. All papers are available as PDFs.

Status and Trends for Sediment Toxicity

NOAA. NOAA's National Status and Trends (NS&T) Program.

http://seaserver.nos.noaa.gov/projects/nsandt/rawdata.html

Provides access to raw data files for several organic and heavy-metal toxicity parameters collected by NOAA's NS&T Program for marine environmental quality.

EPA Office of Water. Contaminated Sediment.

http://www.epa.gov/OST/cs/

Provides access to the U.S. EPA's Report to Congress on contaminated sediment, including information on areas in the United States where sediment contamination levels may adversely affect aquatic life and human health.

(top)

STATE OF THE COASTAL ENVIRONMENT

APPENDICES

This essay has no appendices.

STATE OF THE COASTAL ENVIRONMENT

HOME
SITE INDEX
COVER PAGE
INTRODUCTION
NATIONAL PICTURE
CONTRASTS
CASE STUDIES
EXPERTS
COMMENTS
REFERENCES
APPENDICES
GLOSSARY
CREDITS
DOWNLOAD ESSAY

GLOSSARY

amphipod: a group of generally small-sized crustaceans characterized by flat or compressed bodies, giving them a shrimplike appearance; but unlike shrimp, the amphipod's head and thorax are not fused. Often abundant on the bottom of coastal bays and estuaries, they feed on microalgae, plant fragments, debris, and food particles in the mud.

benthic community: all of the organisms living and interacting with each other in a given area on the bottom of a water body.

bioassay: in toxicology, a procedure to test the response of organisms after exposure to various concentrations of suspected contaminants or to levels of detrimental conditions.

biogenic: something produced by the action of living organisms (e.g., minerals derived from the outer shell-like skeletons of certain algae and deposited on the sea bottom are biogenic sediments; hydrocarbons produced by some terrestrial plants (often associated with waxy coating on the leaves) are biogenic hydrocarbons.

biomarker: a variation in the cellular or biochemical components or processes, or a behavioral response, that is measurable in a biological system or sample after exposure to contaminants or detrimental conditions.

butyltins: a group of tin-containing organic chemicals used as pesticides to protect wood, plastics, and fabrics from fungus, to protect plants from insects, and to protect boat hulls from fouling organisms (e.g., tubeworms, barnacles, mussels). One such compound, tributyltin or TBT, is the principal active ingredient of antifouling paints used on boats and ships. The subsequent release of this compound into water is known to cause mortality and other biological damage to "nontarget" organisms even in extremely low concentrations.

chlorinated pesticide: a member of a large and diverse group of organic compounds containing varying amounts of chlorine and used as pesticides. The group includes dichloro-diphenyl-trichloroethane (DDT) and related compounds, heptachlor, and lindane, among numerous others. These compounds persist in the environment for long periods of time; many are highly toxic and have remained a key feature of environmental problems facing fish and wildlife resources.

crustacean: a class of predominantly aquatic animals having joined feet and mandibles, and segmented bodies with hard external skeletons composed of chitin. Examples include crabs, shrimp, lobsters, barnacles, and amphipods.

ecological index: usually a numerical value to describe the ecological condition or health of the environment, and based primarily on the diversity of species and abundance of fauna in a given area.

effluent: the liquid waste stream from industrial or sewage processing. Occasionally, the terms is used to described outflow from a lake or another body of water (e.g., freshwater effluent from the Columbia River into the northeast Pacific Ocean).

gamete: a mature germ cell (sperm or egg) capable of participating in fertilization.

outfall: the location where a sewerage or industrial waste channel is discharged into the sea or another body of water.

polychlorinated biphenyls (PCBs): a class of 209 discrete chemical compounds in which 1 to 10 chlorine atoms are attached to a biphenyl molecule (phenyl is a benzene ring from which a hydrogen has been removed). PCBs were produced as complex mixtures for use in electrical and other industries. Due to their widespread use, persistence in the environment, and toxicity, PCBs pose a major environmental contamination problem worldwide.

polycyclic aromatic hydrocarbons (PAHs): a large group of organic compounds having two or more fused benzene rings. PAHs are components of crude oil and refined petroleum products, coal, peat, and the combustion residues of many organic materials. The U.S. Environmental Protection Agency has identified several PAHs as "priority pollutants" on the basis of their known or potential ability to cause cancer, mutations, or other genetic damage.

pore water: the water found in spaces among grains of sediment on the sea bottom or in soil.

runoff: water that travels along impervious surfaces (e.g., streets, parking lots), usually after rain events, and empties into streams and nearshore environments. Runoff can contain substantial amounts of contaminants from urban and agricultural land uses (e.g., motor oil from streets and highways, fertilizers from lawns and agriculture, pesticides.)

sink: a system or situation in which an entity is absorbed (e.g., a heat sink).

stratified random design: a field sampling strategy in which the study area is partitioned into sub-areas, known as strata, and samples are collected independently in each stratum. This type of sampling allows some control of the spacing of samples in the study area.

stratum: in the context of field sampling, denotes a sub-area or sub-population selected on the basis of a particular feature or property. Often, the study area is partitioned into strata to maximize the use of resources.

Van Veen grab: a metallic device with weighted jaws and a strong closing mechanism used to collect relatively undisturbed sediment samples from the sea bottom. These devices are manufactured in several sizes suitable for obtaining sediment samples for biological, hydrological, and other environmental studies.

(top)

STATE OF THE COASTAL ENVIRONMENT

HOME
SITE INDEX

COVER PAGE
INTRODUCTION
NATIONAL PICTURE
CONTRASTS
CASE STUDIES
EXPERTS
COMMENTS
REFERENCES
APPENDICES
GLOSSARY
CREDITS
DOWNLOAD ESSAY

CREDITS

Acknowledgments

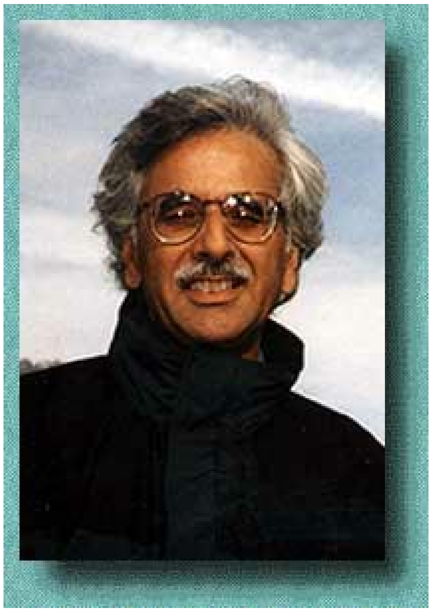
This essay summarizes data from a large number of sediment toxicity studies sponsored by the Center for Coastal Monitoring and Assessment National Oceanic and Atmospheric Administration (NOAA). Each study was performed with partners and collaborators from federal, state and local government agencies, and through contracts with consulting firms in private industry. The essay has benefited greatly from review comments by Andrew Robertson (NOAA), Holly Greening (Tampa Bay National Estuary Program), Jeff Grovhoug (US Department of the Navy), John Paul Tolson (NOAA), and Pam Rubin (NOAA).
(top)

Photo Credits

Photos were gathered from NOAA archives or were generously provided from the personal collections of NOAA staff members.

(top)

About the Authors



Jawed Hameedi is a Team Leader in NOAA's National Ocean Service, Center for Coastal Monitoring and Assessment in Silver Spring, MD. Since 1995, he has developed and managed a variety of studies to evaluate the biological effects of chemical contaminants and other sources of environmental degradation in U.S. coastal waters. From 1981 to 1992, he served as Deputy Director and Director of the Outer Continental Shelf Environmental Assessment Program in Alaska. Prior to joining NOAA in 1981, he conducted applied research at the University of Washington and in private industry on topics related to energy and environmental sciences.

Michelle R. Harmon is a physical scientist at NOAA's National Ocean Service, Center for Coastal Monitoring and Assessment in Silver Spring, MD. She has worked at NOAA since 1990. Since 1995, her work has primarily focused on coastal and estuarine sediment toxicity assessments. She has served as Chief Scientist for multi-agency field sampling, most recently in Delaware Bay and Chesapeake Bay. She has a bachelor's of science in natural resources management from the University of Maryland, and a master's in environmental sciences from the Johns Hopkins University.

Edward Long is a marine biologist at NOAA's National Ocean Service, Center for Coastal Monitoring and Assessment in Seattle, WA. Since joining NOAA in 1975, he has conducted research on the biological effects of toxicants throughout Puget Sound, compared the performance of different tests and assays of toxicant effects in San Francisco Bay, developed numerical sediment quality guidelines for estuaries, and managed studies to assess sediment quality in estuaries of the Atlantic, Gulf of Mexico, and Pacific.

(top)

Return to Introduction

Figure 1. Coastal water bodies in which NOAA's sediment toxicity assessment studies have been completed.

(top)

Return to Introduction

Return to National Picture

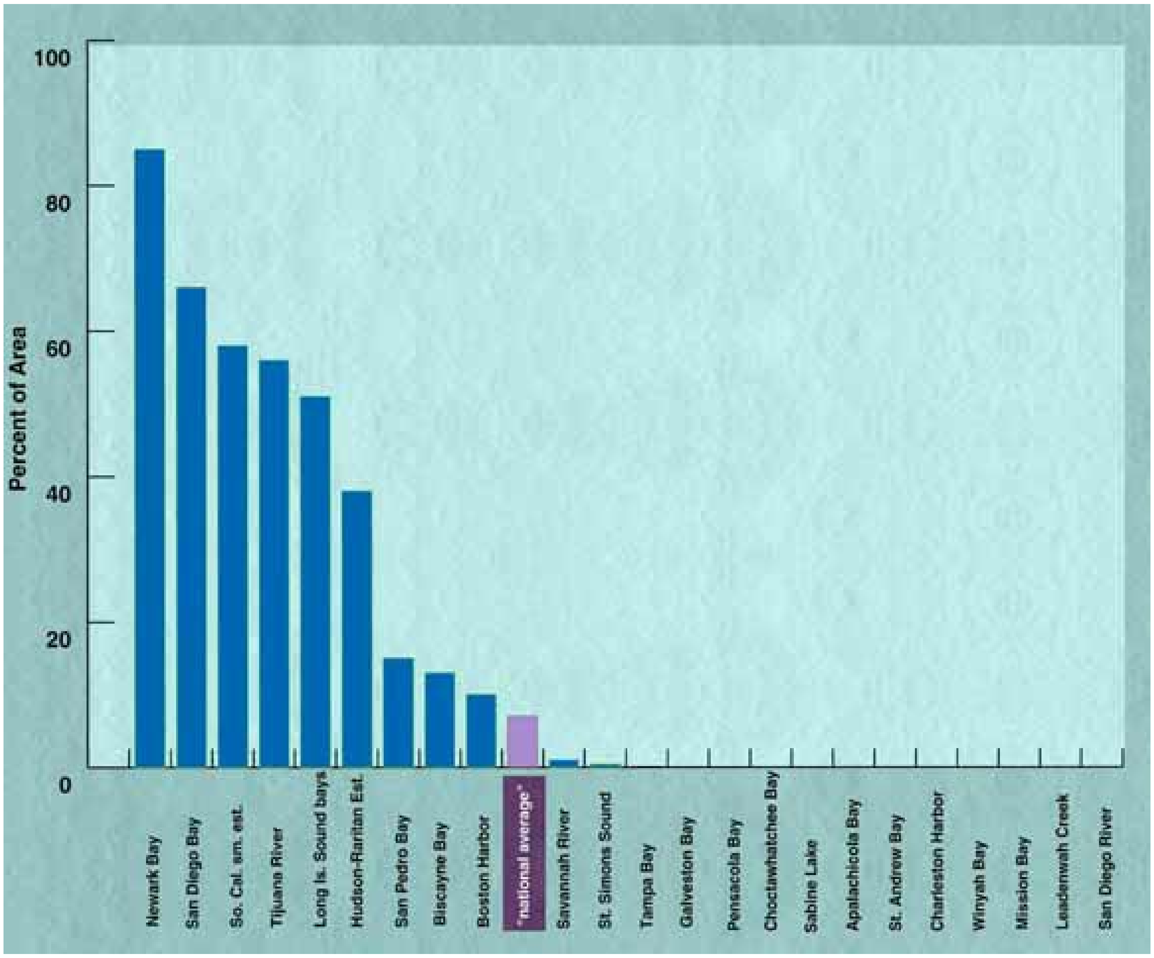


Figure 2. Spatial extent of sediment toxicity in amphipod survival tests in estuaries and overall national average.

Source: Modified from Turgeon et al. 1998.

Return to National Picture

Return to Case Studies

Figure 3. Pattern of sediment toxicity in San Diego Bay, CA

Source: Turgeon et al. 1998.

(top)

Return to Case Studies

Return to Case Studies

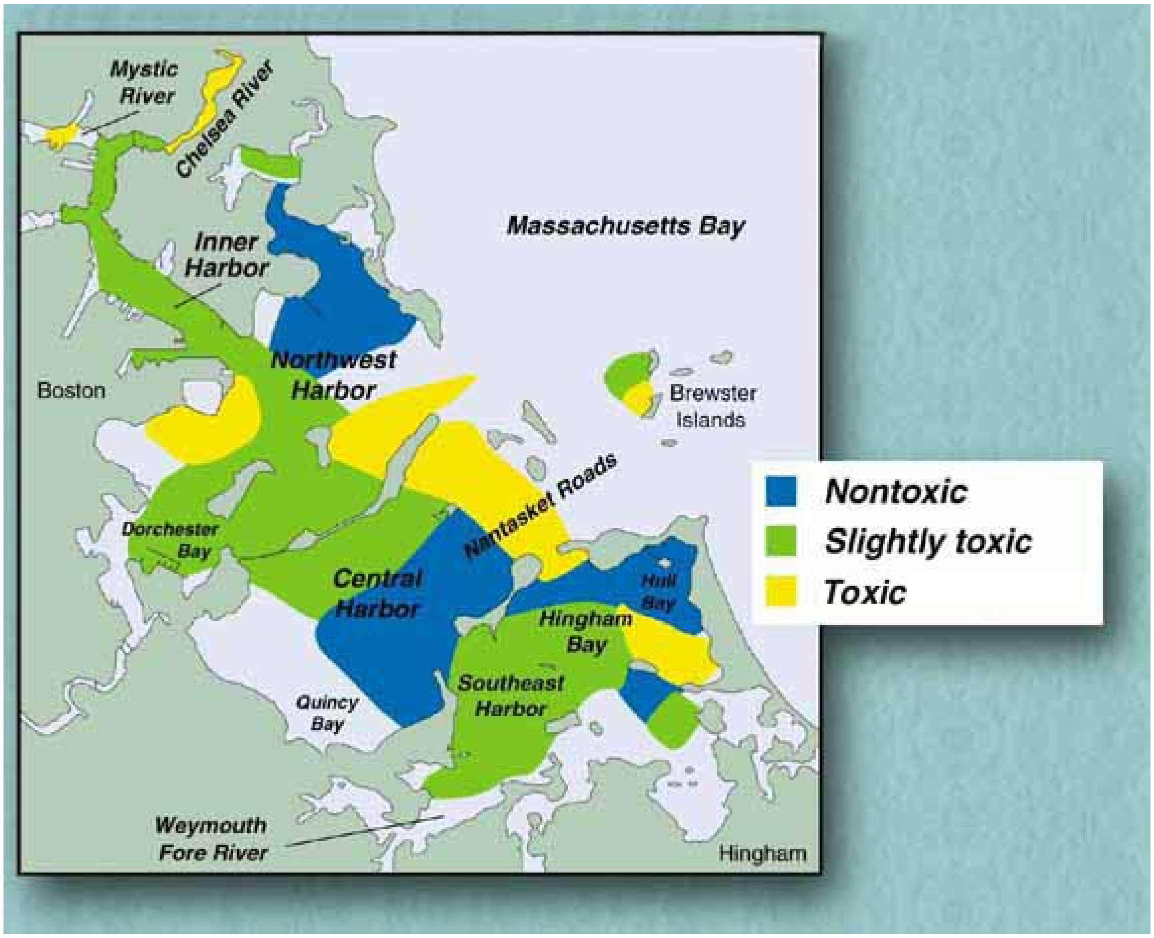


Figure 4. Pattern of sediment toxicity in Boston Harbor, MA

Source: Turgeon et al. 1998.
(top)

Return to Case Studies

Return to Case Studies

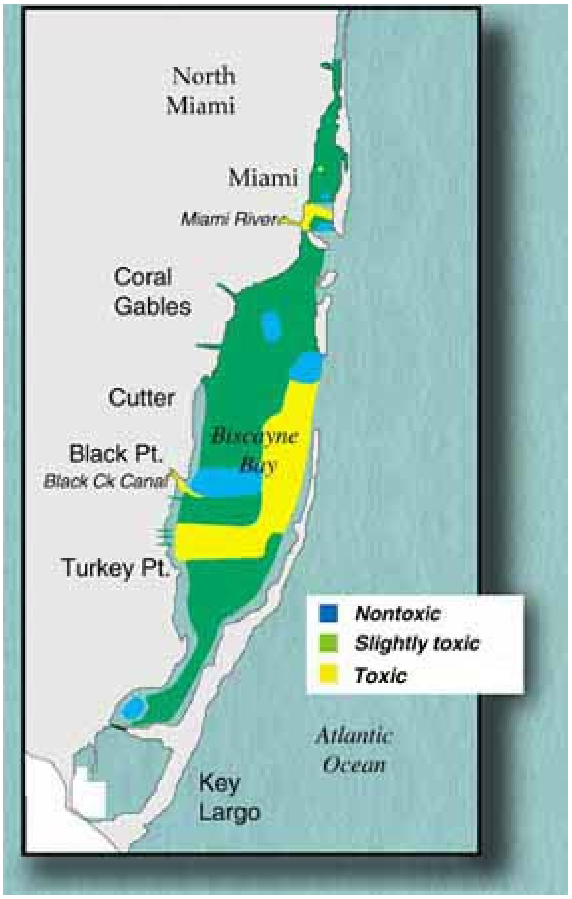


Figure 5. Pattern of sediment toxicity in Biscayne Bay, FL

Source: Turgeon et al. 1998.
(top)

Return to Case Studies

Return to Case Studies

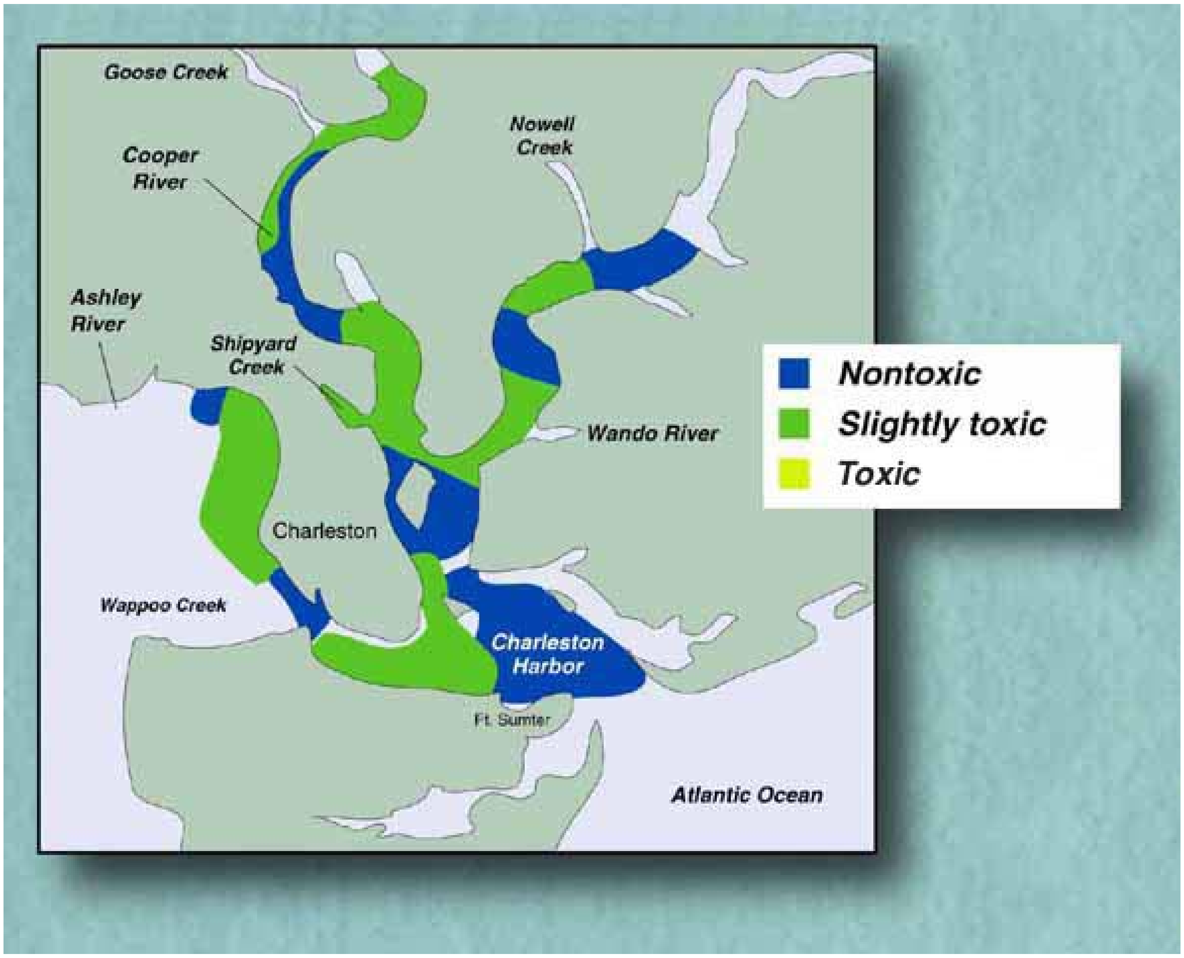


Figure 6. Pattern of sediment toxicity in Charleston Harbor, SC

Source: Turgeon et al. 1998.
(top)

Return to Case Studies

Return to Introduction

Table 1. Chemical and related parameters measured for sediment toxicity by the National Status and Trends Program

Major Elements

Aluminum
Iron
Manganese
Silicon

Trace Elements

Antimony
Arsenic
Cadmium
Chromium
Copper
Lead
Mercury
Nickel
Selenium
Silver
Tin
Zinc

Polychlorinated Biphenyls

PCB congeners
8,18, 28, 44,
52, 66, 77,
101, 105, 118,
126, 128, 138,
153, 169, 179,
180, 187, 195,
206, 209

Mono-, di-, tri-, and tetrabutyltins

Chlorinated Pesticides

DDT and its metabolites
Aldrin
Dieldrin
Chlordanes
Heptachlor
Heptachlor epoxide
Lindane (gamma-HCH)
Alpha-HCH
Hexachlorobenzenes
Tetrachlorobenzenes
Mirex
Endrin
Endosulfans
Chlorpyrifos
Pentachloroanisole
Chlorinated dioxins
Chlorinated dibenzofurans

Related Parameters

Sediment grain size
Sediment toxicity
Total organic carbon
Lipid
Salinity
Temperature
Conductivity
Dissolved oxygen
Clostridium perfringens spores

Polycyclic Aromatic Hydrocarbons

2-ring
Biphenyl
Naphthalene
1-methylnaphthalene
2-methylnaphthalene
2,6-dimethylnaphthalene
1, 6, 7-trimethylnaphthalene
C1-C4 alkylnaphthalenes

3-ring
Fluorene
Phenanthrene
1-methylphenanthrene
Anthracene
Acenaphthene
Acenaphthylene
Dibenzothiophene
C1-C3 alkylfluorenes
C1-C4 alkylphenanthrenes
C1-C3 alkyldibenzothiophenes

4-ring
Fluoranthene
Pyrene
Benz(a)anthracene
Chrysene
C1-C4 alkylchrysenes

5-ring
Dibenz(ah)anthracene
Benzo(a)pyrene
Benzo(e)pyrene
Perylene
Benzo(b)fluoranthene
Benzo(k)fluoranthene

6-ring
Benzo(ghi)perylene
Indeno(1, 2, 3 cd)pyrene

(top)

Return to National Picture
Return to Regional Contrasts

Table 2. Spatial extent of sediment toxicity in each survey area as estimated with each of three toxicity tests

Survey Area	Size of Survey Area km^2	Toxic Areas -km^2 (%) Amphipod Survival Test	Fertilization Success Test[(a)]	Microtox™ Test	Number of Samples	Date of Survey
Boston Harbor	56.1	5.7 (10.0%)	3.8 (6.6%)	25.8 (44.9%)	55	Jun/Jul 1993
Long Island Sound Bays	71.9	36.3 (50.5%)	nd	48.8 (67.9%)	60	August-91
Hudson-Raritan Estuary	350	133.3 (38.1%)	nd	136.1 (38.9%)	117	Mar/May 1991
Newark Bay	13	10.8 (85.0%)	nd	nd	57	Jan/Mar 1993
Winyah Bay	7.3	0	3.1 (42.2%)	5.1 (70.0%)	9	June-93
Charleston Harbor	41.1	0	12.5 (30.4%)	17.6 (42.9%)	63	Jun/Jul 1994
Leadenwah Creek	1.7	0	0	0.3 (20.1%)	9	Jun/Jul 1994
Savannah River	13.1	0.2 (1.2%)	2.4 (18.4%)	7.5 (57.1%)	60	May-95
St. Simons Sound	24.6	0.1 (0.4%)	0.7 (2.6%)	11.4 (46.4%)	20	Aug 1992/93
Biscayne Bay	484.2	62.3 (12.9%)	229.5 (47.4%)	248.4 (51.3%)	226	Jun 1995/96
Tampa Bay	550	0.5 (0.1%)	463.6 (84.3%)	0.6 (0.1%)	165	June-94
Apalachicola Bay	187.6	0	63.6 (33.9%)	186.8 (99.6%)	9	May-93
Choctawhatchee Bay	254.5	0	113.1 (44.4%)	254.5 (100%)	39	June-94
St. Andrew Bay	127.2	0	2.3 (1.8%)	127 (100%)	31	May-93
Pensacola Bay	273	0.04 (0.015%)	14.4 (5.3%)	262.8 (96.4%)	40	August-95
Sabine Lake	245.9	0	14.0 (5.7%)	194.2 (79.0%)	66	August-95
Galveston Bay	1351.1	0	432.0 (32.0%)	1143.7 (84.6%)	75	July-96
S. Cal. small estuaries	5	2.9 (57.9%)	2.1 (42.7%)	nd	30	Aug/Sep 1994
San Pedro Bay (b)	53.8	7.8 (14.5%)	52.6 (97.7%)	nd	105	Jul, Sep 1992
Mission Bay	6.1	0	3.6 (59.5%)	nd	11	Mar/Aug 1993
San Diego River	0.5	0	0.3 (52.0%)	nd	2	Mar/Aug 1993
San Diego Bay	40.2	26.3 (65.8%)	25.8 (63.7%)	nd	113	Mar/Aug 1993
Tijuana River	0.3	0.17 (24.5%)	0.27 (90.0%)	nd	6	Mar/Aug 1993
Total toxic area (km^2)	4158.2	286.4	1439.5	2670.6	1372	
Total area (km^2)		4158.2	3723.3	4039.3		
Percent of total area		6.90%	38.70%	66.10%		

nd = no data (test not performed)
(a) Tests performed with 100% pore water concentrations
(b) Pore water tests performed with abalone embryos

Source: Modified from Long et al. 1996.

(top)

Return to National Picture
Return to Regional Contrasts