STATE OF THE COASTAL ENVIRONMENT

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

Since 1986, the Mussel Watch Project of the National Oceanic and Atmospheric Administration (NOAA) has chemically analyzed mussels and oysters collected annually from coastal sites throughout the Nation. Results show that concentrations of most of the monitored man-made chemicals (e.g., DDT, PCBs) are decreasing. The concentration of cadmium is decreasing as well, but concentrations of other trace metals have stayed more or less constant. Many chemicals, particularly those that are man-made, have high concentration levels near cities. Except in the case of lead, however, there is no apparent association between high concentrations of other trace elements (e.g., mercury, copper, zine) and urban areas.

The following reference format is suggested:

National Oceanic and Atmospheric Administration (NOAA). 1998 (on-line). "Chemical Contaminants in Oysters and Mussels" by Tom O'Connor. NOAA's State of the Coast Report. Silver Spring, MD: NOAA.

URL: http://state_of_coast.noaa.gov/bulletins/html/ccom_05/ccom.html

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

INTRODUCTION

Public concern over the health of the coast led NOAA to initiate its National Status and Trends (NS&T) Program for marine environmental quality. Since 1986, the Mussel Watch Project, one component of the NS&T Program, has monitored contaminants in the Nation's coastal waters by sampling mollusks (mussels and oysters) and sediments. Its objectives are to determine concentrations of trace metals and groups of organic compounds at sites on all coasts (Figure 1) and to identify increasing or decreasing trends. Now, the Mussel Watch Project is providing the longest continuous national record of coastal water quality.

Concentrations of chemicals in mollusks are related to the levels of chemicals in the water that they inhabit and in the food that they filter from the water. When chemical concentrations increase or decrease in the water and in food sources, concentrations increase or decrease in mollusks (Roesijadi et al., 1987; Pruell et al., 1987; Wang et al., 1996). It is possible to monitor chemical concentrations in water and in suspended particles, but for many technical reasons, it is simpler to measure concentrations in mollusks. This, together with their immobility, makes mussels and oysters ideal for monitoring changes in chemical concentrations at fixed locations.

Table 1 lists the contaminants monitored in the Mussel Watch Project. These trace metals and organic compounds can be toxic to marine life and humans under some conditions. In small quantities, however, trace metals are essential to the maintenance of life (Nielsen, 1988).

Table 1. Chemicals measured in the Mussel Watch Project

Trace Metals

Arsenic (As)	Nickel (Ni)
Cadmium (Cd)	Mercury (Hg)
Copper (Cu)	Selenium (Se)
Lead (Pb)	Zinc (Zn)

Organic Compounds

Total DDT (ΣDDT)
Total Chlordane (ΣCdane)
Total Dieldrin (ΣDield)
Total Polychlorinated Biphenyls (ΣPCBs)
Total Polycyclic Aromatic Hydrocarbons (ΣPAHs)
Total Butyltin (ΣBT)

Photo 1. These men are collecting mussels to be analyzed for contaminants. The concentration of contaminants found in mussels and oysters is related to the level of these chemicals in coastal waters, and monitoring the changes in these concentrations gives an indication of water quality.

Photo 2. Detailed chemical analysis determines the concentration of contaminants.

Trace metals occur naturally, but are potential contaminants because human activities influence their levels in the environment (Nriagu, 1989). Five of the six organic compounds monitored are man-made. DDT, dieldrin, and chlordane, also known as chlorinated hydrocarbons, are pesticides. Their use was banned in the 1970s and 1980s. PCBs, used for industrial purposes, were banned in 1976. Tributyltin, used as a biocide on boats and some underwater marine facilities, was banned in 1988 on vessels less than 75 feet long. Human activities such as the burning of fossil fuel and wood, and the incineration of waste, create PAH compounds in excess of those that exist naturally.

The detailed methods, procedures, and statistical analyses used to obtain and interpret the data are available in several reports. Readers interested in learning more about them should consult the *National Status and Trends Program Methods Documents* (Lauenstein and Cantillo, 1993a-d) and papers on trend analysis (O'Connor and Beliaeff, 1995; O'Connor, 1996).
(top)

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

NATIONAL PICTURE

Contamination Trends

Statistical comparisons of annually measured concentrations in samples from each of the 186 sites that were sampled in at least six years identified contamination trends. Calculations for each chemical at each sampling site showed increasing, decreasing, or no trend over time (Appendix A). On the whole, the most common observation was no trend, but when trends did occur, decreases greatly outnumbered increases. Contamination is decreasing for chemicals whose use has been banned (e.g., chlordane, DDT, dieldrin), or severely curtailed (e.g., tributyl tin, cadmium). For other chemicals, there is no evidence on a national scale for either increasing or decreasing trends (Table 2).

Table 2. Numbers of sites with increasing, decreasing, or no trend in concentrations of each chemical.

Chem.	Incr.	Dec.	No Trnd	Chem.	Incr.	Dec.	No Trnd
*ΣCdane	1	81	104	As	11	11	164
*ΣDDT	1	38	147	*Cd	3	28	155
*ΣDield	1	32	153	Cu	7	14	165
*ΣPCB	1	37	148	Hg	7	9	170
ΣPAH	3	3	180	Ni	6	8	172
*ΣBT	0	18	168	Pb	14	9	163
				Se	8	9	169
				Zn	7	9	170

*Chemicals with decreasing trends in concentrations in mussels and oysters, 1986-1995.

The numbers in Table 2 are the result of a statistical test that identifies random sequences as real trends 5% of the time. Thus, in 186 site examinations for each chemical, about 10 of the trends per chemical may be spurious. For this reason, the relatively few trends that appear for most of the trace elements and for PAHs have as yet been given little weight.

Statistical correlations were also developed for the median (middle) value of chemical concentrations among all sites sampled in each year from 1986 to 1995. At this national level of aggregation, there were decreasing trends exist for cadmium, copper in mussels, zinc in mussels, all the chlorinated organic compounds, ΣPAH, and ΣBT (Figure 2 and Appendix B). The copper, zinc, and ·PAH decreases were not evident in the site-by-site results.

Photo 3. Most monitored sites show no trend in chemical concentrations. When a trend was observed, there were far more sites with decreasing than increasing concentrations.

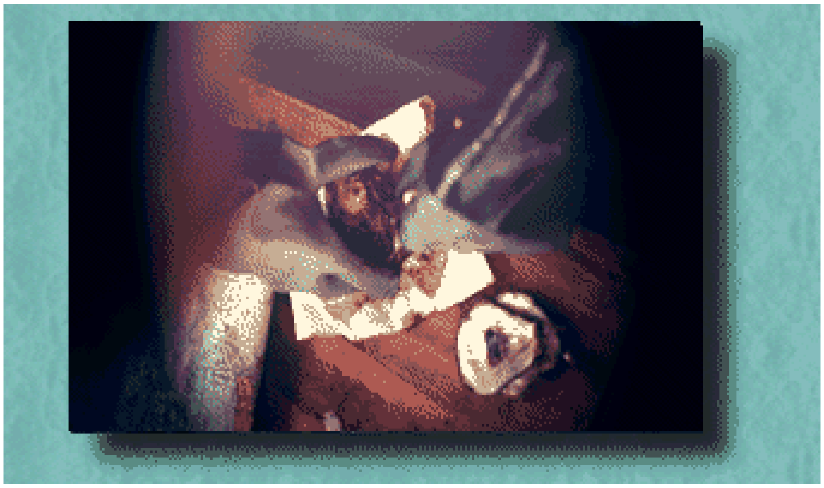

Photo 4. An oyster is prepared for analysis.

Decreasing trends in contamination are not unexpected. All the chlorinated hydrocarbons being monitored have been banned for use in the United States, and tributyl tin has been banned as a biocide on small boats. The annual industrial use of cadmium in the U.S. decreased during the period of 1986 through 1993 (O'Connor and Beliaeff, 1995), and the decrease continued through 1996 (Kuck, 1997).

Decreasing trends are good news, but the fact that no chemical has been increasing in concentration is perhaps of equal importance. So, at least for the chemicals monitored by the NS&T Program, contamination of the coastal United States is not increasing.

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Concentration Levels

The 274 Mussel Watch sites are intended to represent large areas rather than "hot spots" of known contamination. Sampling sites (Figure 1) are not uniformly distributed. Within estuaries and embayments, they average about 20 km apart; along open ocean coastline, the average separation is 70 km. Almost half the sites are near urban areas within 20 km of urban population centers of more than 100,000.

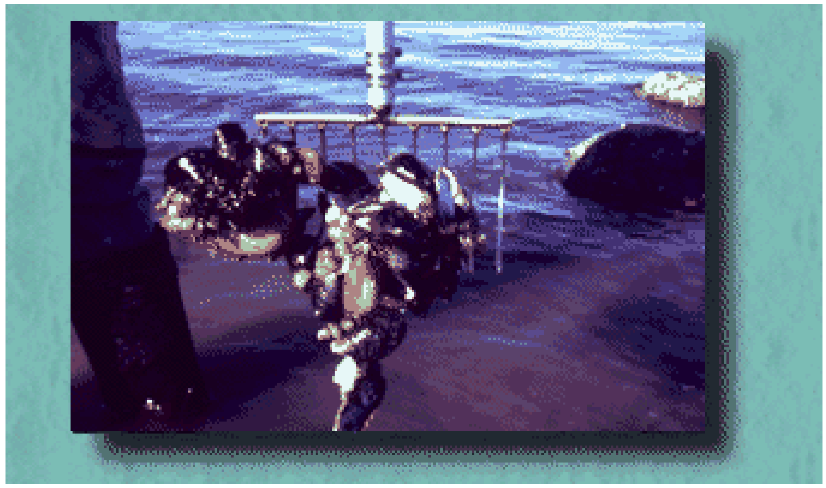

Photo 5. Mussels are sampled at 274 sites around the nation. Half of those sites are within 20 km of urban areas.

Concentration levels for a chemical are considered high if they exceed the values that were established from statistical analyses of all samples taken in 1990, the year when the most sites were sampled (Table 3). These levels are not based on toxic effects of the chemicals on organisms. Instead, a site is said to have a high concentration of a particular contaminant if the level of that contaminant fell within the top 15% of all levels for all sites. A site is rated as an area of high concentration if a contaminant's concentration level exceeds the values in Table 3 in at least half the years in which it was sampled (Appendix C).

Table 3. Concentrations defining the high end of the overall distribution of concentrations measured in mollusks by the Mussel Watch Project.

Chemical	High concentration	Chemical	High concentration
ΣDDT	140 ppb-dry	mercury (Hg)	0.23 ppm-dry
ΣPCB	430	nickel (Ni)	3.3
ΣChlordane	34	selenium (Se)	3.5
ΣDieldrin	9.1	cadmium (Cd)	6.2
ΣPAH	1100	arsenic (As)	17
ΣBT	300 ppb(as Sn)	copper (Cu)[1]	12 (mussels) 370 (oysters)
		zinc (Zn)[1]	200 (mu) 5100 (oy)
		lead (Pb)[1]	4.8 (mu) 0.84 (oy)

[1]High concentrations for copper, zinc and lead must be calculated separately for mussels and oysters.

Many chemicals have high concentrations at sampling sites near cities. For example, there is a strong statistical correlation between human population density and chemical concentrations in oysters and mussels for chlordane, DDT, PCBs, PAHs, butyl tins, and lead. For trace metals other than lead, no association of high concentrations with urban areas is evident.

High concentrations of chemicals in mollusks may not diminish the health, longevity, or reproductive capacity of the mollusks or any other organisms. If the organic contaminants or lead are causing biological effects, however, the most likely areas to find these effects would be near the urban areas.
(top)

REGIONAL CONTRASTS

For organic contaminants and lead, there is a clear difference in concentrations between urban and non-urban sampling sites. For other trace metals, the differences appear to be more a matter of geography than of population density. It is important to determine where high concentrations are not due to human activity, because those concentrations are not subject to human control.

Urban Sites

Of the 276 Mussel Watch Project sites nationwide, 125 (46%) are urban in that they are within 20 km of human populations greater than 100,000. Appendix D is a subset of Appendix C containing only the 36 sites in the vicinity of 800,000 or more people; clearly, the organic chemicals, lead, and some other chemicals high concentration levels at many of these sites. Yet, it is not inevitable that mollusks in urban areas have high concentrations of chemicals. In fact, mollusks at 19 of the 125 urban sites had no chemical at a high concentration.

Despite the density of people around Seattle, WA, for example, the occurrences of high concentrations are like those elsewhere in Puget Sound (i.e. common only for ΣPAH). While most sites near San Diego have high concentrations of several chemicals, there are none at the Mission Bay site. Similarly, mussels from the sites near Los Angeles frequently have high concentrations of chemicals, but the site in Santa Monica Bay does not.

Photo 6. Many urban sampling sites have high concentrations of chemicals. However, 15% of urban sites had no high concentrations at all.

There are many urban sites with high concentrations of cadmium, copper, mercury, nickel, selenium and zinc. Tentatively, these high concentrations may be attributed to human activity. Since the data as a whole do not support a connection between population and concentrations of those metals, the concentrations may be high for natural reasons. For example, nickel is found in high concentrations in mussels not only in the urban area of San Francisco Bay, but also at rural sites in northern California. In this case, nickel is in the minerals of the area (U.S. Geological Survey, 1981).
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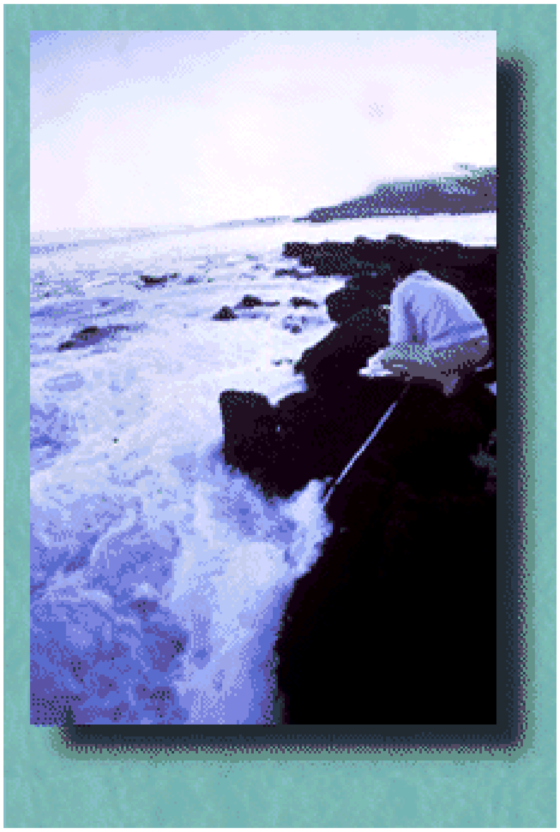

Photo 7. At least one chemical was found to have a high concentration at 62% of the non-urban sites.

Non-urban Sites

Among the 151 non-urban sites, 94 had at least one chemical at a high concentration, and some of these high concentrations were clearly due to human actions. High levels of mercury in oysters from parts of Matagorda Bay, Texas for example, can be attributed to extreme concentrations of mercury in sediments from past discharges of a chlor-alkali plant (Holmes, 1977). Concentrations of several chemicals in Choctawhatchee Bay, Florida in the vicinity of Eglin Air Force Base are also high.

In the absence of a known industrial source, high concentrations may be attributable to nature. There is no unequivocal way to know when high concentrations are natural, but when they appear at several geographically contiguous sites, one can suspect nature as the cause. Table 4 contains such groupings as are evident in Appendix C.

Table 4. Trace metals at high concentrations in particular regions of the coastal United States.

Trace metal	Region
Cadmium	Sites in the Great Lakes
Copper	Sites in the Great Lakes
Nickel	Sites in the Great Lakes
Selenium	Sites in the Great Lakes
Arsenic	Buzzards Bay, MA
Arsenic	All sites from Cape Hatteras, NC to Matanzas River, FL
Cadmium	Sites in MS and LA close to the Mississippi River
Nickel	Chesapeake and Delaware Bays
Selenium	Many sites in LA and TX
Selenium	Prince William Sound, AK

High concentrations of four trace metals in zebra mussels of the Great Lakes are probably due to those metals being more bioavailable in fresh water than in seawater or to that species' being more capable of accumulating the metals than marine mollusks. Because a fresh-water species and a marine species have no common site, it is impossible to directly test these ideas. There is no tendency for the concentrations among the sites at the Great Lakes to be high only near population centers, however, so it is likely that they are high for natural reasons.

Photo 8. Contamination at non-urban sites can be related to natural causes. Nickel concentration is high in the Chesapeake and Delaware Bays due to nearby ore deposits enriched with this trace element.

Independent evidence indicates that some of the other regionally high concentrations are natural. The area around the Chesapeake and Delaware Bays was the world's major source of chromium in the 19th century, and nickel, found today in high concentrations in both bays, is enriched in the same minerals that provide chromium. Similarly, the facts that arsenic is chemically similar to phosphorus and that the Southeast is rich in phosphate deposits may be responsible for the high arsenic concentrations in that region.

As discussed in the following Case Study, although the source is unknown, the high cadmium concentrations in Louisiana and Texas may be caused by human activity.
(top)

HOME
SITE INDEX

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

CASE STUDIES

Statistical analyses of concentrations over time identify trends. There is always a chance that a "trend" is only a random event, but when the same chemical shows the same trend among geographically similar sites, the case for a statistically valid trend is strong.

Decreases in Cadmium Levels along Populated Coasts

Concentrations of cadmium are decreasing at 11 of the 15 sites between New Haven, Connecticut and the Shark River in New Jersey, the most densely populated stretch along the U.S. East Coast. Cadmium levels are also decreasing at seven of the 13 sites along the densely populated coast between Imperial Beach in San Diego and Marina Del Rey in Los Angeles.

Only one of the 28 sites in these two groups is a site with a high concentration of cadmium. Levels at many other sites are higher, perhaps for natural reasons. So it is the trend, not the concentration, that reveals the human influence.

The trend in the national median, especially these trends in highly populated areas, should not be natural. In fact, the decreased use of cadmium as an anticorrosive, particularly on automobile bodies, explains the decrease both across the nation and along these two highly populated stretches of coast.
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Increases in Trace Element Levels near the Mississippi River

Photo 9. A scientist gathers samples of mussels at New York's Liberty Island.

Few trace elements are increasing in concentration on a national scale. However, of eight sites between Pascagoula Bay, Mississippi and Tiger Pass on the Mississippi River in Louisiana, the level of cadmium is increasing at three, copper at three, and zinc at four. Moreover, the concentration of cadmium is high at five of the eight sites, including the three where it shows an increasing trend.

Photo 10. Concentrations of cadmium, copper and zinc are increasing at certain sites near the Mississippi River delta.

These sites are in or west of the mouth of the Mississippi River, so it seems logical to attribute increased concentrations to increased discharges of those metals from the river. There are no discharge data against which to test this idea, but there is reason to believe that the sources of cadmium, copper, and zinc contaminating oysters in the area originate in human activity.
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A Non-representative Site

Sites monitored through the NS&T Program are supposed to be representative of large areas rather than of individual point sources of contamination. Two sites in Lavaca Bay, Texas (Figure 3) have mercury concentrations in the high range as a result of past discharges from a chlor-alkali plant. Those sites are fair representations of Lavaca Bay.

Oysters from one of those sites did not display high mercury concentrations until 1989, when the concentration increased more than tenfold to the highest concentration of any Mussel Watch site in the nation (Figure 4). The reason is that, because no oysters were at the site near the mouth of the Lavaca River in 1988, the sampling team began in 1989 taking oysters from a site that was 1.5 miles closer to a plant that had once discharged mercury. The extreme mercury concentrations that have been measured since then are not representative of Lavaca Bay. It is fair to assert that mercury concentrations are high in Lavaca Bay, but it is not fair to assert that the extreme levels near the former industrial source are typical of the bay as a whole.

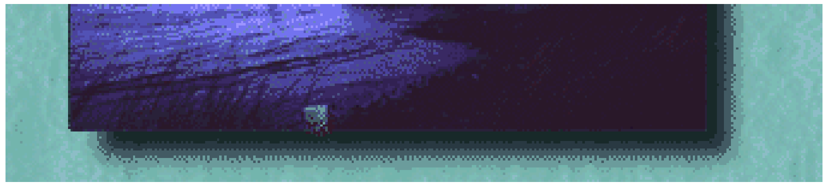

Photo 11. Monitoring sites are intended to be representative of large geographic areas. However, past discharges of chemicals can create localized concentration anomalies that are not typical of the area as a whole.

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EXPERT INTERPRETATION

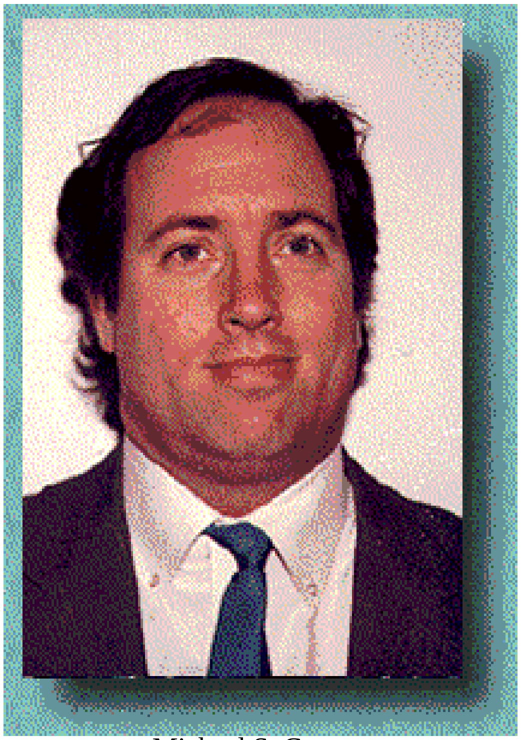
The three individuals below are experts in the topic of chemical contaminants in oysters and mussels. Here they voice their opinions on two questions relevant to that topic.

Question 1– Do you think that chemical contamination is increasing or decreasing along your coast?

Question 2 – Do you think that chemical contamination is causing serious problems along your coast?

Experts

		
Michael S. Connor	**Judith McDowell**	**Alan Mearns**



Michael S. Connor

Director, Environmental Quality Department, Massachusetts Water Resources Authority

Dr. Connor is an authority on assessing impacts to human and environmental health from the discharge of toxic wastes to marine waters. From 1983 to 1986 he developed comprehensive pollution management programs for Long Island Sound, Narragansett Bay and Buzzards Bay. For the last nine years, Dr. Connor has been responsible for monitoring the recovery of Boston Harbor and the environmental health of the waters in Massachusetts and Cape Cod Bays.

Response to Question 1

Response to Question 2

(top)

Question 1. Do you think that chemical contamination is increasing or decreasing along your coast?

Click here for audio response

(audio requires RealPlayer, see Using this Site)

In the industrialized Northeast, we are seeing great progress in the control of the chemicals that most concern us. Generally, the chemical contaminants that pose the greatest risk to marine life and people are chlorinated pesticides and polychlorinated biphenyls (PCBs) that can be bioaccumulated in fish and shellfish. Since the use of PCBs and organochlorine pesticides was banned in the United States in the 1970s, they are slowly disappearing from the environment. NOAA's Mussel Watch Program documents this decline. In addition, over the last two decades, Boston area scientists have measured declining concentrations of PCBs and pesticides in sewage discharges, the waters of Boston Harbor and Massachusetts Bay, surface sediments in the harbor, and flounder and lobsters growing in the harbor. This decline was most accentuated in the 1980s and has slowed somewhat since then. In addition, the health of winter flounder growing in the harbor has dramatically improved. In the 1980s, 10% to 15% of these fish had visible liver tumors. In the last few years, it's rare to find a tumorous fish.
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Question 2. Do you think that chemical contamination is causing serious problems along your coast?

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In the past, polychlorinated biphenyl (PCB) contamination has caused health advisories for shellfish in Boston Harbor and has closed the lobster fishery in New Bedford Harbor. There has been a marked improvement in the health of winter flounder growing in the harbor sediments as the sources of chemical contamination have been reduced. Ten years ago, much of the harbor bottom was covered with a "black mayonnaise" of sludge deposits. Since sludge dumping ended in 1991, the harbor has rebounded, and most of the sediments have been colonized by amphipods living at the surface-water interface.

As the impact of toxic contamination has decreased due to improvements in pollution prevention and treatment, I believe the relative impact of other pollution issues is becoming much more important. These issues include the discharge of nutrients and pathogens, the destruction of marine habitat, overfishing and the release of introduced species.
(top)

Judith McDowell

Senior Scientist, Biology Department, Woods Hole Oceanographic Institution

Dr. McDowell joined the Woods Hole Oceanographic Institution in 1975 as a postdoctoral scholar and shortly thereafter was appointed to the scientific staff. Her research interests have focused on the physiological effects of contaminants on marine animals. She has travelled worldwide to examine the relationship of contaminant exposure to biological effects in bivalve mollusk populations in contaminated estuaries.

Response to Question 1

Response to Question 2

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Question 1. Do you think that chemical contamination is increasing or decreasing along your coast?

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Toxic chemicals have been discharged to coastal areas from a variety of sources for decades. During the past two decades, increased efforts in point source recovery of contaminants and improved waste treatment as a result of enforcement of the Clean Water Act have reduced contaminant inputs in many coastal areas. By most indicators of water quality, coastal habitats are improving. A major exception to this trend is the accidental spillage of petroleum hydrocarbons which continues to present problems in local habitats.

In spite of these improvements in water quality, many coastal habitats continue to be contaminated because of the presence of contaminated sediments. Approximately 14 to 28 million cubic yards of contaminated sediments are managed annually in the U.S., an estimated 5% to 10% of all sediments dredged annually in the U.S. Two examples of areas with highly contaminated sediments are Boston Harbor and New Bedford Harbor, two sites in coastal Massachusetts. For sites such as these where contaminated sediments pose direct threats to ecological systems and potentially to human health, the problem of managing contaminated sediments is very difficult as disposal options are not readily available or acceptable.
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Question 2. Do you think that chemical contamination is causing serious problems along your coast?

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Although general trends in contaminant distributions in urban areas and adjacent waters, such as Boston Harbor/Massachusetts Bay and New Bedford Harbor, have been defined (e.g., higher concentrations of total polycyclic aromatic hydrocarbons in the inner harbor of Boston, lesser concentrations with distance from the inner harbor) critical information on the biological effects of chemical contaminants, specifically on population processes, is lacking. Because harbor sediments will continue to be a major source of contaminants to the ecosystem, even with improvement in water quality from the reduction of point source contamination, the potential risks to populations of marine biota must be defined.

Recent studies of the incidence of tumors and other histopathological disorders in bottom-dwelling fish and shellfish from contaminated coastal areas have suggested a possible link between the levels of lipophilic organic contaminants and the increased incidence of histopathological conditions. In addition to histopathological damage, sublethal toxic effects of contaminants in marine organisms include impairment of physiological processes that may alter the energy available for growth and reproduction and other effects on reproductive and developmental processes including direct genetic damage.

Clam populations in Boston Harbor and mussel populations in New Bedford Harbor have reduced reproductive potential and a reduction in physiological condition in addition to a wide range of histopathological conditions. Chemical contamination of fishery resources has also led to fishery closures or fishery advisories in several areas of the U.S. coastline.
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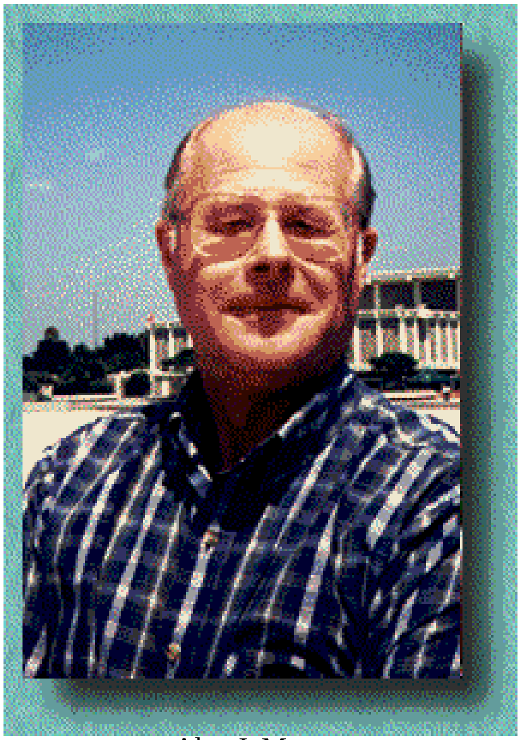
Alan J. Mearns

Biological Assessment Team Leader, Scientific Support Coordination Branch, Hazardous Materials Response and Assessment Division, Office of Ocean Resources Conservation and Assessment, National Ocean Service, NOAA

For the past 10 years, Dr. Mearns has supported the U.S. Coast Guard with scientific information during the clean-up of oil and hazardous substance spills in coastal and marine waters. Prior to this he was the leader of a NOAA scientific survery team that conducted a detailed review of long-term historical trends in coastal contamination along the entire U.S. coastline. During the 1970s he was chief of the Biological Division at the Southern California Coastal Water Research Project in Los Angeles.

Response to Question 1

Response to Question 2

(top)

Question 1. Do you think that chemical contamination is increasing or decreasing along your coast?

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Chemical contamination has been decreasing. In fact, the coasts and coastal resources of California, Oregon, Washington, Hawaii and Alaska are now cleaner and less contaminated with chemicals than at any time since World War II.

Intensive monitoring indicates that there has been a "parade" of pollutants washing our shores. In the 1920s, spillage from the on-shore oil industry was widespread in southern California and San Francisco Bay. In the 1940s, fish and sediments experienced increasing concentrations of PCBs and DDT. In the 1950s, radionuclides from atmospheric testing and releases from the Columbia River began showing up in clams and mussels along the coast. The latest entry into this "pollutant parade," tributyl tin from vessel antifouling paint, reached its peak of contamination in the late 1970s and early 1980s. The combined chemical contamination of West Coast marine life, water and sediments reached an overall peak in the early 1970s, followed by dramatic decreases during the late 1970s and early 1980s.

Most of the decreasing contamination has come as a result of controls on the sale and use of specific chemicals and as a result of pre-treatment or industrial source control. The bottom line is that the coasts and coastal resources of California, Oregon, Washington, Hawaii and Alaska are now cleaner and less contaminated with chemicals than at any time since World War II.
(top)

Question 2. Do you think that chemical contamination is causing serious problems along your coast?

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Chemical contaminants continue to cause problems to marine life. However, whether these are serious or not depends on your point of view. Compared to the past, today's problems are minor, are localized and are not caused by controllable inputs such as sewage or industrial outfalls.

As we now realize, there were very serious and large-scale ecological problems a quarter century ago. These effects were reversed during the

1970s. Nevertheless, significant problems remain, due largely to seepage of toxic chemicals from submerged historical deposits. Petroleum hydrocarbons, PCBs and DDT continue to seep out of sediment hot spots, contaminating local fish and shellfish, in some cases causing continued, but localized, reproductive injury and disease. Although many top-level predators such as seals, sea lions and pelicans are thriving, there still is enough DDT in the southern California ecosystem to cause reproductive failure in a local bald eagle population. There are also human consumption warnings for several species of nearshore fish in localized coastal areas such as Palos Verdes, Santa Monica Bay, San Francisco Bay and Puget Sound. The greatest clean-up challenges are at sites with historical deposits in portions of bays, harbors and estuaries; at inland hazardous waste sites; and in many of the region's inland waters.

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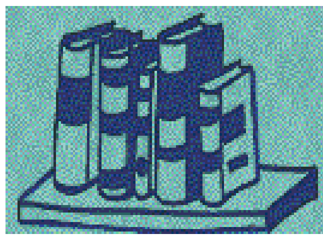

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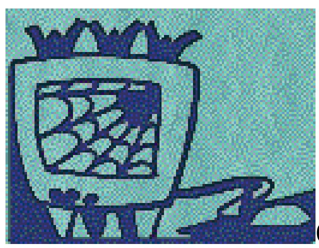

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Downloadable Products

National Oceanic and Atmospheric Administration , Office of Ocean Resources Conservation and Assessment. ORCA Publication List.

http://www-orca.nos.noaa.gov/cgi-bin/orca_productlist.pl?1

There are six downloadable publications on chemical contamination in oysters and mussels. National listing publication numbers are:

39) Results from the NOAA National Status and Trends Program;

49) Mussel Watch: Recent trends in coastal environmental quality;

59) Sampling and analytical methods of the NS&T Program;

73) NOAA NS&T Mussel Watch Project;

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75 Incidence of adverse biological effects.

U.S. EPA, Office of Science and Technology. Methods for sampling and analyzing contaminants in fish and shellfish tissue.

http://www.epa.gov/OST/NEW/PDF/doc2ndx.html

Offers downloadable document: Methods for sampling and analyzing contaminants in fish and shellfish tissue. Document sections include: monitoring strategy, target species, and target analyses.

National Programs

National Oceanic and Atmospheric Administration Office of Ocean Resources Conservation and Assessment. NOAA's National Status and Trends Program.

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Explains the National Status and Trends Program for marine environmental quality. Since 1984, NOAA's National Status and Trends Program has monitored, on a national scale, spatial and temporal trends of chemical contamination and biological responses to that contamination. Includes a national map with Benthic Surveillance sites and Mussel Watch sites.

Moss Landings Marine Laboratories. California State Mussel Watch Program.

http://color.mlml.calstate.edu/www/ groups/mpsl/muslwtch.htm

Describes the California State Mussel Watch Program as a tool to help locate and identify harmful substances in California's coastal waters. Includes program goals, data uses, and techniques.

Shellfish Contaminants

EMAP Estuaries: A report on the condition of the estuaries of the United States in 1990-1993. Do fish and shellfish contain contaminant residues?

http://www.epa.gov/gumpo/emap/module4.html

Section of the U.S. EPA EMAP Estuaries: Report on the condition of the estuaries of the United States in 1990-1993 . Offers background information on contaminant concentrations in fish and shellfish in the United States. Lists percentages of contaminants in tissues in various species.

Food and Drug Administration, Center for Food Safety and Applied Nutrition. Guidance documents for trace elements in seafood.

http://vm.cfsan.fda.gov/~frf/guid-sf.html

Provides access to guidance documents on five trace elements (arsenic, cadmium, chromium, lead and nickel) in seafood. The documents contain sampling procedures, consumption and exposure assessment, hazard assessment, and levels of concern.

U.S. EPA, Office of Wetlands. Indicator 13: Selected coastal surface water pollutants in shellfish.

http://www.epa.gov/OWOW/indic/fs13.html

This fact sheet is part of a larger EPA document, Environmental indicators of water quality in the United States, June 1996. It describes the percent of change in concentrations of six coastal surface water pollutants in shellfish (oysters and mussels) from 1986 to 1993 as a national water quality indicator. This site describes the indicator, how it will be used to track progress, what is being done to improve the indicator, and what is being done to improve conditions measured by the indicator.

Florida Bay Management Committee. Oyster and sediment contaminant levels and trends in South Florida.

http://flabay.saj.usace.army.mil/contaminants.html

Explains the use of oyster and sediment samples to identify trends of contaminants in South Florida from 1986-1994.

Internet Data Bases

National Oceanic and Atmospheric Administration, Office of Ocean Resources Conservation and Assessment. NOAA's National Status and Trends Program.

http://seaserver.nos.noaa.gov/../cgi-bin/orca_prod_details.pl?3_CMBAD_NSandTData

Downloadable data from the National Status and Trends Program. Data base can be searched on various parameters, e.g., benthic surveillance sites, metal contaminant data, organic compound contaminant data.

San Francisco Estuary Institute. SFEI regional monitoring program on-line data base, Wizard.

http://jaguar.sfei.org/ows-bin/owa/webrmp.startit

This on-line regional monitoring program data base includes data collected in the San Francisco Bay area, e.g., chemical analyses of sediments, water, and caged mollusks collected periodically since 1983.
(top)

APPENDICES

Appendix A Trends at sites sampled in six or more years

Appendix B Annual median concentrations and spearman correlation coefficient for concentration with year

Appendix C Indications of sites with 50% or more occurrences of "high" concentrations since 1990

Appendix D High concentrations at 36 most urban sites

Appendix Preview

Following is a segment of Appendix A.

Click here to view the complete Appendix A (260K).

(return to The National Picture)
(return Appendices)

Trends at sites sampled in six or more years

SEQ	SITE	Gen. Location	Specific Location	St.	SP.	Σyrs	AS	CD	CU	HG	NI	PB	SE	ZN	ΣCDANE	ΣDDT	ΣDIELD	ΣPCB	ΣPAH	ΣBT
1	PBPI	Penobscot Bay	Pickering Island	ME	ME	9														
2	PBSI	Penobscot Bay	Sears Island	ME	ME	10			D	I							D	D		
3	MSSP	Merriconeag Snd.	Stover Point	ME	ME	8	I		D			I								
4	CAKP	Cape Arundel	Kennebunkport	ME	ME	6														
5	CAGH	Cape Ann	Gap Head	MA	ME	9							I		D			D		
6	SHFP	Salem Harbor	Folger Point	MA	ME	7							I							
8	BHDI	Boston Harbor	Deer Island	MA	ME	9														D
9	BHDB	Boston Harbor	Dorchester Bay	MA	ME	8					I									
10	BHHB	Boston Harbor	Hingham Bay	MA	ME	9				I										
11	BHBI	Boston Harbor	Brewster Island	MA	ME	10			D						D					
13	DBCI	Duxbury Bay	Clarks Island	MA	ME	7						I								
14	CCNH	Cape Cod	Nauset Harbor	MA	ME	6	I					I								D
18	BBAR	Buzzards Bay	Angelica Rock	MA	ME	9									D					
19	BBRH	Buzzards Bay	Round Hill	MA	ME	6	I													
20	BBGN	Buzzards Bay	Goosebury Neck	MA	ME	9											D			

(back to Appendices)

Field Name	Definition/Description
SEQ	Sequence used for sorting
SITE	Site Code
Gen. Location	General Location
St.	State
SP.	Species (See additional text below)
Total yrs.	Total years sampled
AS	Arsenic (µg/g or ppm dryweight)
CD	Cadium (µg/g or ppm dryweight)
HG	Mercury (µg/g or ppm dryweight)
NI	Nickel (µg/g or ppm dryweight)
SE	Selenium (µg/g or ppm dryweight)
CU	Copper (µg/g or ppm dryweight)
PB	Lead (µg/g or ppm dryweight)
ZN	Zinc (µg/g or ppm dryweight)
ΣCDANE	Total chlordane (ng/g or ppb)
ΣDDT	Total DDT (ng/g or ppb)
ΣDIELD	Total dieldrin (ng/g or ppb)
ΣPCB	Total polychlorinated biphenyl (ng/g or ppb)
ΣPAH	Total polycyclic aromatic hydrocarbons (ng/g or ppb)
ΣBT	Total butyl tin (ng/g or ppb as SN)

Values

D	Decreasing (95% stastical certainty)
I	Increasing

Species

Since no species of mollusk is common on all coasts, it was necessary to collect seven different species.

ME	Blue mussel, *Mytilus edulis* , on the East Coast from Maine to Cape May, NJ
CV	American Oyster, *Crassostrea virginica* , from Delaware Bay south thru the Gulf of Mexico
MC	Mussels, *M. edulis* and *M. californianus,* on the West Coast
OS	Oyster, *Ostrea sandvicensis,* in Hawaii
DP	Zebra mussel, *Dreissena polymorpha* , at sites in the Great Lakes
CR	Mangrove oyster, *Crassotrea rhizophorae* , in Puerto Rico
CS	Smooth-edged jewel box, *Chama sinuos* , at the one site in the Florida Keys

(back to Appendices)

Appendix B

Following is the complete Appendix B.

(return to The National Picture)
(return to Appendices)

Annual median concentrations and spearman correlation coefficient for concentration with year

chem/Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	rs (conc v yr)
As	9.67	9.03	8.80	8.22	9.11	9.10	9.18	8.30	8.96	10.14	0.103
Cd	3.20	2.83	2.86	2.63	2.80	2.45	2.15	2.57	2.25	2.30	-0.867
Hg	0.11	0.10	0.11	0.12	0.09	0.11	0.10	0.11	0.10	0.11	-0.271
Ni	2.13	1.93	1.80	1.73	1.67	2.07	2.19	1.66	1.50	2.03	-0.273
Se	2.57	2.60	2.93	2.28	2.44	2.57	2.58	2.48	2.61	3.28	0.267
Cu(mus)	9.80	9.97	9.73	9.93	8.60	8.83	8.67	8.22	8.69	8.76	-0.685
Cu(oys)	103	118	139	118	139	120	130	118	98	134	0.068
Pb(mus)	2.32	1.83	2.05	1.63	1.63	2.00	1.55	1.70	2.03	1.83	-0.345
Pb(oys)	0.41	0.46	0.47	0.46	0.52	0.56	0.46	0.52	0.67	0.45	0.426
Zn(mus)	143	133	128	120	133	128	120	120	120	120	-0.837
Zn(oys)	1633	1758	2300	2246	2383	1996	2089	2100	2047	2038	0.152
Σcdane	14.69	19.29	14.18	13.72	13.16	5.59	6.02	6.96	6.24	5.37	-0.879
Σddt	37.07	41.13	37.63	35.53	30.11	18.38	24.40	23.80	26.10	23.63	-0.806
Σdield	6.07	8.30	4.50	4.20	3.28	3.01	3.61	3.61	2.82	2.70	-0.888
Σpcb	145	121	137	118	110	58	70	62	92	74	-0.770
Σpah			506	273	248	215	237	232	229	191	-0.857
Σbt				106.12	71.09	64.25	47.36	15.52	22.59	14.57	-0.964

(back to Appendices)

Field Name	Definition/Description
AS	Arsenic (µg/g or ppm dryweight)
CD	Cadium (µg/g or ppm dryweight)
HG	Mercury (µg/g or ppm dryweight)
NI	Nickel (µg/g or ppm dryweight)
SE	Selenium (µg/g or ppm dryweight)
CU	Copper (µg/g or ppm dryweight) (mu-mussels; oys-oysters)
PB	Lead (µg/g or ppm dryweight) (mu-mussels; oys-oysters)
ZN	Zinc (µg/g or ppm dryweight) (mu-mussels; oys-oysters)
Σcdane	Total chlordane (ng/g or ppb)
Σddt	Total DDT (ng/g or ppb)
Σdield	Total dieldrin (ng/g or ppb)
Σpcb	Total polychlorinated biphenyl (ng/g or ppb)
Σpah	Total polycyclic aromatic hydrocarbons (ng/g or ppb)
Σbt	Total butyl tin (ng/g or ppb as SN)

(back to Appendices)

Appendix Preview

Following is a segment of Appendix C.

Click here to view the complete Appendix C (394K).

(return to The National Picture)
(return to Regional Contrasts)
(return to Appendices)

Indications of sites with 50% or more occurrences of high concentrations since 1990

SEQ	SITE	Gen. Location	Sp. Location	ST	SP	POP	Σyrs	AS	CD	CU	HG	NI	PB	SE	ZN	ΣCDANE	ΣDIELD	ΣDDT	ΣPCB	ΣPAH	ΣBT	P20
1	PBPI	Penobscot Bay	Pickering Island	ME	ME		5															8300
2	PBSI	Penobscot Bay	Sears Island	ME	ME		6				x											22881
3	MSSP	Merriconeag Snd.	Stover Point	ME	ME		6															48648
4	CAKP	Cape Arundel	Kennebunkport	ME	ME		5															60699
5	CAGH	Cape Ann	Gap Head	MA	ME		6	x			x											48003
6	SHFP	Salem Harbor	Folger Point	MA	ME		5						x									434847
7	MBNB	Massachusetts Bay	Nahant Bay	MA	ME		4				x											737880
8	BHDI	Boston Harbor	Deer Island	MA	ME	x	5				x		x						x	x		1682509
9	BHDB	Boston Harbor	Dorchester Bay	MA	ME	x	4			x	x		x			x	x	x	x	x		1743726
10	BHHB	Boston Harbor	Hingham Bay	MA	ME	x	5				x		x						x			838613
11	BHBI	Boston Harbor	Brewster Island	MA	ME	x	6				x		x						x			1022679
12	MBNR	Massachusetts Bay	North River	MA	ME		3				x		x									222558
13	DBCI	Duxbury Bay	Clarks Island	MA	ME		6															120415
14	CCNH	Cape Cod	Nauset Harbor	MA	ME		5															39345
15	BBNI	Buzzards Bay	Naushon Island	MA	ME		4	x											x			58364
16	BBWF	Buzzards Bay	West Falmouth	MA	ME		4	x														95251
17	BBCC	Buzzards Bay	Cape Cod Canal	MA	ME		4															108365
18	BBAR	Buzzards Bay	Angelica Rock	MA	ME		5	x											x			160402
19	BBRH	Buzzards Bay	Round Hill	MA	ME		2	x											x	x		156304
20	BBGN	Buzzards Bay	Goosebury Neck	MA	ME		5															79782

(back to Appendices)

Field Name	Definition/Description
SEQ	Sequence used for sorting
SITE	Site Code
Gen. Location	General Location
St.	State
SP.	Species (See additional text below)
Total yrs.	Total years sampled
AS	Arsenic (µg/g or ppm dryweight)
CD	Cadium (µg/g or ppm dryweight)
HG	Mercury (µg/g or ppm dryweight)
NI	Nickel (µg/g or ppm dryweight)
SE	Selenium (µg/g or ppm dryweight)
CU	Copper (µg/g or ppm dryweight)
PB	Lead (µg/g or ppm dryweight)
ZN	Zinc (µg/g or ppm dryweight)
ΣCDANE	Total chlordane (ng/g or ppb)
ΣDDT	Total DDT (ng/g or ppb)
ΣDIELD	Total dieldrin (ng/g or ppb)
ΣPCB	Total polychlorinated biphenyl (ng/g or ppb)
ΣPAH	Total polycyclic aromatic hydrocarbons (ng/g or ppb)
ΣBT	Total butyl tin (ng/g or ppb as SN)
P20	Population within 20 kilometers

Values

D	Decreasing (95% stastical certainty)
I	Increasing

Species

Since no species of mollusk is common on all coasts, it was necessary to collect seven different species.

ME	Blue mussel, *Mytilus edulis* , on the East Coast from Maine to Cape May, NJ
CV	American Oyster, *Crassostrea virginica* , from Delaware Bay south thru the Gulf of Mexico
MC	Mussels, *M. edulis* and *M. californianus,* on the West Coast
OS	Oyster, *Ostrea sandvicensis,* in Hawaii
DP	Zebra mussel, *Dreissena polymorpha* , at sites in the Great Lakes
CR	Mangrove oyster, *Crassotrea rhizophorae* , in Puerto Rico
CS	Smooth-edged jewel box, *Chama sinuos* , at the one site in the Florida Keys

(back to Appendices)

Appendix Preview

Following is a segment of Appendix D.

Click here to view the complete Appendix D (403K).

(return to Reginal Contrasts)
(back to Appendices)

High concentrations at 36 most urban sites

SEQ	SITE	Gen. Location	Sp. Location	ST	SP	POP	Σyrs	AS	CD	CU	HG	NI	PB	SE	ZN	ΣCDANE	ΣDIELD	ΣDDT	ΣPCB	ΣPAH	ΣBT	P20
40	HRUB	Hudson/Raritan Estuary	Upper Bay	NY	ME	x	5			x	x	x	x	x	x		x	x	x	x	x	6,738,557
31	LITN	Long Island Sound	Throgs Neck	NY	ME	x	5						x			x	x		x	x		6,038,771
39	HRJB	Hudson/Raritan Estuary	Jamaica Bay	NY	ME	x	5			x	x		x				x		x	x		3,730,946
41	HRLB	Hudson/Raritan Estuary	Lower Bay	NY	ME	x	3			x			x				x	x	x	x		3,432,602
32	LIHH	Long Island Sound	Hempstead Harbor	NY	ME	x	5										x					2,387,568
193	MDSJ	Marina Del Rey	South Jetty	CA	ME	x	5						x	x	x	x		x				2,149,169
188	ABWJ	Anaheim Bay	West Jetty	CA	MC	x	5									x	x	x				1,862,519
9	BHDB	Boston Harbor	Dorchester Bay	MA	ME	x	4			x	x		x			x	x	x	x	x		1,743,726
8	BHDI	Boston Harbor	Deer Island	MA	ME	x	5				x		x						x	x		1,682,509
30	LIMR	Long Island Sound	Mamaroneck	NY	ME	x	4			x			x			x	x		x			1,672,492
43	NYSH	New York Bight	Sandy Hook	NJ	ME	x	4			x	x	x	x			x	x	x	x	x		1,647,821
209	SFEM	San Francisco Bay	Emeryville	CA	ME	x	5		x		x	x		x	x		x		x	x	x	1,632,630
192	RBMJ	Redondo Beach	Municipal Jetty	CA	MC	x	5							x				x				1,621,636
265	LMCB	Lake Michigan	Calumet Breakwater	IN	DP	x	2		x	x		x		x			x				x	1,545,104
42	HRRB	Hudson/Raritan Estuary	Raritan Bay	NJ	ME	x	3			x		x					x		x	x		1,511,916
189	LBBW	Long Beach	Breakwater	CA	ME	x	5						x		x		x	x				1,440,576
38	LIJI	Long Island	Jones Inlet	NY	ME	x	3				x						x					1,336,118

(back to Appendices)

Field Name	Definition/Description
SEQ	Sequence used for sorting
SITE	Site Code
Gen. Location	General Location
St.	State
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Total yrs.	Total years sampled
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ΣPAH	Total polycyclic aromatic hydrocarbons (ng/g or ppb)
ΣBT	Total butyl tin (ng/g or ppb as SN)
P20	Population within 20 kilometers
Values	
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I	Increasing

Species

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DP	Zebra mussel, *Dreissena polymorpha* , at sites in the Great Lakes
CR	Mangrove oyster, *Crassotrea rhizophorae* , in Puerto Rico
CS	Smooth-edged jewel box, *Chama sinuos* , at the one site in the Florida Keys

(back to 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

annual trend: a statistically validated correlation between a chemical concentration and a certain year.

chlor-alkali plant: an industrial plant producing chlorine and caustic soda.

contamination: the presence of a chemical due to human activities.

man-made chemicals: organic chemicals that would not exist if not synthesized.

mollusks: in general, a phylum; in this article, however, the term pertains only to bivalve mollusks that are either mussels or oysters (see "species").

monitoring: periodic measurements of the same parameters.

organic compounds: in general, all chemical compounds containing the element carbon (except as a carbonate); in this article, it pertains to specific compounds.

sediment: particulate material lying on the seafloor.

species: in this article, one of seven different species of mollusk: the blue mussel *Mytilus edulis* on the East Coast from Maine to Cape May, New Jersey; the American oyster *Crassostrea virginica* from Delaware Bay southward and throughout the Gulf of Mexico; the mussels *M. edulis* and *M. californianus* on the West Coast; the oyster *Ostrea sandvicensis* in Hawaii; the zebra mussel *Dreissena polymorpha* at sites in the Great Lakes; the mangrove oyster *Crassostrea rhizophorae* in Puerto Rico; and the smooth-edged jewel box *Chama sinuos* at one site in the Florida Keys.
(top)

statistical: related to a rigorous mathematical test for a correlation.

status: in the context of chemical concentrations in mollusks, the geographic distribution of concentrations.

total butyl tin (·BT): the sum of the concentrations of tributyl tin and its breakdown products, dibutyl tin and monobutyl tin.

total chlordane (·Cdane): the sum of concentrations of two major constituents of chlordane mixtures, cis-chlordane and trans-nonachlor, and two minor components, heptachlor and heptachlorepoxide.

total dichlorodiphenyltrichloroethane (·DDT): The sum of concentrations of DDT and its metabolites, DDE (dichlorodiphenyltrichloroethylene) and DDD (dichlorodiphenyldichloroethylene).

total dieldrin (·Dield): the sum of concentrations of two compounds: aldrin and dieldrin.

total polychlorinated biphenyls (·PCBs): the sum of the concentrations of di-, tri-, tetra-, penta-, hexa-, hepta-, octa-, and nonachlorobiphenyls. Since 1988, the equivalent ·PCB has been calculated from the sum of concentrations of 18 individual PCB congeners.

total polycyclic aromatic hydrocarbons (·PAHs): the sum of concentrations of 24 PAH compounds: twelve 2- and 3-ring compounds (biphenyl, naphthalene, 1-methylnaphthalene, 2-methylnaphthalene, 2,6-dimethylnaphthalene, 1,6,7-trimethylnaphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, 1-methylphenanthrene, and anthracene); and twelve 4-, 5- , and 6-ring compounds (fluoranthene, pyrene, benz[a]anthracene, chrysene, benzo[a]pyrene, benzo[e]pyrene, perylene, benzo[b]fluoranthene, benzo[k]fluoranthene, dibenz[a,h]anthracene, indeno[1,2,3-cd]pyrene and benzo[ghi]perylene).

trace metals: a general term for all elements (even non-metallic elements) that are usually found in concentrations of less than 1,000 parts per million in sediments or animal tissue.

(top)

STATE OF THE COASTAL ENVIRONMENT

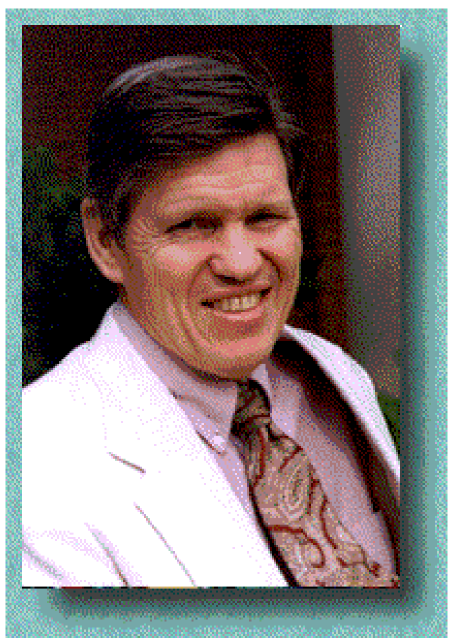
CHEMICAL CONTAMINANTS IN OYSTERS AND MUSSELS

CREDITS

Acknowledgments

The NS&T Program Mussel Watch samples have been collected and analyzed by the Texas A&M University Geochemical and Environmental Research Group in College Station, Texas; the Battelle Laboratories in Duxbury, Massachusetts and Sequim, Washington; and the La Jolla, California laboratory of the Scientific Applications International Corporation.
(top)

About the Author



Tom O'Connor is Chief of the Coastal Monitoring Branch in the Coastal Monitoring and Bioeffects Assessment Division, Office of Ocean Resources Conservation and Assessment, National Oceanic and Atmospheric Administration (NOAA). He initially joined the NOAA Ocean Dumping Program in 1977, and in 1987 became manager of the National Status and Trends Program for marine environmental quality. In all of these positions, his responsibilities have centered on quantifying the extent and effects of chemical contamination in the marine environment.
(top)

Return to Introduction
Return to National Picture

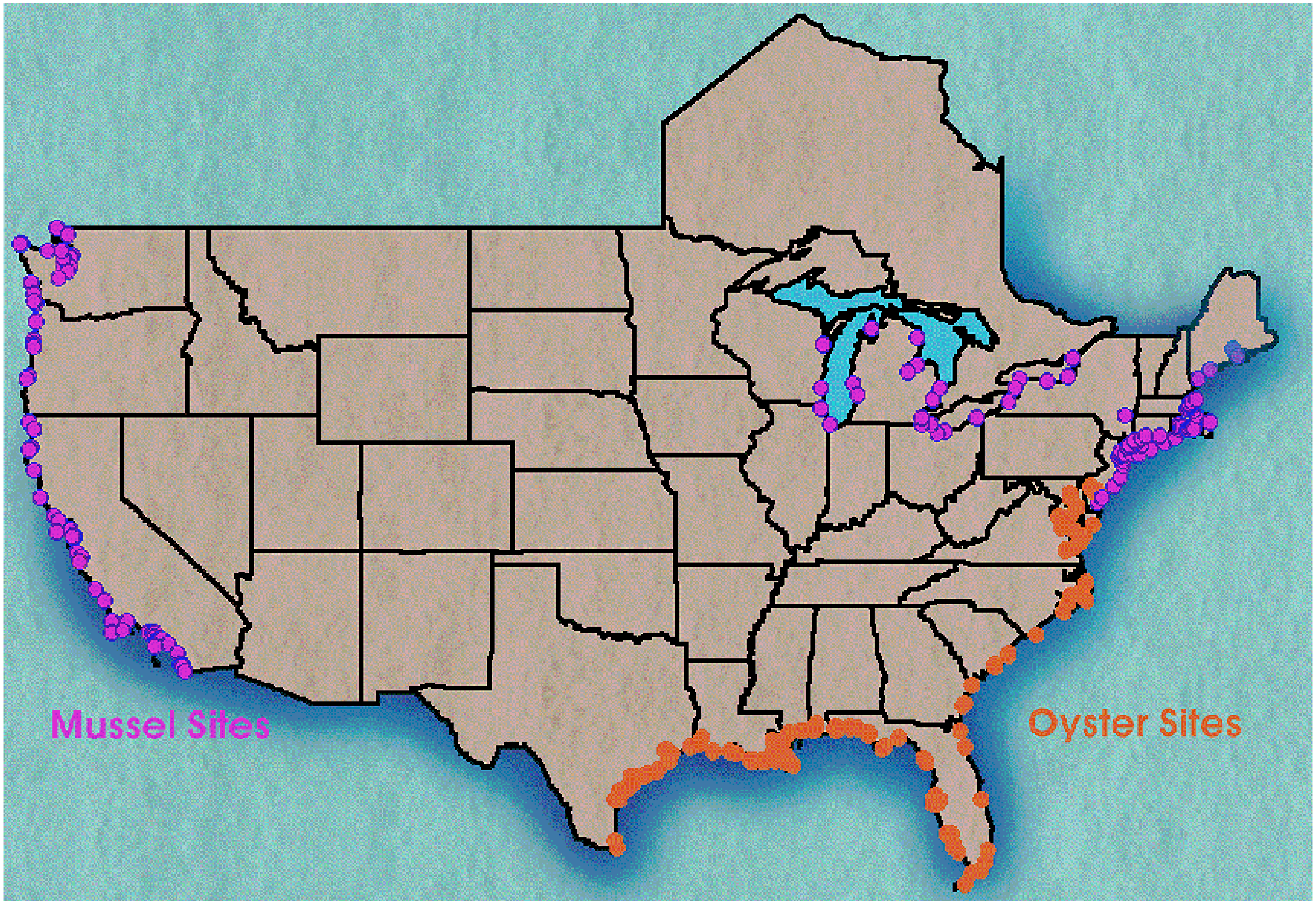


Figure 1. Monitoring sites for National mussel watch project.

[Return to National Picture]

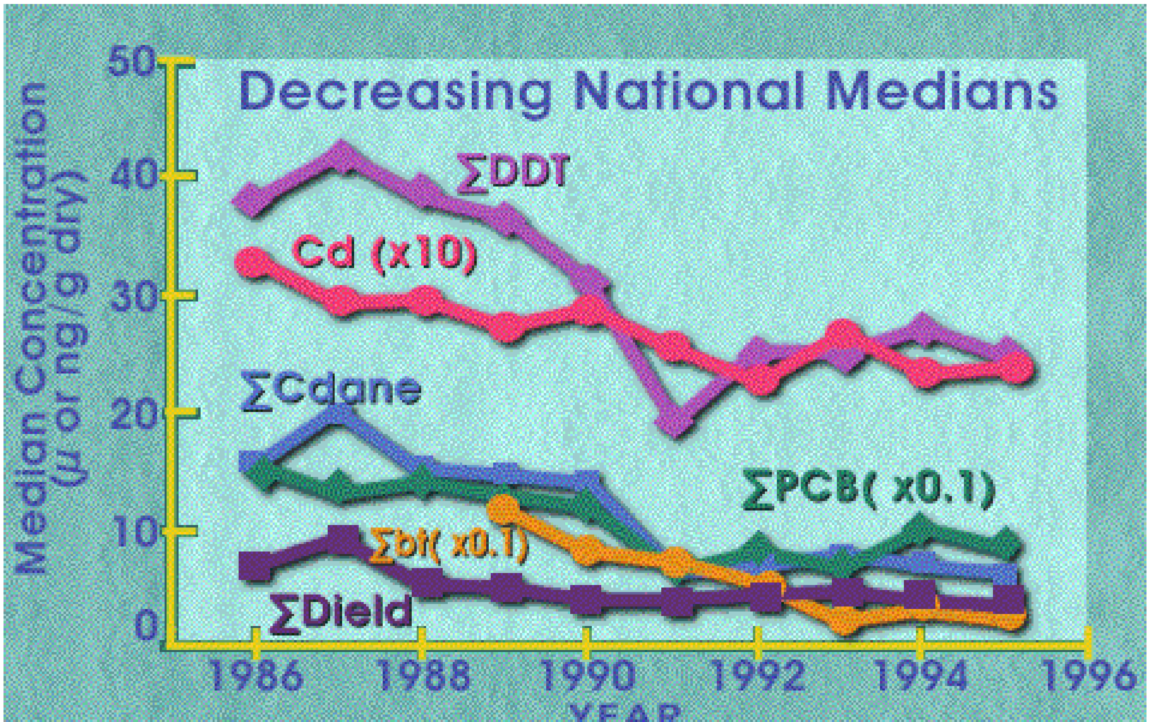


Figure 2. Decreasing national medians of six contaminants

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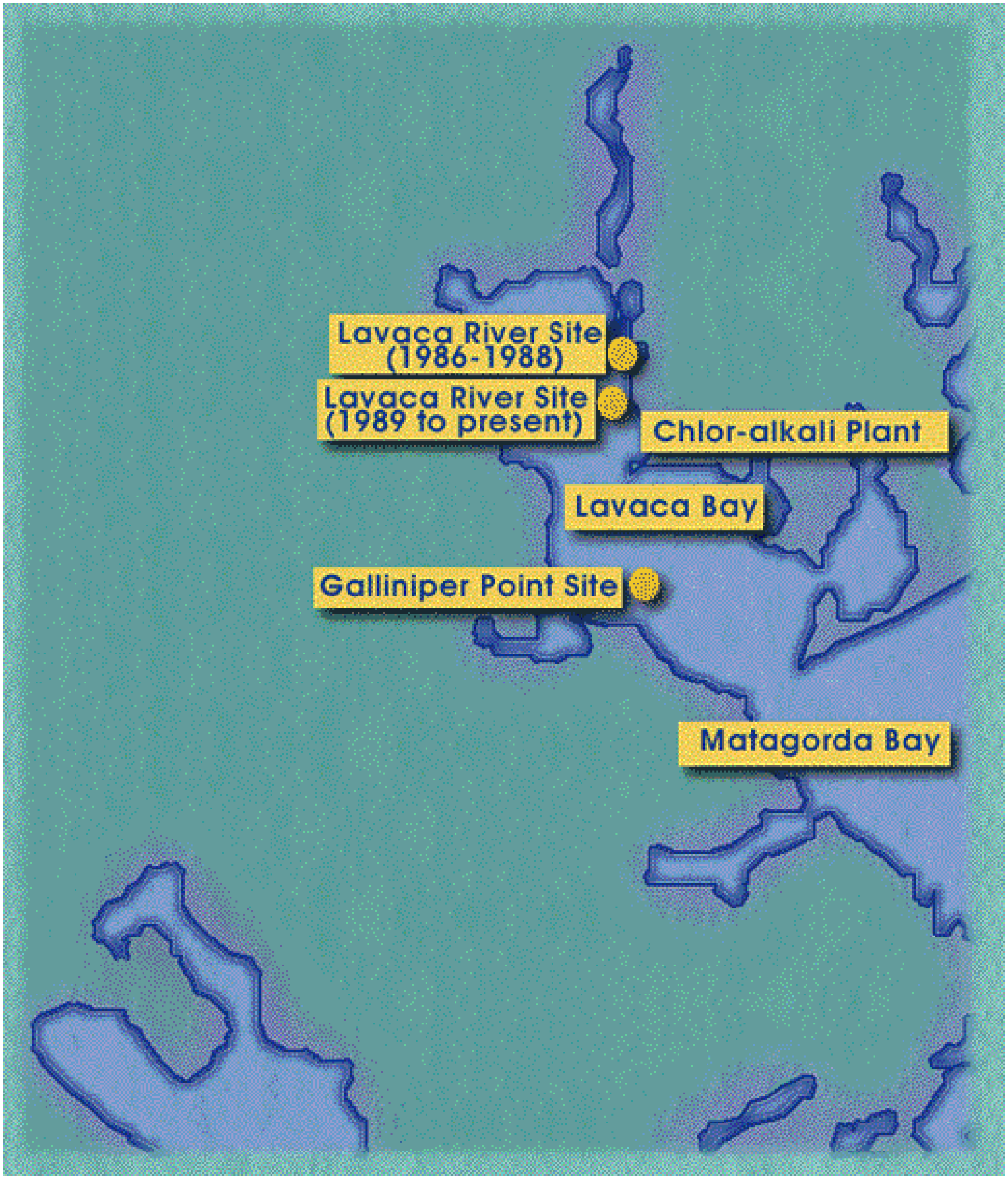

Figure 3. Sites monitored by NS&T monitoring program in Lavaca Bay, Texas.

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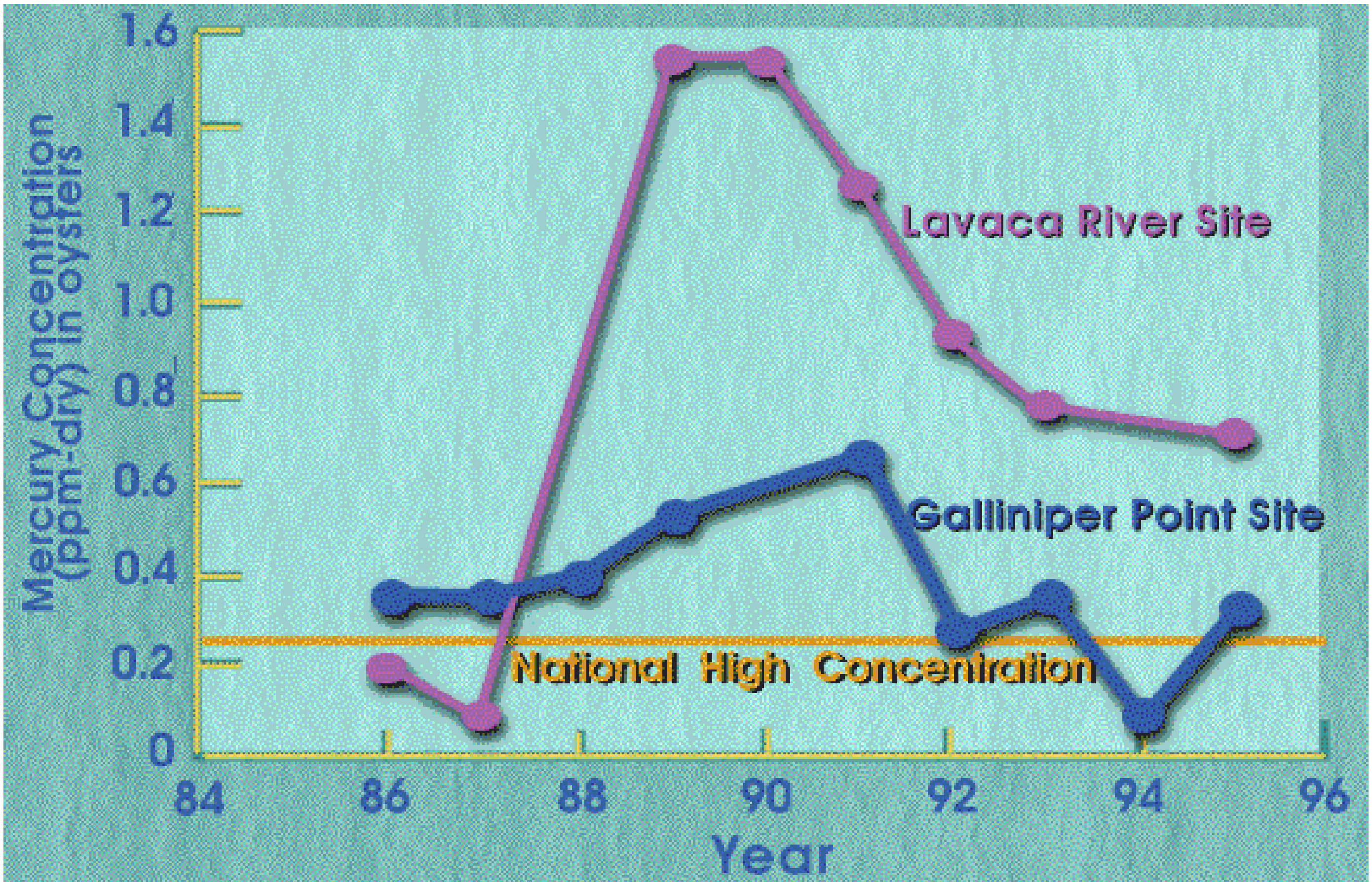

Figure 4. Mercury Concentrations in Lavaca Bay