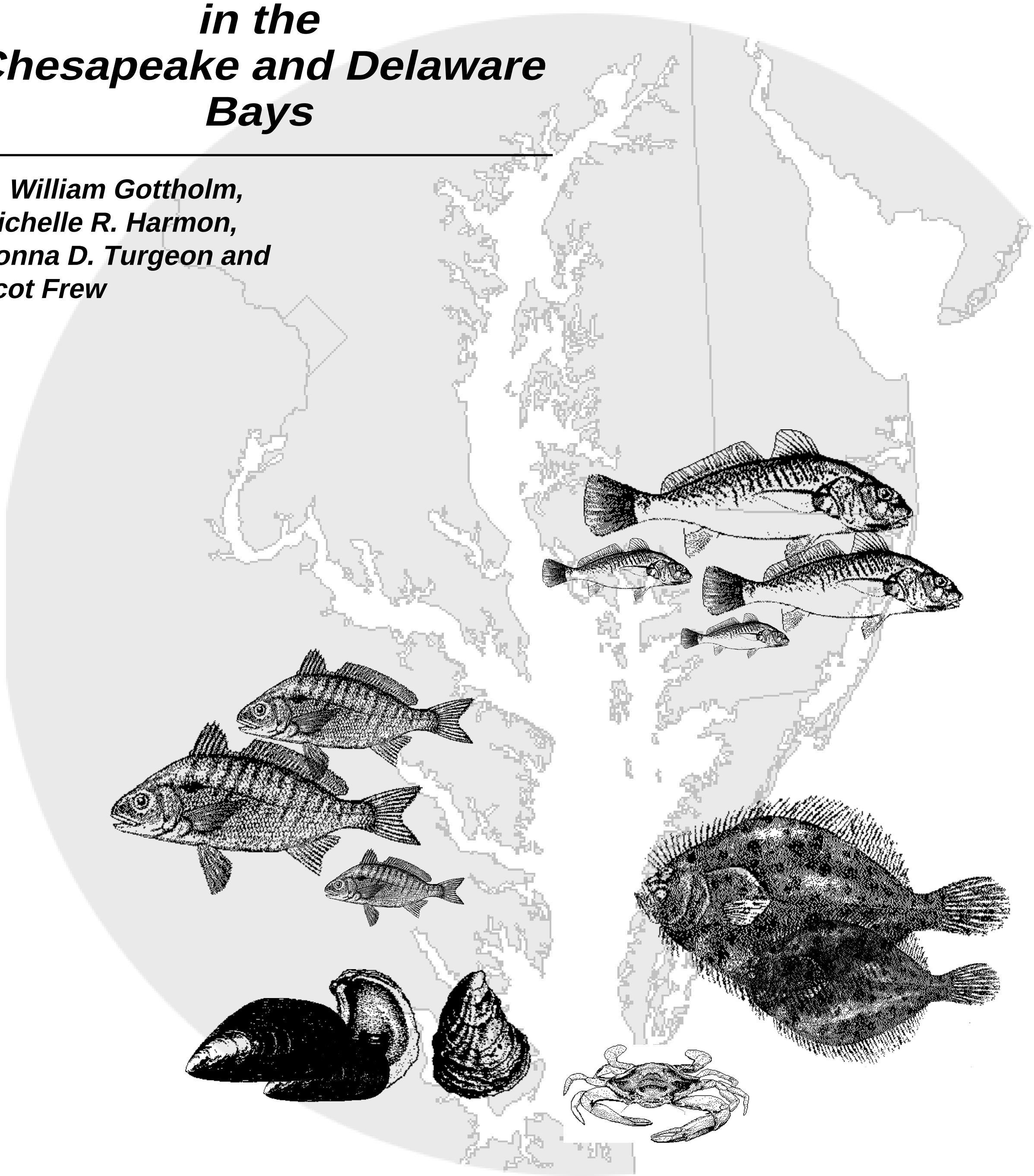
NATIONAL STATUS AND TRENDS PROGRAM

MARINE ENVIRONMENTAL QUALITY

Assessment of Chemical Contaminants in the Chesapeake and Delaware Bays

B. William Gottholm,
Michelle R. Harmon,
Donna D. Turgeon and
Scot Frew



U. S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Ocean Resources Conservation and Assessment
Coastal Monitoring and Bioeffects Assessment Division
Silver Spring, Maryland 20910-3281

About this Report

This coastal contamination assessment report summarizes results of the National Status and Trends (NS&T) Program from sites in the Chesapeake and Delaware Bays. It characterizes the systems, drainage basins, and inputs that influence the concentrations of contaminants and biological responses to those substances. These results are shown in relation to those obtained at all other NS&T sites around the United States. This summary is intended to provide information to assist local and state resource managers evaluate toxic contaminant conditions in their areas and place those conditions in perspective to those throughout the nation.

In response to the need for information assessing the effects of human activities on environmental quality in coastal and estuarine areas, and the need to develop management strategies to deal with these conditions, the Coastal Monitoring and Bioeffects Assessment Division (CMBAD) of the National Oceanic and Atmospheric Administration (NOAA) initiated, in 1984, the National Status and Trends (NS&T) Program. The purpose of this program is to determine the current status and detect changes that are occurring in the environmental quality of our nation's estuarine and coastal waters. Because of concern over inputs of contaminants to U.S. coastal waters, it was decided to focus the program initially on these substances and their effects. Major components of the NS&T Program include: the **Mussel Watch Project,** the **Benthic Surveillance Project, Bioeffects Surveys, Historical Trends, Coastal Contamination Assessments,** the **Quality Assurance Project,** and **Specimen Banking**.

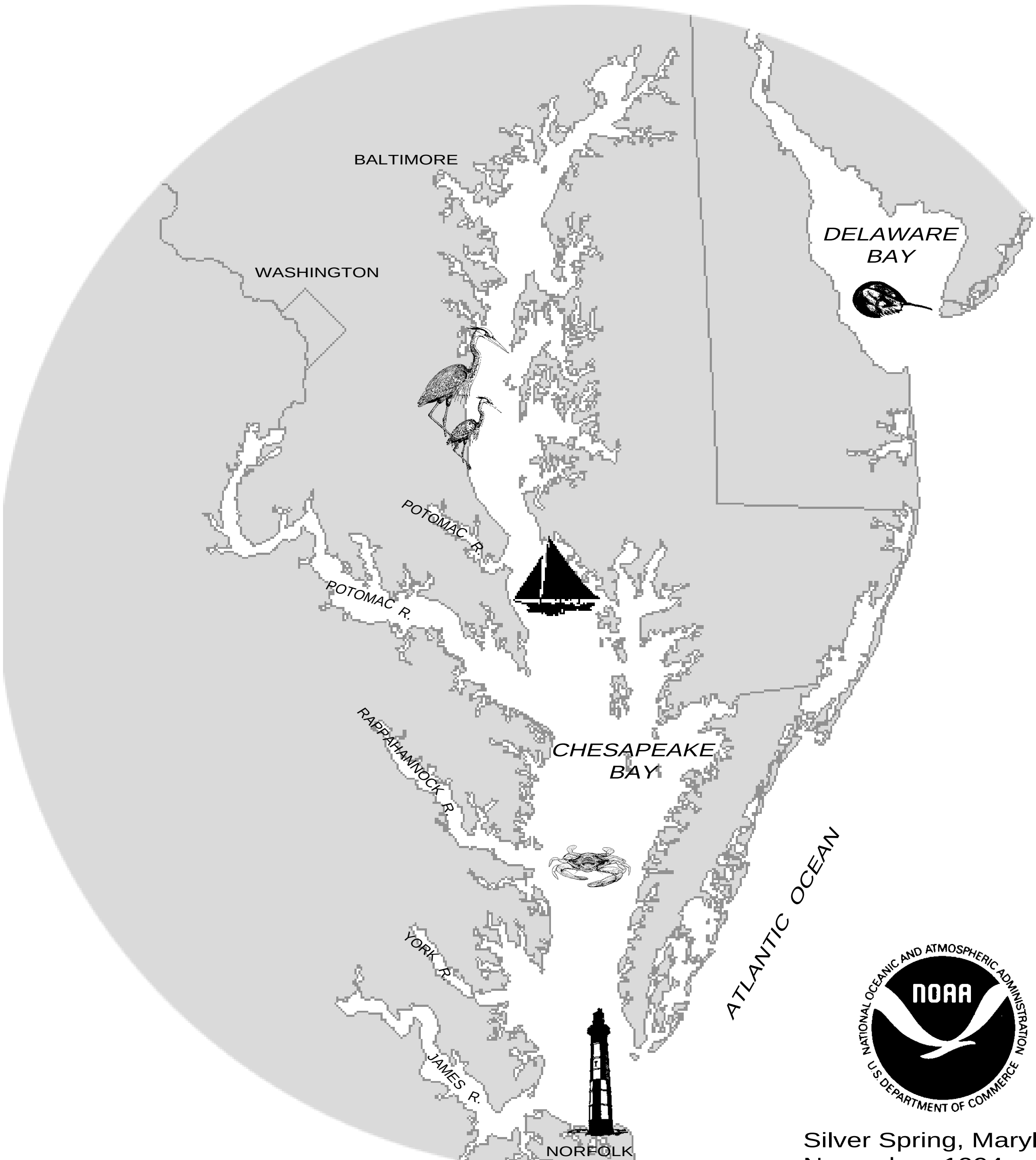
As part of its nationwide monitoring, the NS&T Program monitors the levels of more than 70 contaminants and certain associated effects in biota and sediments. It provides data for making spatial and temporal comparisons of contaminant levels to determine which regions around our coasts are of greatest concern regarding existing or developing potential for environmental degradation. It includes measurements of concentrations of 24 polycyclic aromatic hydrocarbons (PAHs); 20 congeners of polychlorinated biphenyls (PCBs); DDT, its breakdown products DDD and DDE; nine other chlorinated pesticides; butyltins; four major elements; and 12 trace elements in sediments, mussels, and oysters at over 240 coastal and estuarine sites by the **Mussel Watch Project**. Additionally, determinations of the levels and effects of the same chemicals in the livers of bottom-dwelling fish and associated sediments are made by the **Benthic Surveillance Project** at over 100 sites (refer to the map inside back cover). The frequency of external and internal disease conditions in the sampled fish is documented and data from all monitored sites are stored in the NS&T Data Base. This information is analyzed and made available to coastal and marine resource managers and the public in a variety of reports and publications (over 400 to date).

Sampling and analyses for the NS&T monitoring projects are performed using well-documented methods and techniques, so that a known level of confidence can be assigned to all data. Analytical procedures adhere to the standards of its **Quality Assurance Project**, established for all laboratories participating in the NS&T Program. Selected samples collected as part of the NS&T's **Specimen Banking** are preserved in liquid nitrogen and stored at -150 °C. A specimen archive of these samples has been established at the National Institute of Standards and Technology (formerly the National Bureau of Standards) in Gaithersburg, MD. Specimens from the archive will be available for retrospective analyses as new analytical techniques become available and perceptions of environmental quality issues change.

In 1986, the NS&T Program initiated **Bioeffects Surveys** in those regions where NS&T analyses indicated a potential for substantial environmental degradation and biological effects due to contamination. Most studies focus on living marine resources, especially bottom-dwelling fish. Studies are done on such subjects as reproductive impairment, genetic damage, sediment toxicity, refinement of methodologies, and evaluation of new indicators of contamination (DNA damage and enzymatic activity in fish livers), as well as on the relation of such effects to contaminant concentration gradients.

Historical Trends synthesizes available data and ancillary information pertaining to the trends of toxic contaminants in regions of concern. Recently, the NS&T Program added sediment coring to better assess the trends of chemical contaminants. For many areas of concern, the NS&T data have been used to develop **Coastal Contamination Assessments**, which place regional contaminant findings for specific sites in perspective with chemical concentrations around the nation.

Assessment of Chemical Contaminants in the Chesapeake and Delaware Bays



Silver Spring, Maryland
November, 1994

Copies of this report can be obtained by writing to:

Coastal Monitoring and Bioeffects Assessment Division
NOAA/NOS
N/ORCA2, SSMC4
1305 East-West Highway
Silver Spring, Maryland 20910-3281

NS&T Data can be obtained on either MacIntosh or DOS formatted diskettes by writing or calling:

Dr. Thomas P. O'Connor
N/ORCA21, SSMC4
1305 East-West Highway
Silver Spring, Maryland 20910
(301) 713-3032
FAX: (301) 713-4388

Assessment of Chemical Contaminants in the Chesapeake and Delaware Bays

Summary

Results to date from the NS&T monitoring data have been used to assess levels of toxic contaminants and certain related biological effects in estuarine and coastal marine organisms and sediments. Although most major urban centers exhibit elevated levels of a number of contaminants, most U.S. coastal areas have been found to have low, and in some cases decreasing, levels of contamination.

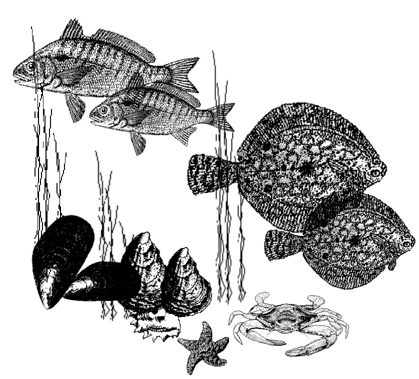
Chemical Contaminant Summary. Results to date from the National Status and Trends Program monitoring efforts show that, with few exceptions, "high" levels of contamination in sediments and associated biota are found at sites near urban areas. Some conclusions that have been drawn from bioeffects studies are that there is a positive correlation of certain physiological response mechanisms (e.g., AHH, DNA-adducts, and neoplasms) in fish species with sites that have high levels of certain chemicals.

The NS&T data from the Chesapeake and Delaware Bays show that for sediments, at least one site exceeds the ER-M concentration (above which adverse biological responses can occur) for three of the metals (chromium, lead, and zinc) and two of the organics (total chlordane and total PCB). Three sites (Fort McHenry, Elizabeth River, and Hope Creek) are considered to have "very high" sediment concentration levels of zinc.

In general, Delaware Bay sites have higher concentrations of contaminants in oyster tissue than those in the Chesapeake Bay. All six of the Delaware sites have mean concentrations of tDDT that are higher than any of those found in the Chesapeake Bay sites.

Results from the NS&T fish liver data indicate that for five metals (silver, chromium, lead, mercury, and zinc) and for three organics (total chlordane, total PCB, and total DDT), two or more sites are above the 60th percentile of NS&T sites nationwide.

Contaminant Effects Summary. Results from some studies of contaminant effects on organisms in both the Chesapeake and Delaware Bays have detected symptoms existing in portions of each bay that are consistent with findings from studies done in other heavily impacted estuaries.



The nation's coastal areas containing bays, estuaries, coastal watersheds, and coastal oceans, face ever increasing problems of growing populations, deteriorating environmental quality, loss of critical habitats, diminishing levels of fish and shellfish populations, reduced biodiversity, and increased risk from natural hazards. Effective management will require continual monitoring and assessment in order to determine the optimal mix of products and services from our coastal areas over time (Ehler and Basta, 1993).

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General Information

This assessment report, based on NS&T monitoring results, summarizes the status of chemical contamination in the Chesapeake and Delaware Bays. The information presented in this report is meant to complement the many detailed studies being conducted by other Federal, state, and regional programs. To better understand and interpret the NS&T contaminant data, the following regional and estuarine characteristics should be noted.

Introduction

NOAA's National Estuarine Inventory Data Base has characterized five estuaries and eight sub-estuaries within the region encompassed by this report (Figure 1), the most significant of which are the Delaware and Chesapeake Bays.

The Delaware Bay drainage basin encompasses roughly 13,000 square miles, occupying most of Delaware, much of western New Jersey and eastern Pennsylvania, and a portion of New York State (Sharp, 1986). The Delaware Bay has a water surface area of 768 square miles, an average depth of 21 feet, a volume of 448 billion cubic feet, and an average daily fresh water inflow of 19,800 cubic feet per second (Basta et al., 1990). It is influenced by semidiurnal tides which have a mean variation that increases from approximately 4.1 feet near the bay mouth at Cape May, NJ to 6.1 feet at the northern end of the bay near Arnolds Point, NJ (NOS, 1990).

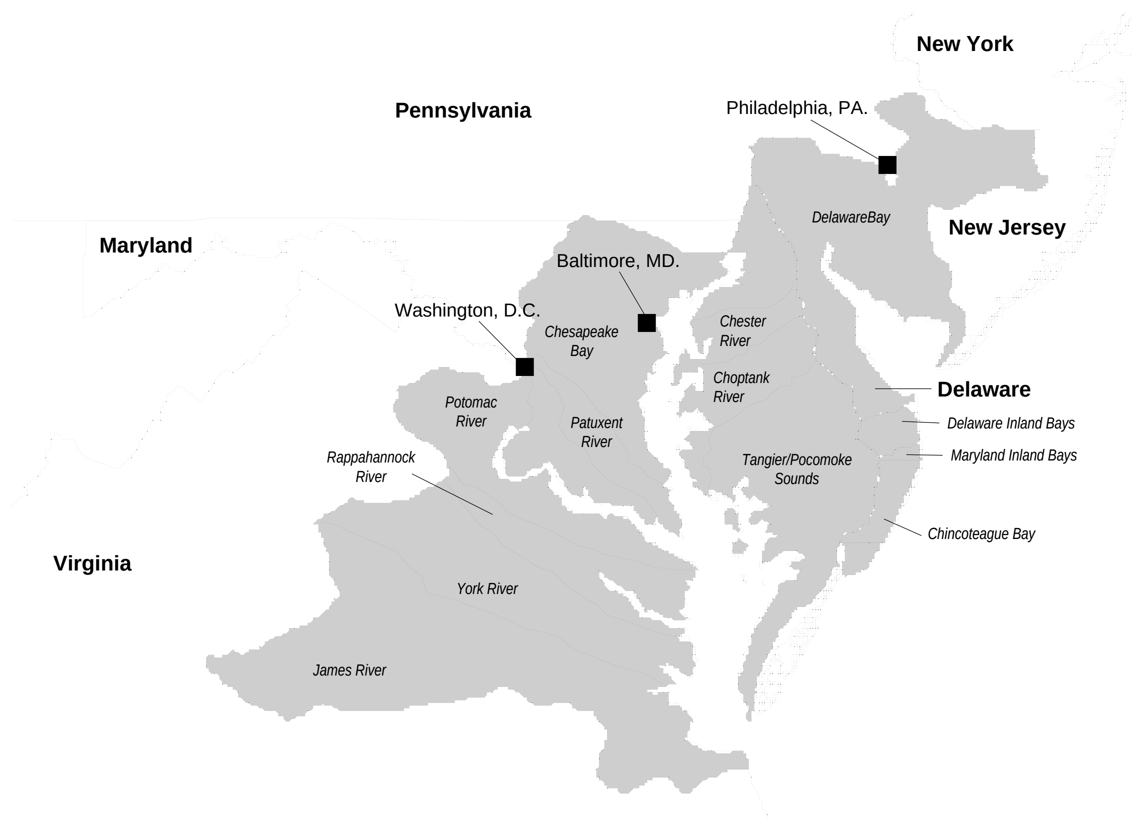
The Chesapeake Bay is the largest estuary in the United States, with a length of 200 miles and a width ranging from 4 miles near Annapolis, MD to 30 miles near the mouth of the Potomac River (USEPA, 1982). It has a total drainage area of 76,800 square miles, stretching from Cooperstown, NY to Norfolk, VA and encompassing parts of New York, Pennsylvania, West Virginia, Delaware, Maryland, and Virginia. The bay and its tributaries have a combined water surface area of 3,830 square miles, an average depth of 24 feet, and a total volume of 2,510 billion cubic feet. Fifty major tributaries flow into the Chesapeake, however, about half of the bay's fresh water is supplied by the Susquehanna River. The average daily freshwater inflow into the bay is 85,800 cubic feet per second, the highest of any estuary on the Atlantic coast. The Chesapeake is influenced by semidiurnal tides, which have a mean variation that ranges from about 2.8 feet near the bay mouth at Cape Henry, VA to 0.9 feet in the north near Annapolis, MD (NOS, 1990).

The Delaware and Chesapeake Bays have a combined estuarine drainage area (EDA) of approximately 26,800 square miles. The EDA is defined as the portion of a watershed that drains directly into estuarine waters and contains, for the most part, the complete extent of tidal influences (Basta et al., 1990). Agricultural and forest land account for over half of this area, comprising 7,442 square miles and 9,645 square miles, respectively (Strategic Assessment Branch, 1987). In 1987, these two EDAs had the largest areas of harvested crop land of all EDAs in the Middle Atlantic region, with approximately 2,969 square miles in the Chesapeake Bay EDA and 781 square miles in the Delaware Bay EDA (Pait et al., 1992).

The Delaware and Chesapeake Bay EDAs contain approximately 2,188 square miles of coastal wetlands. Of these, 1,232 square miles (56%) are forested and scrub/shrub, 664 square miles (30%) are salt marsh, 184 square miles (8%) are tidal flats, and 117 square miles (5%) are fresh marsh (Field et al., 1991).

New Jersey, Delaware, Maryland, and Virginia had a combined population of 19,680,000 in 1988. Approximately 78% of this population resided in coastal counties, which comprise 39% (59,004 square miles) of the total land area of these states (Culliton et al., 1990).

Figure 1. *Estuary drainage areas (Source: Basta et al., 1990)*



In 1987, the Chesapeake Bay EDA had the highest pesticide application in the nation, with approximately 4.1 million pounds of herbicides, 745,000 pounds of insecticides, and 46,000 pounds of fungicides. Pesticide application in the Delaware Bay EDA was the fifth highest in the nation, exceeded by three southern estuaries and the Chesapeake Bay. Approximately 1.0 million pounds of herbicides, 304,000 pounds of insecticides, and 83,000 pounds of fungicides were applied to this EDA in 1987 (Pait et al., 1992).

The 1992 commercial fishery catch in coastal and inland waters of Delaware, Maryland and Virginia was 552,646,205 pounds (lbs.) valued at $76,071,488. The top five landings in the region by weight were: blue crab (*Callinectes sapidus)*, Atlantic menhaden *(Brevoortia tyrannus)*, spot *(Leiostomus xanthurus)*, oyster *(Crassostrea virginica)*, and catfish *(Ictalurus sp.)* (Sutherland, pers. comm.).

An estimated 72,384,000 fish were caught for recreational purposes in the Mid-Atlantic region in 1993, down 10% from 1991 and 45% from 1990. The top five landings by number were: summer flounder *(Paralichthys dentatus)*, Atlantic croaker *(Micropogonias undulatus)*, black sea bass *(Centropristis striata), spot,* and bluefish *(Pomatomus saltatrix)* (Fisheries Statistics Division, 1994).

The Delaware and Chesapeake Bays contained approximately 661 square miles and

2,825 square miles, respectively, of waters classified as safe for shellfish growing in 1991. Between 1985 and 1990, the proportion of classified shellfish-growing waters approved for harvest declined from 83% to 74% in the Delaware Bay and 96% to 94% in the Chesapeake Bay, primarily due to a decline in water quality. Shellfish landings also declined dramatically in the region. In the Chesapeake Bay, oyster harvests dropped from over 32 million pounds annually before 1959 to only about four million pounds in 1989, primarily as a result of overharvesting and the parasitic diseases MSX (*Haplosporidium nelsoni*) and Dermo (*Perkinsus marinus*). MSX also has contributed to depleted oyster populations in the Delaware Bay, where landings decreased from over 640,000 pounds in 1980 to virtually no harvest in 1989 (Leonard et al., 1991).

Dredging activities are conducted periodically in the Delaware and Chesapeake Bays to ensure that commercial waterways remain open. Each year, approximately 5.8 million cubic yards of material are dredged from the Delaware Bay (State of Delaware Department of Natural Resources and Environmental Control, 1992b), and between 6.8 and 9.3 million cubic yards of material are dredged from the Chesapeake Bay and its tributaries (DePrefontaine, Whitehurst, and Mainquist, pers. comm.). Areas of major dredging activities include Wilmington Harbor and the Delaware River main channel in Delaware Bay, the Chesapeake and Delaware Canal (which connects the two bays), and Baltimore Harbor and James River in Chesapeake Bay.

In 1991, the Chesapeake Bay had 99 square miles of submerged aquatic vegetation (SAV), with 8.4%, 45.5%, and 46.1% occurring in the Upper, Middle, and Lower Bay zones, respectively (Orth et al., 1992). Dominant SAV species include *Myriophyllum spicatum* (eurasian water milfoil) in the Upper Bay and *Ruppia maritima* (widgeon grass) and *Zostera marina* (eel grass) in the Middle and Lower Bay. A widespread decline in SAV occurred between 1965 and 1975, with the greatest loss occurring in the early 1970s, following Tropical Storm Agnes. Between 1984 and 1993, SAV coverage increased by 75% (Chesapeake Bay Program, 1993). Even with this increase in coverage, only 10% of the bay's historical SAV remains (Dennison et al., 1993). Field observations and controlled experiments suggest that nutrient overenrichment and increased turbidity are primarily responsible for the decline (Orth and Penhale, 1988). SAV is virtually absent in the Delaware Bay, due possibly to the high turbidity experienced in much of the area (Biggs, 1986). Historical aerial photographs reveal no significant coverage of SAV in the Delaware Bay since at least 1930 (State of Delaware Department of Natural Resources and Environmental Control, 1992a).

A concerted effort to manage and restore the Chesapeake Bay has been underway since 1983, when state and federal representatives from around the bay region signed the Chesapeake Bay Agreement. In 1987, a new Chesapeake Bay Agreement was signed by the governors of Maryland, Pennsylvania and Virginia; the mayor of the District of Columbia; the administrator of the U.S. Environmental Protection Agency; and the chairman of the tri-state Chesapeake Bay Commission. The agreement established specific goals and objectives regarding a host of regional issues, including population growth, development, living resources, and water quality. The signers of the agreement pledged to reduce point and nonpoint sources of pollution, and, in particular, reduce the amounts of nitrogen and phosphorus entering the Chesapeake Bay by 40% from the 1985 levels by the turn of the century. The actual target reduction in millions of pounds is 74.1 for nitrogen and 8.43 for phosphorus. As a result of these measures, there has been a 16% reduction in phosphorus. Nitrogen levels, however, have remained constant (Chesapeake Bay Program, 1993). An amendment to the agreement in 1992 called for specific nutrient reduction goals for each of the bay's major tributaries and proposed an expansion of the Bay's partnership by forging relationships with New York, West Virginia, and Delaware (Alliance for the Chesapeake Bay, 1993; Office of the Governor, 1992; Maryland Department of Natural Resources, 1992).

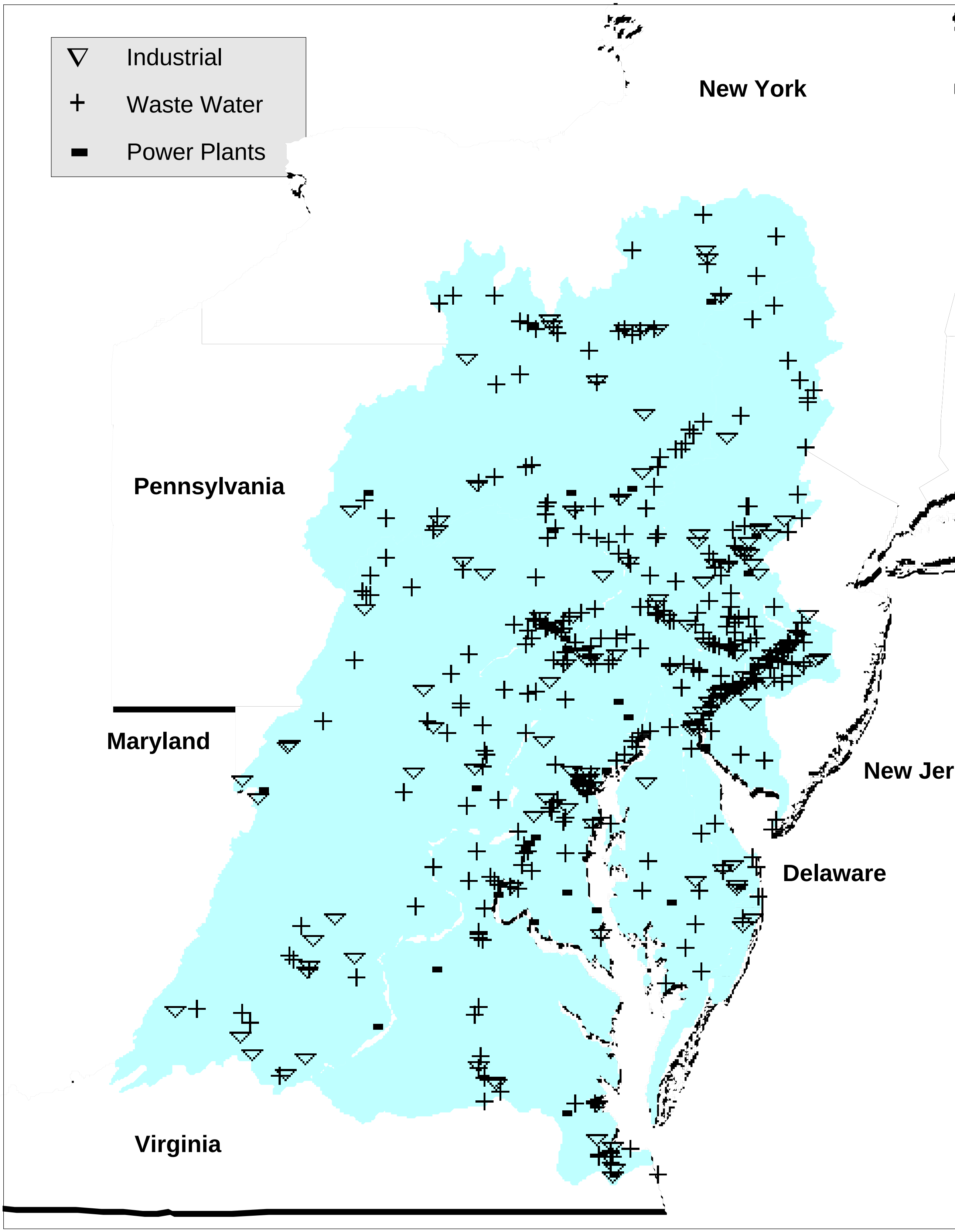


Figure 2. *Point sources of pollutant discharge (Source: Environmental Protection Agency, pers. comm.)*

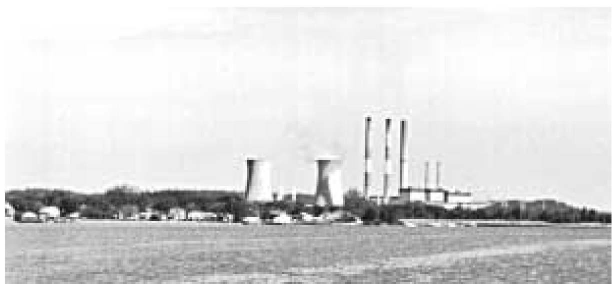
Stresses on the Bays

Increasing growth of human population and resulting urban development along with agriculture threaten the bays with complex ecosystem stresses.

Contaminant Sources

Contaminants enter the Delaware and Chesapeake Bays from several distinct sources. The relative impact of each source varies both temporally and in accordance with each estuary's physical, hydrologic, and human-use characteristics. Because of their relatively large volumes and low tidal exchanges, the Delaware and Chesapeake Bays are considered to be relatively susceptible to pollutant retention. NOAA has developed a relative classification index to approximate the ability of an estuary to retain dissolved and particulate-attached pollutants (Klein et al., 1988). In general, the lower an estuary's flushing rate to the open ocean and/or the lower its dilution capability, the greater its susceptibility to retain dissolved pollutants. Table 1 lists general estuarine characteristics taken from NOAA's National Estuarine Inventory, including the dissolved concentration potential (DCP), an estimate of the relative ability of an estuary to concentrate dissolved pollutants. The DCP is moderate for the Delaware Bay and high for the Delaware Inland Bays. For the main stem of the Chesapeake Bay, which includes the lower Susquehanna River, the DCP is low, however, it is high for the seven individual major tributaries to this estuary.

POINT SOURCES OF POLLUTANT DISCHARGE include wastewater treatment plants and industrial facilities that discharge directly to surface water. Estuaries with a large freshwater inflow, such as the Chesapeake Bay, receive substantial contaminant inputs from upstream sources, including industrial and municipal facilities. With the exception of Galveston Bay, more major point sources lie within the Chesapeake Bay estuarine drainage area than within any other estuary in the nation (Basta et al., 1990). Within the Chesapeake's fluvial drainage area, contaminants are discharged from facilities located as far away as Pennsylvania and New York (see Figure 2). The Susquehanna River alone contributes about 12.5 thousand pounds of toxic metals to the Chesapeake each day (Alliance for the Chesapeake Bay, 1993). Point sources also are responsible for about a quarter of the total nitrogen (14 million pounds) and a third of the total phosphorus (91 million pounds) delivered to the Chesapeake. About 94% of the phosphorus and 88% of the nitrogen point source loads are discharged from municipal waste treatment facilities. The largest municipal flows occur within the Potomac and Susquehanna basins, which receive approximately 521.3 and 336.2 million gallons of wastewater per day, respectively (Chesapeake Bay and Watershed Management Administration, 1993; Chesapeake Bay Program, 1988).



Although the Delaware Bay watershed contains fewer major point source facilities than the Chesapeake Bay watershed, the number of facilities per unit area is greater. Point sources of discharge to the Delaware Bay are located primarily along the heavily urbanized Trenton-Philadelphia-Camden-Wilmington corridor of the Delaware and Schuylkill Rivers. Over 300 sewage outfalls and the nation's second largest petrochemical complex are located in this zone (Scudlark and Church, 1993). Municipal and industrial facilities are estimated to contribute 41% of the total inorganic nitrogen entering the Delaware Bay.

NONPOINT SOURCES OF POLLUTANT DISCHARGE include dissolved and particulate materials that discharge to surface waters via surface runoff from precipitation. Nonpoint discharges can be

Table 1. *Selected Estuarine Characteristics (Source: modified from Basta et al., 1990)*

ESTUARY	Estuarine Drainage Area (100 sq. mi.)	Total Drainage Area (100 sq. mi.)	Water Surface Area (sq. mi.)	Avg. Depth (ft)	Avg. Daily Freshwater Inflow (100 cfs)	Volume (billion cu. ft.)	Point Sources of Pollution (1982-87 data) Industrial	MWTP	Susceptibility to Pollution DCP*	PRE*
Delaware Bay	48	135	768	21	198	448	181	153	M	M
Delaware Inland Bays	3	3	32	4	3	4	9	7	H	M
Maryland Inland Bays	2.6	2.6	21	5.4	—	3	1	2	—	—
Chincoteague Bay	3	3	137	6	4	23	21	16	H	H
Chesapeake Bay	220	693	3,830	24	858	2,510	650	275	L	M
Patuxent River	9	9	47	19	9	25	6	12	H	M
Potomac River	31	146	494	19	159	266	59	58	H	M
Rappahannock River	12	27	145	16	29	66	46	12	H	M
York River	26	26	74	16	25	32	9	22	H	M
James River	44	102	236	14	125	90	126	63	H	M
Chester River	5	5	57	14	5	22	13	11	H	H
Choptank River	9	9	110	13	10	40	24	13	H	H
Tangier/Pocomoke Sounds	26	26	459	13	29	160	47	22	H	H
Total	**436**	**1,184**	**6,410**	**13.8**	**1,454**	**3,689**	**1,081**	**664**		

Note: Sub-estuaries are in italics.
* DCP is designated Dissolved Concentration Potential and PRE is the Particle Retention Efficiency

divided into four categories: agricultural, forest, urban, and other nonurban sources, such as rangeland and pasture. During periods of heavy precipitation, contaminants are flushed into coastal waters from lawns, roads, crop lands, and pastures. Approximately 4.7 million cubic yards of shoreline erodes into the Chesapeake Bay each year, thereby releasing nutrients and other contaminants trapped over time (Alliance for the Chesapeake Bay, 1993a). Nonpoint sources of pollution pose a particular threat to both the Delaware and Chesapeake Bays, because of the high percentage of agricultural land and the intensity of pesticide application (Basta et al., 1990; Pait et al., 1992), as well as the discharge of nutrients from fertilizers and animal manure in their watersheds. In 1982, the Delaware and Chesapeake Bays had the highest chemical fertilizer

applications of the estuaries in the Middle Atlantic region (Basta et al., 1990) and among the highest for the nation. In the Chesapeake Bay watershed, nonpoint sources, mostly agricultural runoff, contribute about 77% of the nitrogen and 66% of the phosphorus entering the bay during an average rainfall year (Chesapeake Bay Program, 1993). In urban areas, nutrients from lawns, roads, and other developed areas contribute about 14% of the phosphorus and 11% of the nitrogen inputs. Additional nonpoint source pollutants in urban areas include automobile-associated contaminants, such as gasoline and oil.

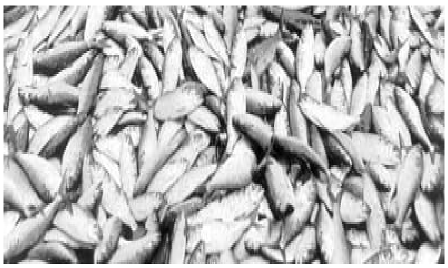
ATMOSPHERIC SOURCES, from within and beyond the watersheds of the middle Atlantic estuaries, including those of the Delaware and Chesapeake Bays, account for significant inputs of contaminants to those bays. Airborne pollutants enter the bays either through direct deposition or indirectly with watershed runoff. These contaminants are potentially more harmful than those delivered from other nonpoint sources, since they have had less time to break down before reaching the water surface (Blankenship, 1992). Many of the pollutants, including zinc, arsenic, selenium, and cadmium, are associated with industry and automobile emissions. Of perhaps greater concern is airborne nitrogen, which is released from the combustion of fossil fuels, and, to a lesser degree, wind-blown fertilizers. Recent studies have concluded that the direct and indirect atmospheric deposition of nitrogen may account for up to 25% of the nitrogen entering both the Delaware and Chesapeake Bays (Alliance for the Chesapeake Bay, 1993a; Scudlark and Church, 1993).

CONTAMINANT SPILLS are a major public concern due to their potential long-term impact on the marine environment. Four Chesapeake and Delaware Bay ports, Norfolk Harbor (Hampton Roads)(54 million tons), Philadelphia (42 million tons), Baltimore Harbor (40 million tons), and Newport News (25 million tons), are among the top 30 ports in the nation by cargo tonnage (Waterborne Commerce Statistics Center, 1992). Heavy shipping traffic, as well as ship building activities at Hampton Roads and Newport News, increases the likelihood of accidental spills from vessels and related shoreside facilities. In the Chesapeake Bay alone, four billion gallons of petroleum is transported annually (Blistein, 1994). Hundreds of spill incidents occur in the Chesapeake and Delaware Bay region each year. The largest reported spills in Delaware for the last five years include: 150,000 gallons of gas on August 18, 1990 near Cape Henlopen; 746,424 gallons of crude oil on October 30, 1990 at Dewey Beach in the Delaware Inland Bays; and 41,538,462 gallons of crude oil on March 9, 1989 at Big Stone on the Delaware River (Swartzell, pers. comm.; Delaware River Basin Commision, 1991b). Two major oil spills have occurred in the Chesapeake Bay, both near the mouth of the Potomac River. The largest spill to date occurred in 1976 when a tugboat ran aground spilling 250,000 gallons of oil. The second largest spill occurred in 1988 when a barge cracked in half spilling 212,000 gallons of oil. Another significant source of petroleum contamination in this area is from pipelines that are also used to transport oil. Since 1990, six spills in the Chesapeake Bay region have occurred from pipelines used to transport oil. In 1989, 200,000 gallons of kerosene were released into the Rappahannock River due to pipeline fatigue and in 1993, 407,000 gallons of diesel fuel were released into a tributary of the Potomac River due to construction damage to a pipe. As the pipelines age and construction increases, such instances are likely to become an increasing problem (Blistein, 1994).

Effects of Stresses

Increasing human activities continue to disrupt the natural processes of the Bays' ecosystems and threaten their ecological, economic, and aesthetic value.

FISH KILLS. Between 1980 and 1989, 158 fish-kill events were reported in the Delaware Bay EDA. In the same period, 553 fish kills were recorded in the Chesapeake Bay EDA. The number of fish killed in these events ranged from fewer than 100 in many instances, to 1,000,000 or more in 30 of the events. The principle reported cause of the events was low dissolved oxygen, due possibly to the poor tidal circulation and seasonal stratification experienced in much of the area. Of the total of 711 reported fish kill events that occurred between 1980 and 1989 for this region, approximately one-third occurred in two adjacent Maryland counties: Baltimore County (47 events) and Anne Arundel County (182 events). Forty-three of the Anne Arundel County fish-kills occured in the Magothy River Basin, a waterbody which has a history of eutrophication-related problems. Many of these events took place between May and October 1986, following the break of a sewage line (Lowe et al., 1991).



PUBLIC HEALTH ADVISORIES. Advisories prohibiting the consumption of fish or shellfish have been issued for several portions of the Delaware River by the Pennsylvania Fish Commission and the New Jersey Department of Environmental Protection. The advisories pertain to: white suckers *(Catostomus commersoni)* caught in the vicinity of the Delaware Water Gap near Easton, PA, due to high chlordane levels observed in 1986; American eels *(Anguilla rostrata)*, channel catfish *(Ictalurus punctatus)*, and white perch*(Morone americana)* taken between Yardley, PA and the Delaware/Pennsylvania boundary, because of elevated chlordane and PCB levels observed in fish tissue at various sites in 1986 and 1987; and blue crabs taken at Eddystone, PA, due to PCB levels observed at FDA action levels in 1988 (Delaware River Basin Commission, 1991b). The State of Delaware Department of Natural Resources and Environmental Control (1992a) has issued fish consumption advisories for three Delaware Bay tributaries (Red Clay Creek, Red Lion Creek and St. Jones River) on the basis of high organic contaminant levels observed in fish tissue. Due to elevated bacteria levels, advisories prohibiting either year-round or seasonal harvesting of shellfish are in effect for 42 square miles of the Delaware Bay and portions of Delaware's Inland Bays.

Due to elevated chlordane levels, fish consumption advisories have been issued by the Maryland Department of the Environment for American eels and channel catfish taken in Baltimore Harbor and the Back River in Baltimore County. The Virginia Office of Health Education has issued advisories for fish caught in several portions of the Shenandoah River, a tributary of the Potomac River, including: the South River, from Waynesboro, VA through the Shenandoah South Fork confluence to the Warren/Page County line, because of high mercury levels; and the Shenandoah mainstem, from the State Road 619 bridge at the North Fork and from Passage Creek at the South Fork, to the West Virginia state line, due to elevated PCBs. The advisory extends into West Virginia, where the West Virginia Department of Commerce, Labor and Environmental Resources prohibits consumption of channel catfish, carp *(Cyprinus carpio)*, and white sucker taken in the Shenandoah River, from the Virginia border to the Potomac River confluence (USEPA, pers. comm.).

The objectives of the NS&T Program include defining the geographic distribution of contaminant concentrations in tissues of marine organisms and in sediments, and documenting biological responses to contamination. Benthic fish and sediments have been collected and analyzed from sites around the coastal and estuarine United States, including Alaska, since 1984 by the NS&T Program's National Benthic Surveillance Project (NBSP). Initiated in 1986, the Mussel Watch Project (MWP) has collected and analyzed bivalve mollusks and associated sediments from around the United States, including the Great Lakes, Alaska, Hawaii, and Puerto Rico.

The National Benthic Surveillance Project has been a cooperative effort between three NOAA elements: the Office of Ocean Resources Conservation and Assessment, the Office of NOAA Corps Operations, and the National Marine Fisheries Service. The Mussel Watch Project field collection and analyses have been performed by non-NOAA contract laboratories; Texas A&M University (TAMU) Geochemical and Environmental Research Group, College Station, TX, and the Battelle Laboratories at Duxbury, MA, and Sequim, WA.

Characteristics of the contaminants selected for sampling and analysis by the NS&T Program were that they should pose a potential threat to marine organisms and /or seafood safety, have been released into the environment in significant quantities so that they are measurable, should have long half-lives once released, and should have a high potential for bioaccumulation (refer toTable 2).

DDT and its metabolites

2,4'-DDD
4,4'-DDD
2,4'-DDE
4,4'-DDE
2,4'-DDT
4,4'-DDT

Tetra, tri-, di-, and monobutyltins

Chlorinated pesticides other than DDT

Aldrin
cis-Chlordane
trans-Nonachlor
Dieldrin
Heptachlor
Heptachlor epoxide
Hexachlorobenzene
Lindane (gamma-HCH)
Mirex

Polychlorinated biphenyls

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

Toxaphene at some sites

Polycyclic aromatic hydrocarbons

2-ring
Biphenyl
Naphthalene
1-Methylnaphthalene
2-Methylnaphthalene
2, 6-Dimethylnaphthalene
1,6,7-Trimethylnaphthalene

3-ring
Fluorene
Phenanthrene
1-Methylphenanthrene
Anthracene
Acenapthene
Acenaphthylene

4-ring
Fluoranthene
Pyrene
Benz[*a*]anthracene
Chrysene

5-ring
Benzo[*a*]pyrene
Benzo[*e*]pyre
Perylene
Dibenz[*ah*]anthracene
Benzo[*b*]fluoranthene
Benzo[*k*]fluoranthene

6-ring
Benzo[*ghi*]perylene
Indeno[1,2,3-*cd*]pyrene

Major elements

aluminum
iron
manganese
silicon

Trace elements

antimony
arsenic
cadmium
chromium
copper
lead
mercury
nickel
selenium
silver
tin
zinc

Related parameters

Grain Size
Total Organic Carbon (TOC)
Clostridium perfringens spores

Table 2. *List of NS&T chemicals*

The NS&T results included in this report are based on the sampling of three stations per site, with each station providing separate sample material for organic and trace element analyses. NBSP fish were collected primarily with otter trawls. Occasionally, along the Southeast and Gulf Coasts, fish were taken with hook and line, or with gill nets. Due to the variable number of trawls required to collect samples with appropriate numbers of fish within the defined size range, a nominal site center of 2 km in diameter was defined for all NBSP sites. Criteria for the MWP are: that indigenous populations of mollusks, with adequately sized individuals, must exist at the potential sampling site (5-8 cm for mussels, 7-10 cm for oysters); since NS&T selection of monitoring sites is based on collecting samples from areas that are representative of the body of water sampled, MWP or NBSP sites must not knowingly be located near waste discharge points, local dump sites, or "hot spots"; sampling substrates are limited to natural substrates or structures; bivalve sites are to coincide with historical monitoring sites when feasible and all other criteria are met; and the site must be suitable for follow-up sampling. For both projects, surficial sediments (1-3 cm depth) have been collected and analyzed allowing for comparison of contamination levels among sites.

For more detailed descriptions of NS&T sampling and analytical protocols refer to:

Lauenstein, G.G. and A.Y. Cantillo (eds.). 1993. Sampling and Analytical Methods of the NOAA National Status and Trends Program National Benthic Surveillance and Mussel Watch Projects 1984-1992: Vol. I-IV. Tech. memo 71, NOAA/NOS/ORCA, Silver Spring, MD.

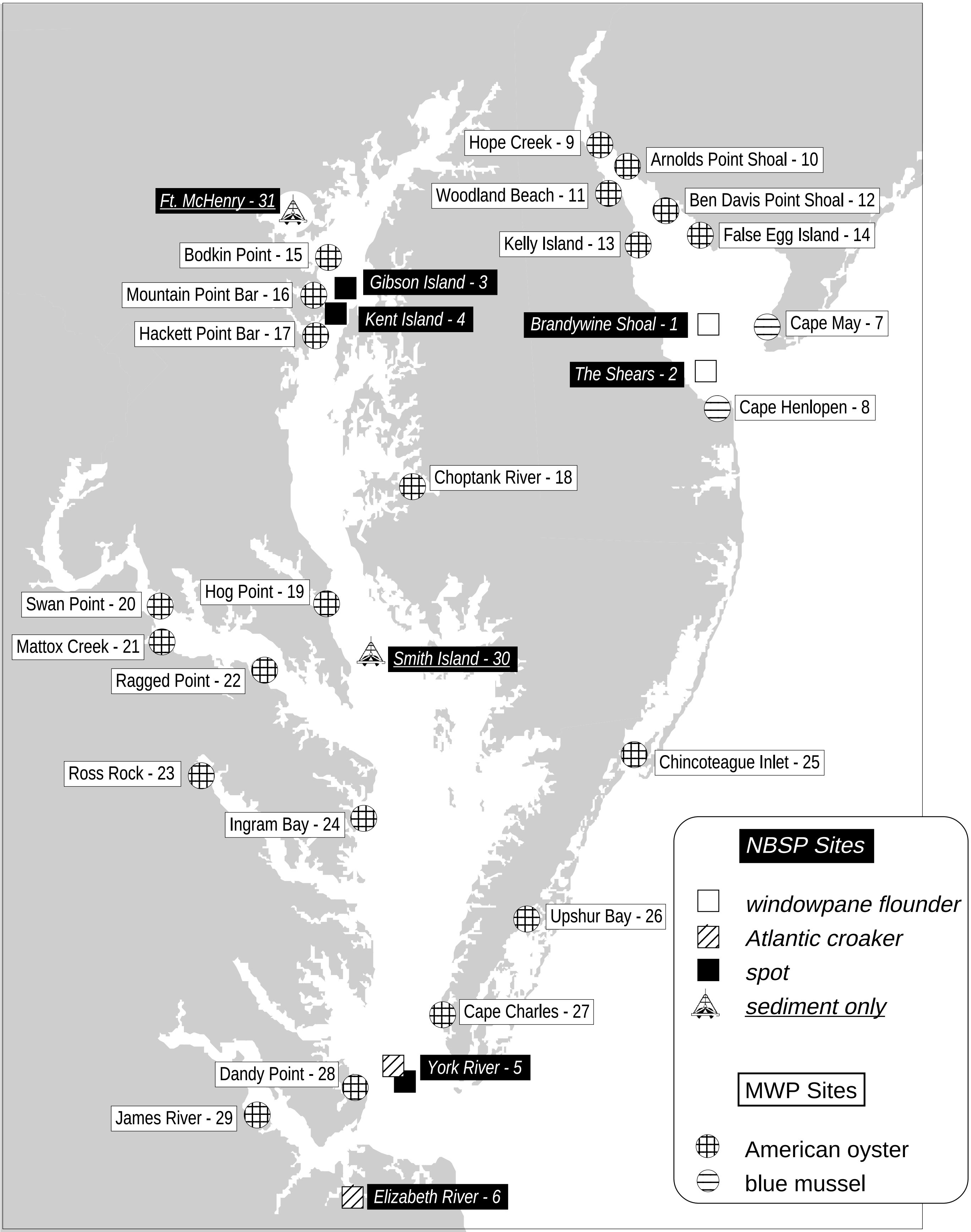


Figure 3. *National Status and Trends Program monitoring sites (Chesapeake and Delaware Bay areas)*

National Status & Trends Contaminant Data

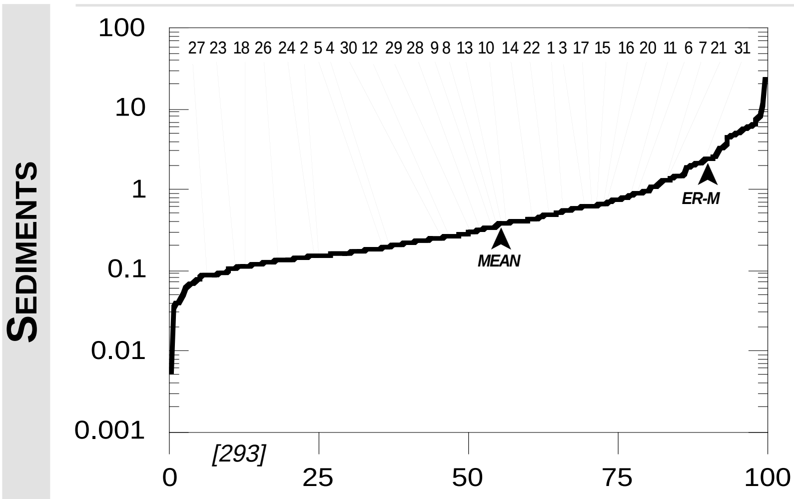
The graphs on the following pages show the mean concentrations of contaminants found at the Chesapeake and Delaware Bays area sites in relation to the concentrations found nationwide at all NS&T sites. The curves are formed by connecting the rank-ordered log (base 10) mean concentrations of chemical contaminants at all NS&T sites. Concentrations of contaminants in sediments, mussels, and fish at these sites are indicated by the vertical lines. Numbers at the top of each vertical concentration line refer to the site locations indicated in Figure 3 (Appendix A lists those sites where concentrations are defined as "high" and "very high").

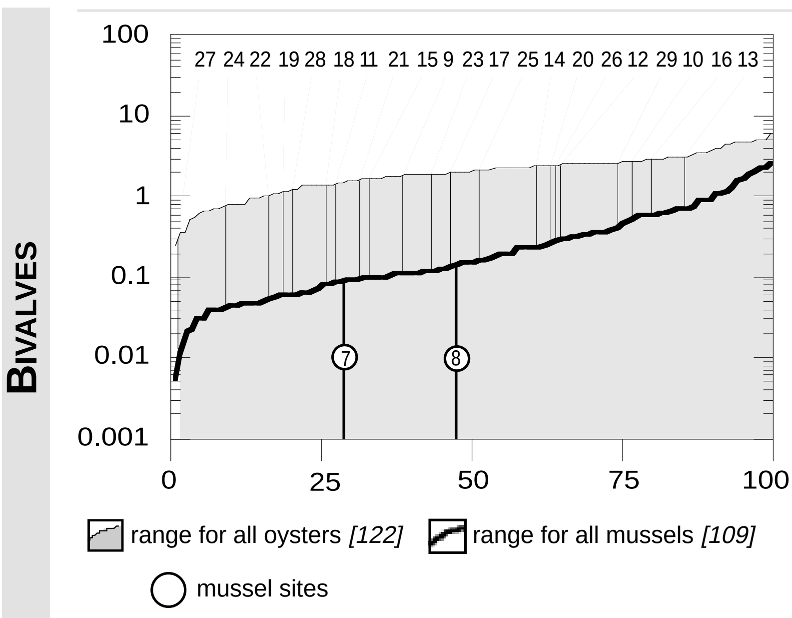
Metal concentrations are in micrograms per gram (µg/g) dry weight and organic compounds are expressed in nanograms per gram (ng/g) dry weight. The number in brackets illustrated with each graph represents the number ["n"] of sites used to create the curve. The sediment data have been adjusted so that data from samples containing more than 80% sand-sized particles [greater than 63 microns (µ)] were not used in comparisons among sites. Values for sediment samples containing less than 80% sand have been adjusted by dividing the contaminant concentrations by the fractions of the sediment that were fine-grained (i.e., dividing by numbers between 0.20 and 1.00). The arrows (▲) on the sediment graphs represent the national mean concentrations and the Effects Range-Medians (ER-M). The ER-M value denotes toxicant concentrations in sediments above which aquatic organisms usually exhibit adverse biological effects (Long and Morgan, 1990). Values used for the sediment curves include 1984-1988 NBSP and 1986-1991 MWP data. The curves for bivalve molluscan tissue were derived from five-year (1986-1990) means (or less for sites where sampling was initiated more recently). In a study where contaminant concentrations in blue mussels (Mytilus edulis) and American oysters (Crassostrea virginica) from the same locations were compared, no statistically significant differences were found between their organic contaminant accumulating abilities. However, there were statistically significant differences for some trace elements. Oysters were found to have a greater affinity for silver, copper, and zinc, while mussels were found to have a greater affinity for chromium and lead (Ocean Assessments Division, 1989; O'Connor, 1992). For reporting purposes, NS&T mussel and oyster data have been analyzed separately and the graphs overlayed. The shaded area beneath the thin-lined curve represents the range for all NS&T oyster data. The solid vertical lines within this shaded area represent American oyster data from the Chesapeake and Delaware Bays. The thicker-lined curve represents the range for all NS&T mussel data, with the two heavy vertical lines representing blue mussel data from the Cape May [7] and Cape Henlopen [8] sites. The fish curves are derived from five-year (1984-1988) means (or less for sites where sampling was initiated more recently) from analyses of the livers of various species of fish collected nationwide. The solid shaded area indicates the concentration range of all NS&T spot data, and the striped shaded area represents the range of all NS&T Atlantic croaker data. The number in parentheses illustrated with each graph represents the total number of NS&T sites where that species was collected. The solid vertical lines represent spot (Leiostomus xanthurus) data from the Gibson Island [3], Kent Island [4], and York River [5] sites; the larger dashed vertical lines represent Atlantic croaker (Micropogonias undulatus) data from the York River [5] and Elizabeth River [6] sites; and the smaller dashed vertical lines represent windowpane flounder (Scopthalmus aquosus) from the Brandywine Shoal [1] and the Shears [2] sites which are the only two sites where NS&T collects windowpane flounder.

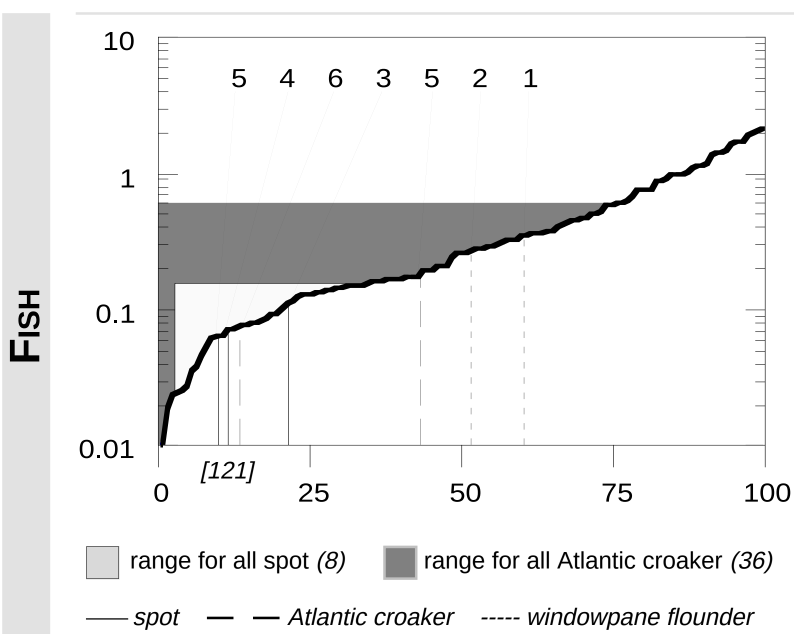
For a detailed description of NS&T Mussel Watch and Benthic Surveillance Projects monitoring sites refer to:

Lauenstein, G.G., M.R. Harmon, and B.W. Gottholm. 1993. National Status and Trends Program: Monitoring Site Descriptions (1984-1990) For the National Mussel Watch and Benthic Surveillance Projects. Tech. Memo. NOS ORCA 70, NOAA/NOS/ORCA, Silver Spring, MD. 358 pp.

Ag (µg/g dry weight)







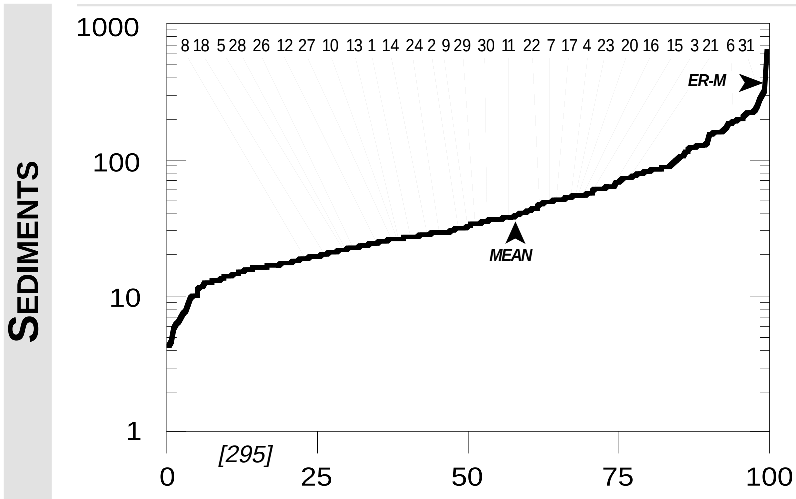
Three sediment sites and one bivalve site are in the "high" concentration range. No sites have "very high" concentrations for silver.

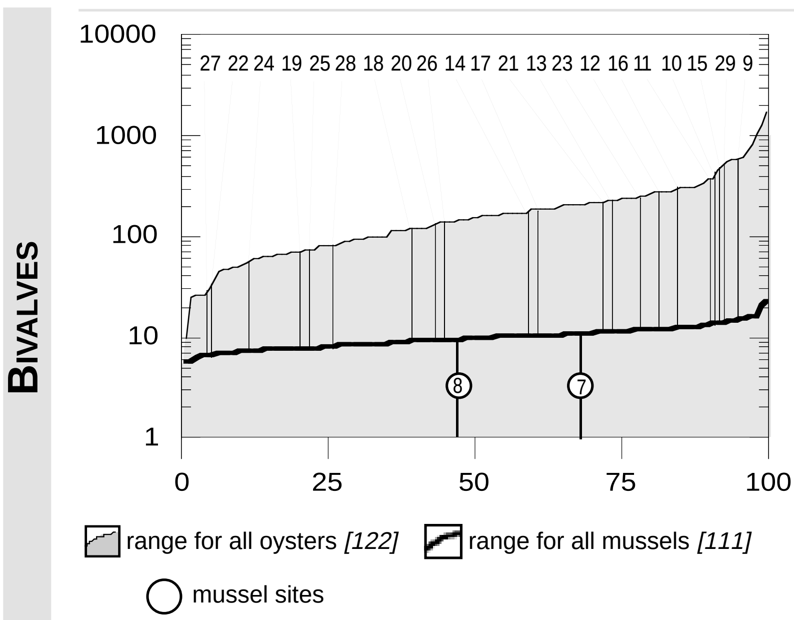
Silver. Sediment mean concentrations of silver for the Chesapeake and Delaware Bays sites are distributed widely, ranging from a low of 0.1 ppm at Cape Charles [27] to a high of 2 ppm at Ft. McHenry [31]. Ft. McHenry [31], Mattox Creek [21], and Cape May [7] have statistically "high" concentrations that are above the 83rd percentile for the nation, although all the sites have levels below the ER-M concentration of 2.2 ppm.

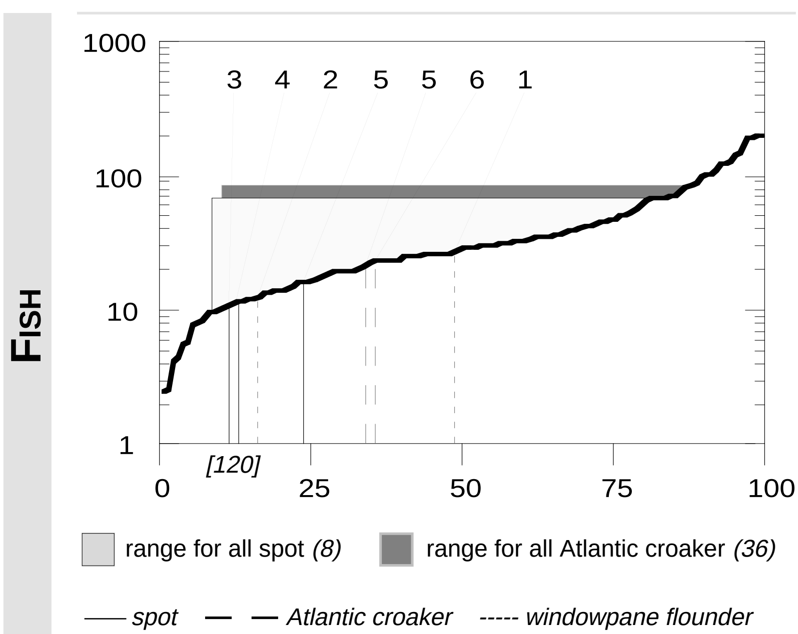
Mean concentrations in oysters range from a low of 0.3 ppm at Cape Charles [27] (the second lowest concentration in the nation) to a high of 3 ppm at Kelly Island [13] in the Delaware Bay. All the Delaware Bay sites have levels above the national mean of 3 ppm, except for two sites [11, 9]. The Kelly Island [13] mean concentration for silver falls in the "high" concentration range and is in the top 12th percentile. The mean concentration levels in mussels (both sites in Delaware Bay) are 0.09 ppm at Cape May [7] and 0.14 ppm at Cape Henlopen [8]. Both of these concentrations are below the national mean of 2 ppm.

Mean concentrations of silver found in fish livers from the Chesapeake and Delaware Bays range from a low of 0.1 ppm in spot from the York River [5] to a high of 0.4 ppm in windowpane flounder from Brandywine Shoal [1]. The two windowpane flounder sites in the Delaware Bay have the highest mean concentrations of all the NS&T fish sampling sites in the Chesapeake and Delaware Bays. The spot and Atlantic croaker mean concentrations in the Chesapeake Bay are at or around the mean concentrations of all the NS&T sites with the same species. All the NS&T fish sampling sites in these areas fall below the 62nd percentile for fish sites analyzed nationwide.

Cu (µg/g dry weight)







One sediment site is in the "high" concentration range and one in the "very high" concentration range. Four bivalve sites are in the "high" range and one in the "very high" range.

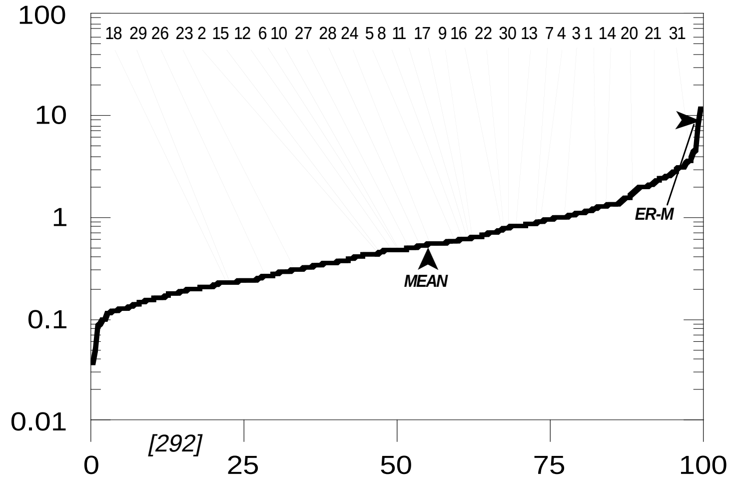
Copper. Copper concentrations are widely spread, ranging from 18 ppm at Cape Henlopen [8] to 269 ppm at Ft. McHenry [31]. All of the Delaware Bay sediment samples have levels below the national mean concentration value, except for the Cape May [7] site. The concentrations at all sites in both bays are below the ER-M value of 390 ppm, although the Elizabeth River [6] is a "high" concentration site and Ft. McHenry [31] is a "very high" site. The levels at these sites are above the 90th percentile for the nation.

The mean concentrations in oysters range from a low of 29 ppm at Cape Charles [27] to a high of 1,030 ppm at Hope Creek [9]. All of the Delaware Bay oyster sites have levels above the national concentration mean of 140 ppm. The Hope Creek [9] site has a "very high" concentration which is above the 98th percentile and is the 3rd highest concentration for all oyster sites nationwide. In addition, Woodland Beach [11], Arnolds Point Shoal [12], Bodkin Point [15], and James River [29] have concentration values that are considered "high" and are above the 93rd percentile nationwide. The mean concentrations in mussels range from 10 ppm at Cape Henlopen [8] to 11 ppm at Cape May [7]. The level at Cape Henlopen [8] is just below the national mean for copper (50 ppm), and it ranks just below the 50th percentile. Cape May [7] ranks in the 70th percentile.

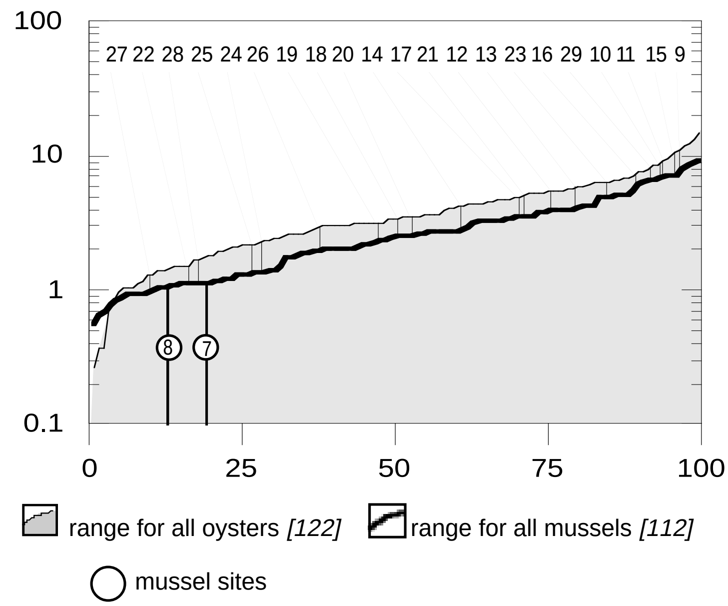
Mean copper concentrations in fish livers range from a low of 10 ppm in spot at Gibson Island [3] to a high of 27 ppm in windowpane flounder at Brandywine Shoal [1]. The three spot sampling sites in the Chesapeake Bay have levels well below the mean concentration of all the NS&T spot sites nationwide, as do the Atlantic croaker sites in the Chesapeake Bay. Mean copper concentrations in windowpane flounder from Brandywine Shoal [1] are twice as high as the mean concentration at The Shears [2]. All fish sites have levels at or below the 50th percentile.

Cd (μg/g dry weight)

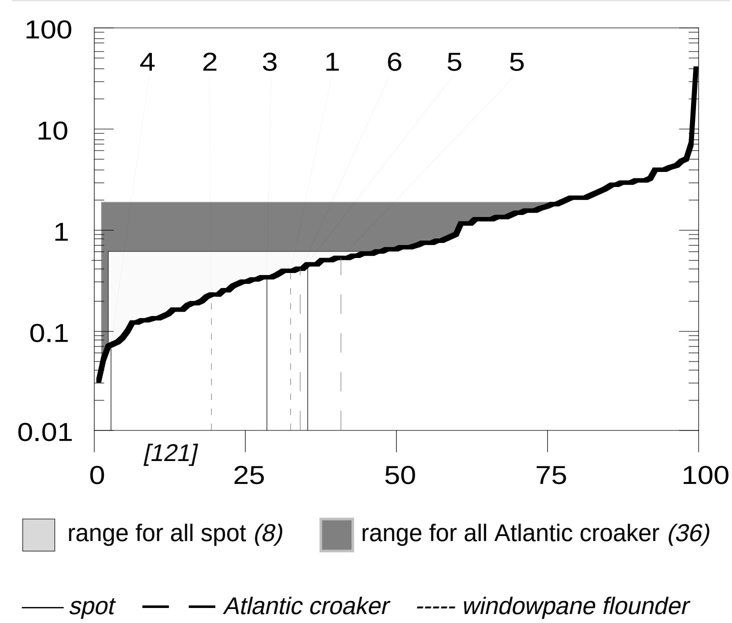
SEDIMENTS



BIVALVES



FISH



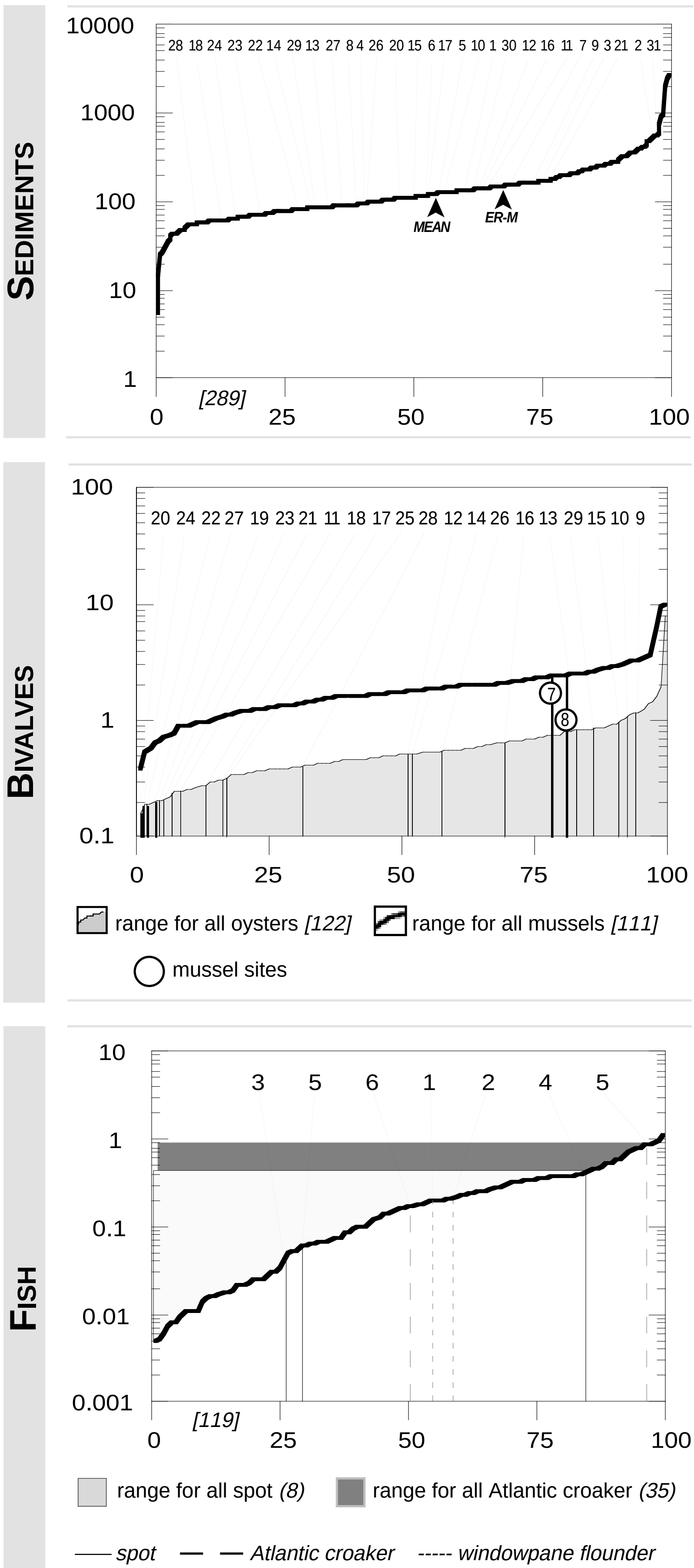
Three sediment and six bivalve sites have "high" concentration values. One sediment and one bivalve site have levels that fall into the "very high" concentration range.

Cadmium. The sediment concentrations for cadmium range from a low of 0.2 ppm at the Choptank River [18] site to a high of 3 ppm at Ft. McHenry [31]. All sites in both bays have levels that fall below the ER-M concentration of 9 ppm. Two sites in the Potomac River [20 & 21] and the Elizabeth River [6] site have levels in the "high" concentration range and the Ft. McHenry [31] site is in the "very high" concentration range.

Mean oyster concentrations for cadmium range from 1 ppm at Cape Charles [27] to 15 ppm at Hope Creek [9]. Most of the sites for the two bays, including all of the Delaware Bay sites, have levels above the national mean of 3 ppm. Hope Creek [9] has the highest mean concentration for cadmium of all oyster sites in the U.S. and is the only site with a level in the "very high" concentration range. In addition, the levels at the Ross Rock [23], Mountain Point Bar [16], James River [29], Arnolds Point Shoal [10], Woodland Beach [11], and Bodkin Point [15] sites are all above the 87th percentile and in the "high" concentration range. Mussel concentrations are 1 ppm for Cape Henlopen [8] and Cape May [7]. Both of these sites have levels that fall below the national mean concentration (for mussels) of 2 ppm for cadmium.

Concentrations of cadmium in fish livers range from a low of 0.1 ppm at Kent Island [4] in spot to a high of 0.5 ppm at York River [5] in Atlantic croaker. Kent Island [4] has the third lowest mean concentration of all NS&T fish sites and the lowest of all the spot sites. The levels at the remaining spot sites in the Chesapeake Bay are above the mean for all spot collected by NS&T. The levels at the two Atlantic croaker sites are slightly above the mean concentration for all of the Atlantic croaker sites nationwide. All the NS&T fish sites in these bays have levels that fall below the 42nd percentile for all fish sampled nationwide.

Cr (µg/g dry weight)



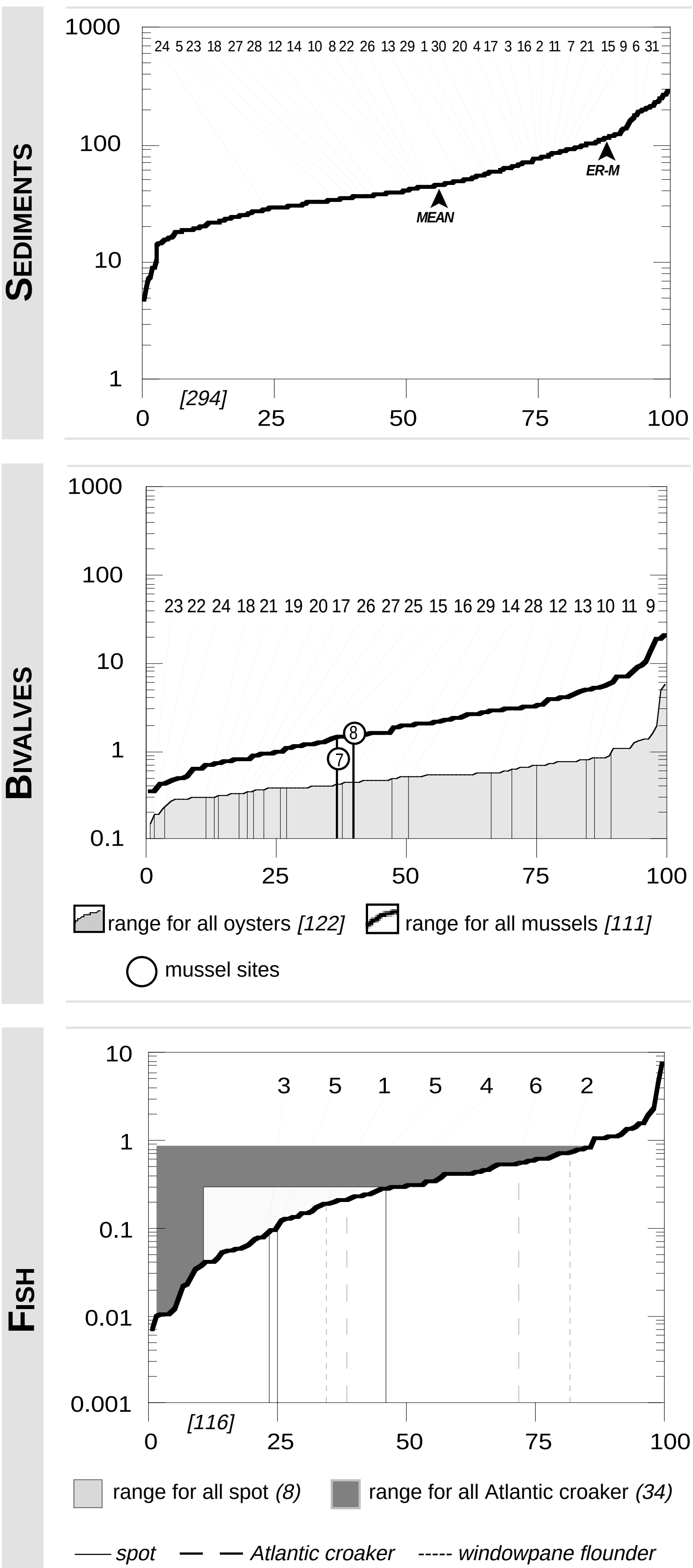
Two sediment sites have levels in the "very high" concentration range and four bivalve sites have levels in the "high" concentration range.

Chromium. The sediment concentrations for chromium range from a low of 53 ppm at Dandy Point [28] to a high of 561 ppm at Ft. McHenry [31]. Three sites in Delaware Bay [7, 9, 2] and three sites in the Chesapeake Bay [3, 21, 31] have levels above the ER-M concentration value (145 ppm). One site in each bay [2, 31] has a level above the "very high" concentration which is also above the 97th percentile nationwide.

Mean concentrations of chromium in oysters for the Delaware and Chesapeake Bays range from the lowest concentration nationwide at Swan Point [20] (0.2 ppm) to a high of 1 ppm at Hope Creek [9]. The levels at twelve sites fall below the national mean of 0.5 ppm, and eleven of these have levels that fall below the 18th percentile. In addition, seven of the ten lowest mean concentrations in the nation are in the Chesapeake Bay. Of the nine sites that have levels above the national mean, James River [29], Bodkin Point [15], Arnolds Point Shoal [12], and Hope Creek [9] are in the "high" range. Hope Creek [9] has the fourth highest mean concentration in the nation. Mean concentrations for the two mussel sites are 2.4 ppm for Cape May [7] and 2.5 ppm for Cape Henlopen [8]. The levels at both of these sites are above the national mean for mussels (1.7 ppm) and are above the 80th percentile.

Chromium mean concentration values in fish livers sampled in the Delaware and Chesapeake Bays range from 0.05 ppm in spot from Gibson Island [3] to 0.9 ppm in Atlantic croaker from York River [5]. Kent Island [4] has the highest mean concentration of all NS&T sites for spot, with a mean concentration that is at least eight times higher than that of any other site. Both Atlantic croaker sites in the Chesapeake Bay have levels above the mean concentration of all NS&T Atlantic croaker sites, with the York River [5] site having the highest concentration of all the sites where Atlantic croaker are sampled and the second highest mean concentration of all NS&T fish sites.

Pb (µg/g dry weight)



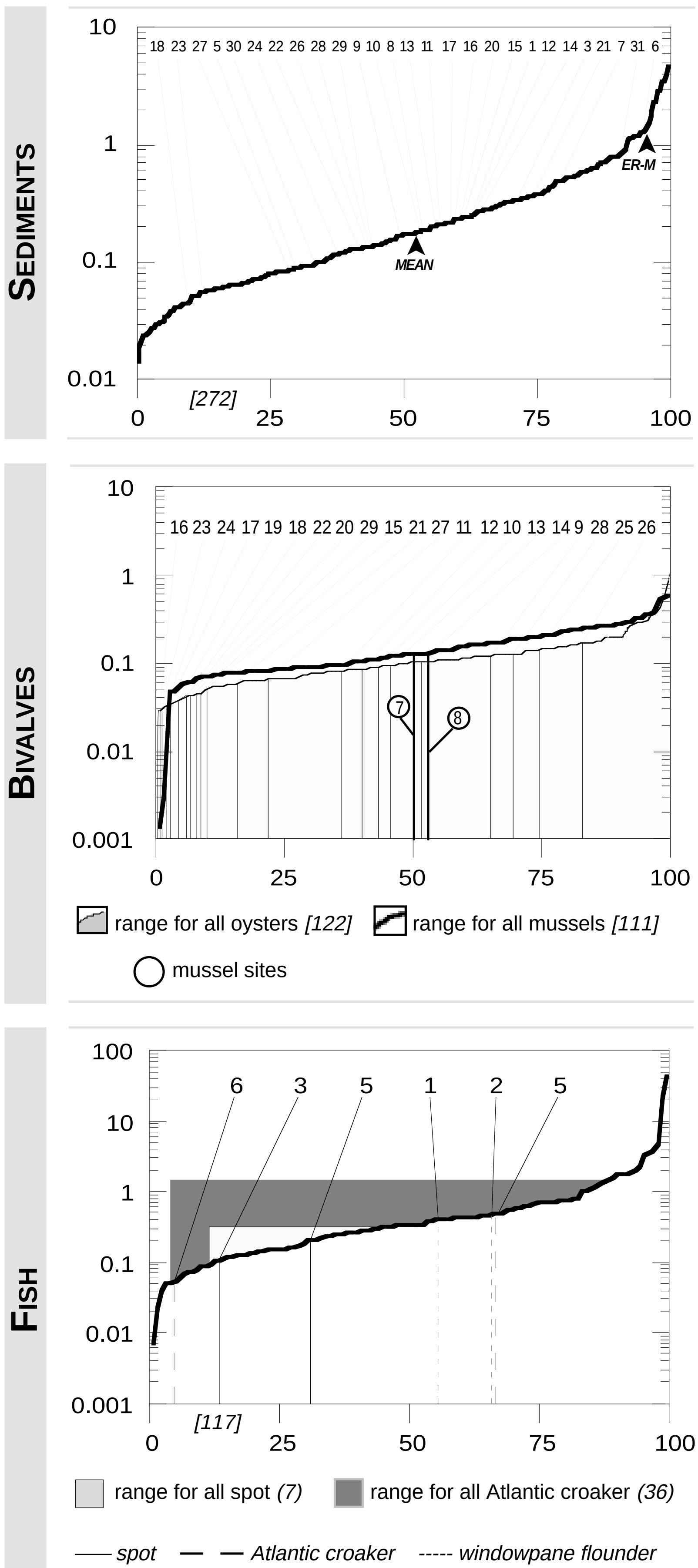
Two sediment sites and one bivalve site have levels in the "high" concentration range.

Lead. The sediment concentration values for lead range from a low of 28 ppm at Ingram Bay [24] to a high of 190 ppm at Ft. McHenry [31]. The levels at the Ft. McHenry [31] and Elizabeth River [6] sites in the Chesapeake Bay fall in the "high" concentration range and are above the 110 ppm ER-M concentration. The levels at these sites also are above the 90th percentile for sites nationwide.

Oyster concentrations for lead in the bays range from the lowest in the nation (0.2 ppm) at Ross Rock [23] in the Rappahannock River to a high of 1.0 ppm at Hope Creek [9]. Ross Rock [23], Ragged Point [22], and Ingram Bay [24] have among the five lowest NS&T concentration values for lead in oysters in the nation. The levels at all the sites in the Chesapeake Bay are below the national mean of 0.5 ppm, except for Dandy Point [28]. Conversely, all the Delaware Bay sites have levels above the national mean with the exception of False Egg Island [14]. The Hope Creek [9] site level is above the 92nd percentile for the nation and falls in the "high" concentration range. Mean mussel concentrations range from 1.4 ppm at Cape May [7] to 1.5 ppm at the Cape Henlopen [8] site. Both of these concentrations are below the national mean of 1.9 ppm for lead in mussels.

Fish liver concentrations range from a high of 0.09 ppm in spot at the Gibson Island [3] site to a low of 0.8 ppm in windowpane flounder at The Shears [2]. Kent Island [4] has the highest mean concentration of all NS&T spot sites sampled, while the Gibson Island [3] and York River [5] sites have levels just below the national mean concentration for spot. Both of the Atlantic croaker sites in the Chesapeake Bay have levels above the national mean concentration for all NS&T Atlantic croaker sites sampled.

Hg (µg/g dry weight)



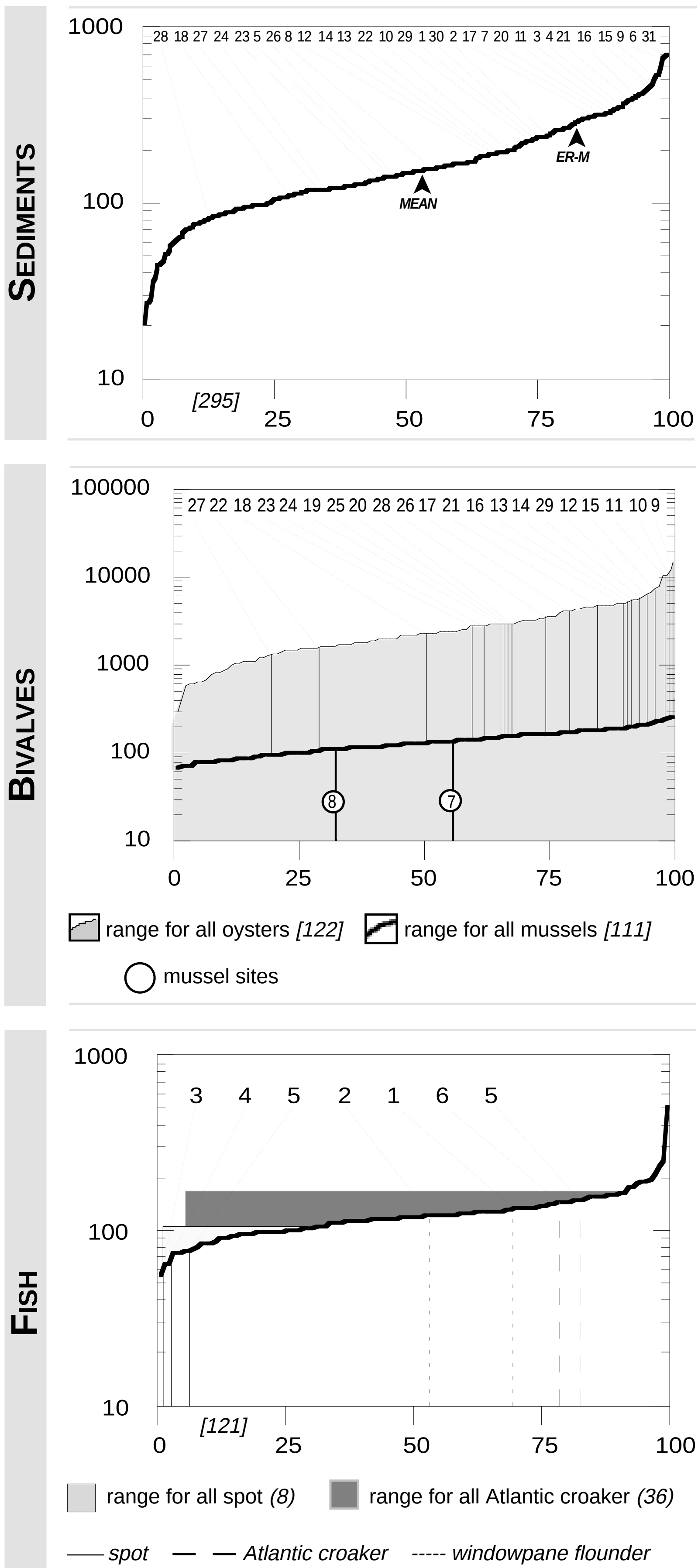
Two sediment sites have "high" concentration values, while ten of the bivavle sites sampled are among the lowest in the nation. Levels of mercury were below NS&T detectable limits at one site.

Mercury. Sediment concentration values for mercury range from a low of 0.04 ppm at the Choptank River [18] to a high of 1.3 ppm at the Elizabeth River [6]. All of the sites in the Delaware Bay, except Hope Creek [9], have concentrations above the national mean with the Ft. McHenry [31] and Elizabeth River [6] sites falling in the "high" concentration range. All of the sites in both bays have levels below the ER-M concentration of 1.3 ppm.

The curves for mussels and bivalves are very similar for mercury. In oysters, both bays have mean concentrations ranging from a low of 0.03 ppm at Mountain Point Bar [16] to a high of 0.2 ppm at Upshur Bay [26]. Only five sites have levels above the national mean of 0.1 ppm, and no site has a level that falls in the "high" or "very high" concentration ranges. Of the twelve lowest concentrations for mercury nationwide, ten are in the Chesapeake Bay, with Mountain Point Bar [16] having the lowest concentration in the nation. Mean mercury concentrations in mussels at Cape May [7] and Cape Henlopen [8] are just above the national mean concentration of 0.12 ppm.

Mean concentration for mercury in fish livers from the bays ranges from a low of 0.05 ppm in Atlantic croaker at the Elizabeth River [6] site to a high of 0.5 ppm in Atlantic croaker at the York River [5] site. York River [5] and The Shears [2] have almost the same mean concentration, although the species are different. For spot, the level at the York River [5] site is slightly above the NS&T mean concentration for all sites where spot were analyzed. However, the level at the Gibson Island [3] site is below the mean concentration while the Kent Island [4] site level was below the NS&T detectable limit. The level at the York River [5] site is above the mean concentration for all NS&T Atlantic croaker sites. The level at the Elizabeth River [6] site is well below this concentration.

Zn (µg/g dry weight)



Sites sampled in the bays have among the highest concentrations for zinc in the nation. Three sediment and three bivalve sites have "very high" concentrations and nine sediment and six bivalve sites have levels that fall into the "high" concentration range.

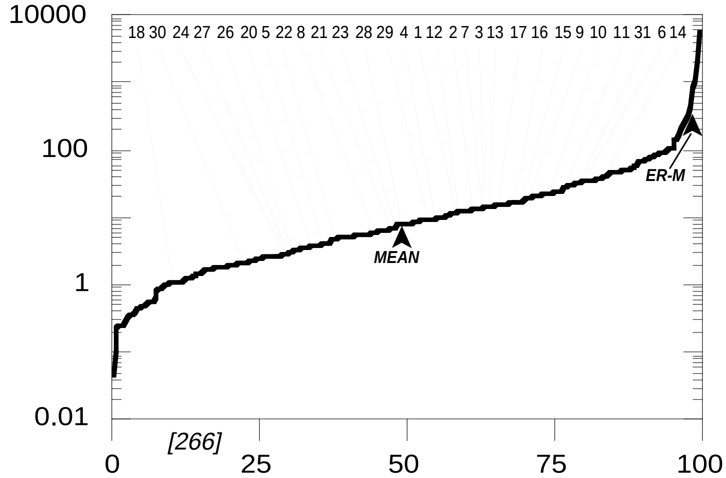
Zinc. Sediment concentrations for zinc in the bays range from a low of 80 ppm at Dandy Point [28] to a high of 689 ppm at Ft. McHenry [31]. The concentration at three sites, Hope Creek [9] in Delaware Bay and Elizabeth River [6] and Ft. McHenry [31] in the Chesapeake Bay, all fall into the "very high" concentration range and rank eighth, third, and first in concentrations (respectively) for all NS&T sites. All of the Delaware Bay sites have mean concentrations above the national mean, with a total of 12 sites from both bays with levels above the 270 ppm ER-M concentration.

Mean concentrations in oysters range from 1,340 ppm at Cape Charles [27] to 18,333 ppm at Hope Creek [9]. All the sites, except for three in the Chesapeake Bay [27, 22, and 18] have levels above the national mean of 2,297 ppm. Ten of the highest twenty mean values for zinc in NS&T sampled oyster sites are in these bays. Of these ten sites, Woodland Beach [11], Arnolds Point Shoal [10], and Hope Creek [9] (all located in Delaware Bay), have the highest concentrations of all NS&T oyster sites. The remaining seven all have "high" mean concentration values. The concentrations at all Delaware Bay sites for oysters are above the 85th percentile. Mean mussel concentrations range from 110 ppm at Cape Henlopen [8] to 138 ppm at Cape May [7].

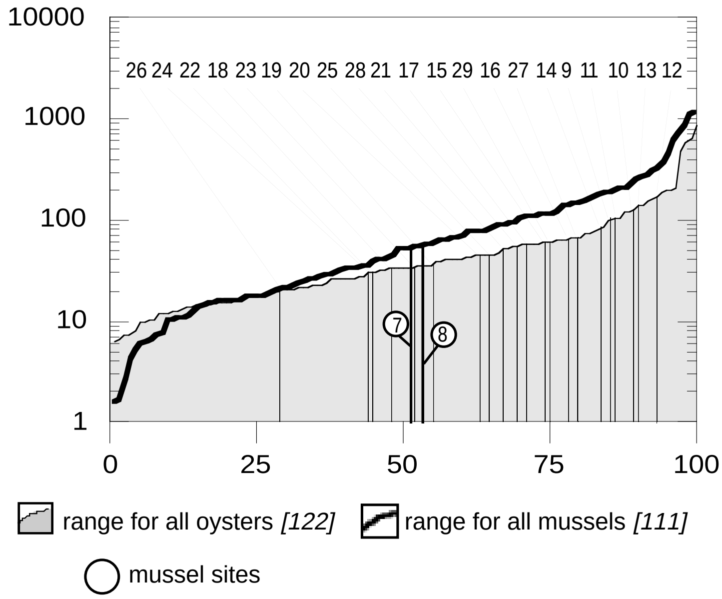
Concentrations of zinc in fish livers range from 63 ppm in spot at Gibson Island [3] to 145 ppm in Atlantic croaker at the York River [5] site. Spot collected from Gibson Island [3], Kent Island [13], and York River [5] had the second, third, and eighth lowest concentrations of the fish collected at all NS&T sites, respectively. These concentrations all fall below the mean concentration for all sites where spot were collected. Atlantic croaker from the Elizabeth River [6] and York River [5] sites have concentrations above the mean concentration for all NS&T Atlantic croaker sites. Delaware Bay windowpane flounder sites are intermediate.

tDDT (ng/g dry weight)

SEDIMENTS



BIVALVES



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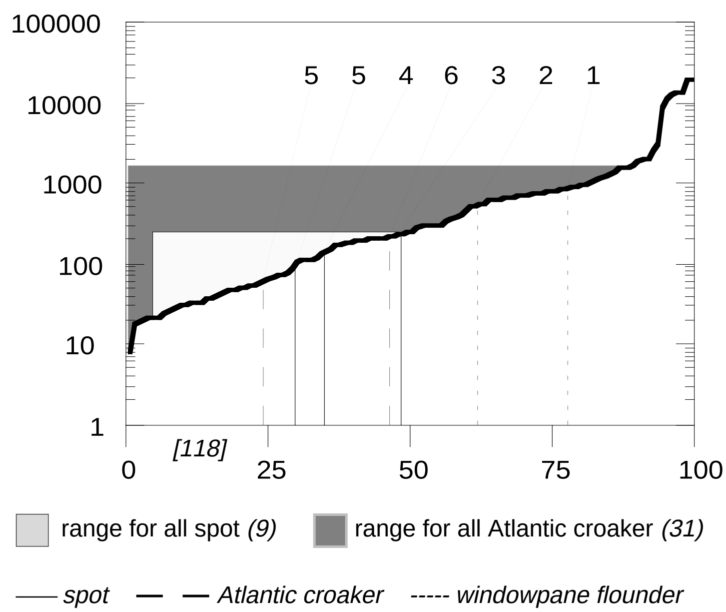


One sediment site and six bivalve sites have mean concentrations in the "high" range for total DDT.

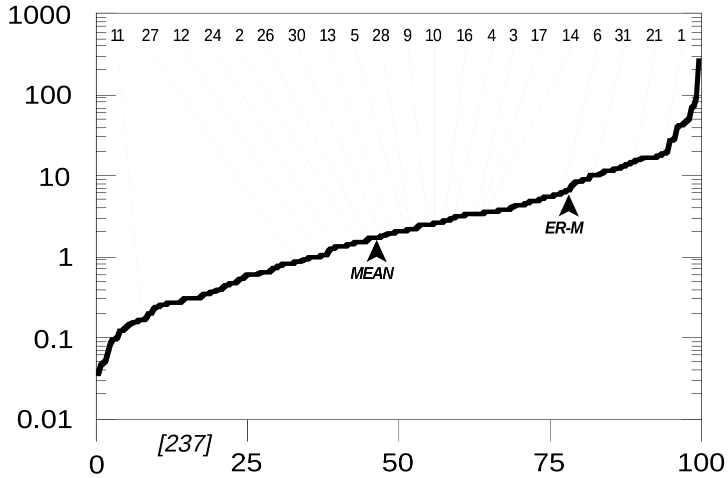
Total DDT *(The sum of o,p'-DDD, p,p'-DDD, o,p'-DDE, p,p'-DDE, o,p'DDT, and p,p'DDT)*. Sediment concentrations range from 1 ppb at the Choptank River [18] site to 43 ppb at the False Egg Island [14] site. Nine of the ten Delaware Bay sites have concentrations above the 7.5 ppb national mean concentration, only the Cape Henlopen [8] site has a value below this level. All sites in both bays have levels below the ER-M concentration of 350 ppb. The False Egg Island [14] concentration is in the statistically "high" concentration range.

Mean concentrations of tDDT in oysters range from a low of 20 ppb at Upshur Bay [26] to a high of 202 ppb at Ben Davis Point Shoal [12]. Only five sites [26, 24, 22, 18, and 23] have levels below the national mean of 36 ppb. The concentrations at the remaining sites are above the national mean concentration, with the top six sites [14, 9, 11, 10, 13, and 12] in the Delaware Bay. These Delaware Bay sites have "high" concentration values and are in the top 14th percentile nationwide. The mean mussel concentration for Cape Henlopen [8] is 53 ppb and for Cape May [7] 55 ppb. Both of these sites have concentrations above the national mean of 49 ppb.

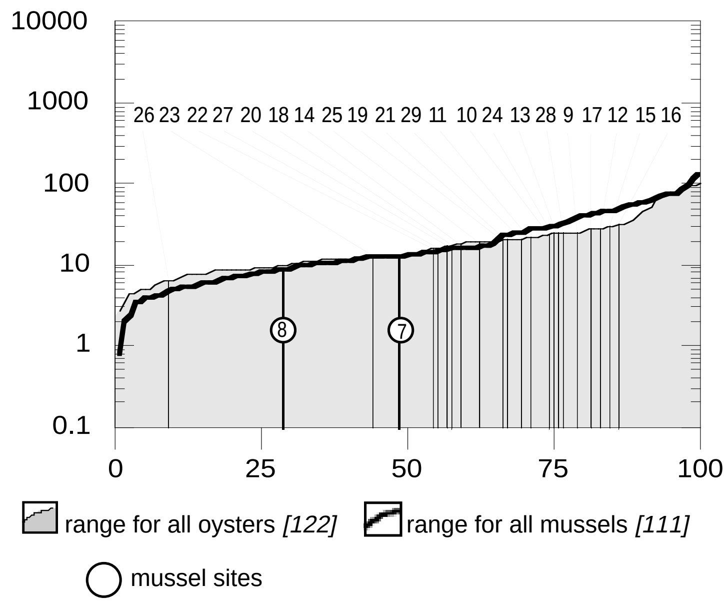
Mean concentrations for tDDT in fish livers collected in these two bays range from 61 ppb in Atlantic croaker from the York River [5] site to 914 ppb in windowpane flounder from Brandywine Shoal [1]. All of the sites in the Chesapeake Bay where spot were collected have levels above the NS&T mean concentration. Fish from Kent Island [4] and Gibson Island [3] have the highest concentrations of tDDT in their livers of all the NS&T spot sites. The York River [5] site for Atlantic croaker is below the mean concentration for all the NS&T Atlantic croaker sites, but the Elizabeth River [6] site is above this concentration. The windowpane flounder sites in the Delaware Bay have the highest concentrations of tDDT in fish livers of all fish collected in these two bays.

tCdane (ng/g dry weight)

SEDIMENTS



BIVALVES



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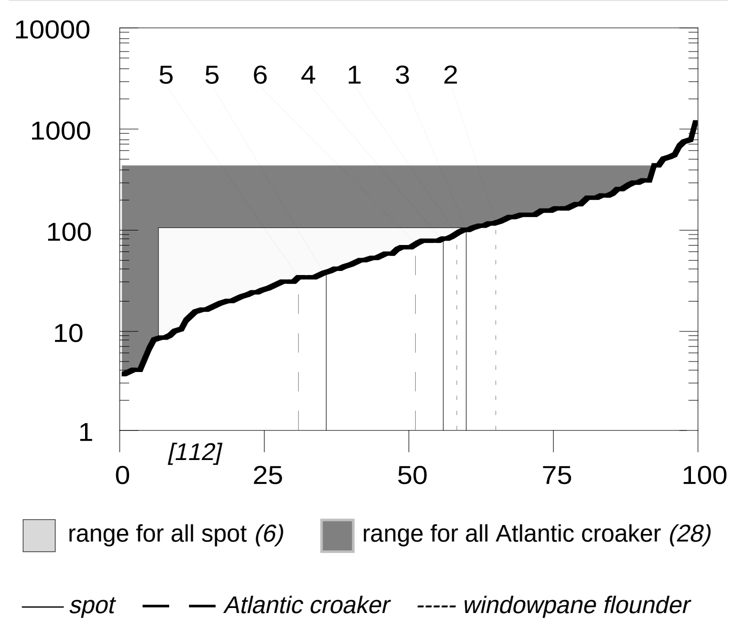


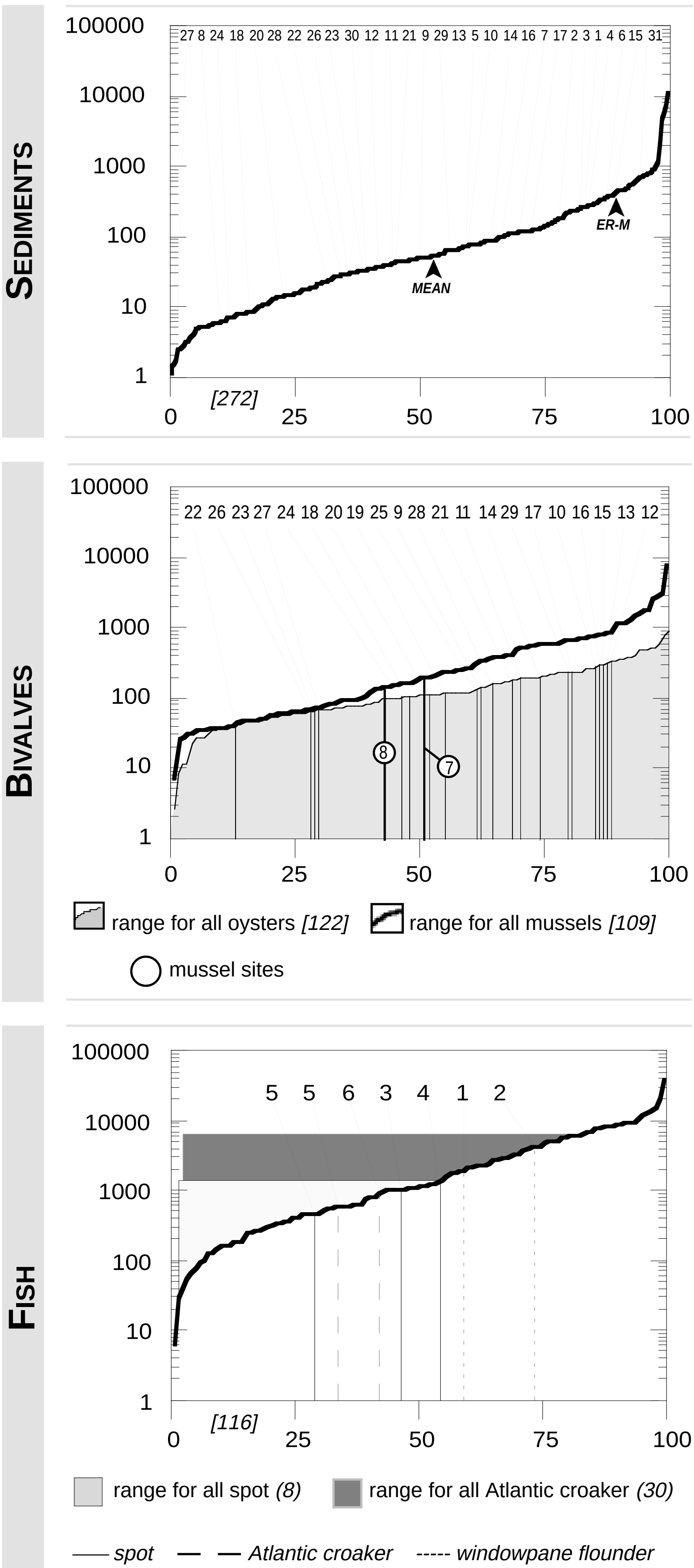
Three sediment sites and two bivalve sites have concentrations in the "high" range for total chlordane.

Total Chlordane *(The sum of trans-nonachlor-, heptachlor-, and hexachlorobenzene).* Sediment concentrations range from a low of 0.2 ppb at Woodland Beach [11] to a high of 17 ppb at Brandywine Shoal [1]; both sites are in the Delaware Bay. Three sites in each of the bays have sediment levels below the national concentration mean; all others have levels above. Ft. McHenry [31] and Mattox Creek [21] in the Chesapeake Bay, and Brandywine Shoal [1] in Delaware Bay, have "high" concentrations that are above the ER-M concentration of 6 ppb.

Mean oyster concentrations range from 6.5 ppb in Upshur Bay [26] to 41 ppb at Mountain Point Bar [16]. All sites except Upshur Bay [26] and Ross Rock [23] have levels above the national mean of 16 ppb. Bodkin Point [15] and Mountain Point Bar [16] have the highest concentrations in the two bays, and their concentrations fall into the "high" concentration range. Both of the mussel sites have levels below the national mean concentration for mussels (15 ppb). Cape Henlopen [8] oysters have a mean concentration of 8.5 ppb and those from Cape May [7] a mean concentration level of 12.5 ppb.

Mean concentrations of total chlordane in fish livers from these two bays range from 32 ppb in Atlantic croaker from the York River [5] site to 123 ppb in windowpane flounder at The Shears [2]. These values are in the mid-range of those for all NS&T fish sites. Kent Island [4] and Gibson Island [3] have the highest concentrations of all sampled spot sites. The York River [5] spot mean concentration is below the mean concentration for all spot sites. Mean concentrations for Atlantic croaker from the York River [5] are below the concentration for all NS&T Atlantic croaker sites while mean concentrations at the Elizabeth River [6] site are above the NS&T mean concentration for all Atlantic croaker sites sampled.

tPCB (ng/g dry weight)



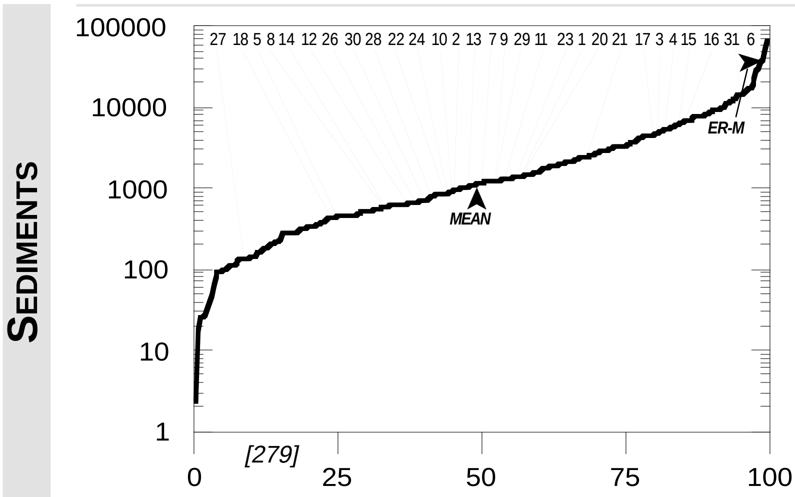
Concentrations for four sediment sites and five bivalve sites are in the "high" concentration range.

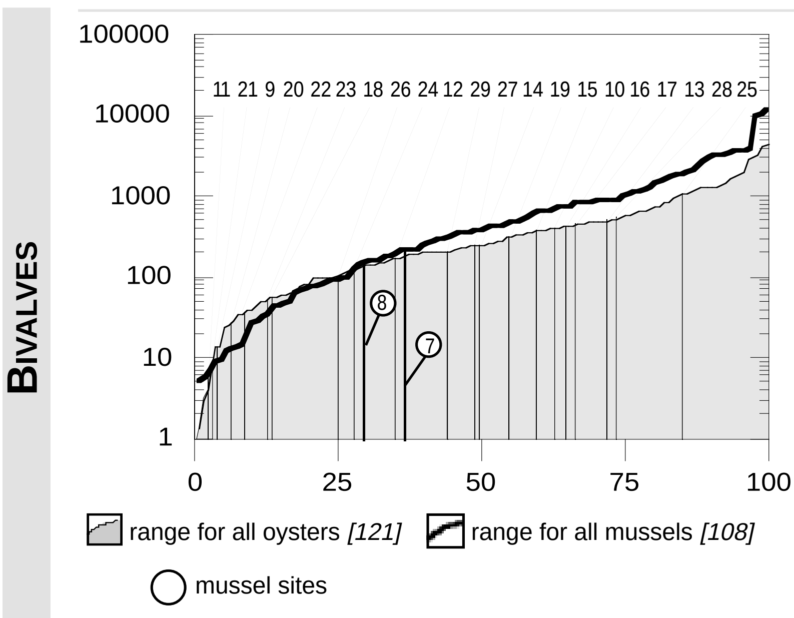
Total PCB *(sum of 20 polychlorinated biphenyl congeners)*. Sediment concentrations for tPCB range from a low of 1.4 ppb at Cape Charles [27] (second lowest concentration nationwide) to 679 ppb at Ft. McHenry [31]. The sites in the two bays are evenly distributed around the national mean, with some of the lowest, as well as some of the highest concentrations nationwide. Ft. McHenry is the only NS&T site with a level above the ER-M concentration of 400 ppb. Four Chesapeake Bay sites, Kent Island [4], Elizabeth River [6], Bodkin Point [15], and Ft. McHenry [31], have levels in the "high" concentration range.

Oyster concentrations in the bays range from 42 ppb at Ragged Point [22] to 377 ppb at Ben Davis Point Shoal [12]. Five sites, all in the Chesapeake Bay, have levels below the national mean of 106 ppb. Arnolds Point Shoal [10], Mountain Point Bar [16], Bodkin Point [15], Kelly Island [13], and Ben Davis Point Shoal [12] have levels in the top 12th percentile of all NS&T oyster sites and have "high" concentration values. Mean mussel concentrations fall on each side of the national mean for mussels of 192 ppb. Cape Henlopen [8] has a mean concentration of 141 ppb and Cape May [7] has a mean concentration of 193 ppb.

Fish liver concentrations from the bays range from a low of 438 ppb in spot from the York River [5] site to a high of 4,077 ppb in windowpane flounder from The Shears [2]. The windowpane flounder sites in the Delaware Bay have the fish with the highest mean concentrations of all the fish sites in these bays. Gibson Island [3] and Kent Island [4] spot have the two highest concentrations of all sites sampled by NS&T. The York River [5] mean concentration is below the mean concentration for all NS&T sites sampled for spot. The Elizabeth River [6] level is well above the mean concentration for all Atlantic croaker sites collected by NS&T, while the York River [5] Atlantic croaker site has a level below this concentration.

tPAH (ng/g dry weight)





Three sediment sites and one bivalve site have concentrations in the "high" range and one sediment site has a level that falls into the "very high" concentration range.

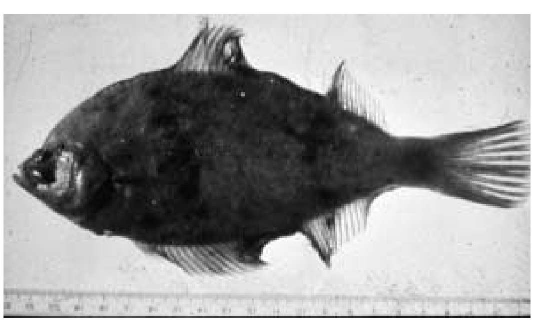
Total PAH *(sum of 24 polycyclic aromatic hydrocarbons)*. Sediment concentration means for tPAH in the bays range from a low of 125 ppb at Cape Charles [27] to a high of 34,843 ppb at Elizabeth River [6]. The Elizabeth River [6] level is in the "very high" concentration range and Bodkin Point [15], Mountain Point Bar [16], and Ft. McHenry [31] values are in the "high" concentration range. Elizabeth River [6] is the only site in both bays with a concentration mean above the ER-M concentration of 35,000 ppb.

Mean concentrations for tPAH in oysters for the bays range from a low of 4 ppb at Woodland Beach [11] to a high of 1,074 ppb at Chincoteague Inlet [25]. The sites in the two bays are evenly distributed around the national mean concentration of 239 ppb. Woodland Beach [11], Mattox Creek [21], and Hope Creek [9] have the third, fourth, and fifth lowest mean concentrations of total PAHs of all NS&T oyster sites. The Chincoteague Inlet [25] level is above the 85th percentile and is a "high" value. Both mussel sites have levels below the national mean of 314 ppb, with the Cape Henlopen [8] site having a mean concentration of 150 ppb and the Cape May [7] site a concentration of 214 ppb.

Contaminant Effects Studies

The continuing evidence of decline in coastal and estuarine resources related to pollution, development, and natural effects has increased public and political awareness of the need to implement integrated coastal management strategies.

In 1990, the U.S. EPA initiated the Environmental Monitoring and Assessment Program (EMAP) Demonstration Project in estuaries of the Virginian Province, which includes the Delaware and Chesapeake Bays. A series of indicators of the overall health of estuarine resources were measured at randomly selected sites throughout the two estuarine systems. Two indicators measured were the acute toxicity of sediment samples to estuarine biota exposed under controlled laboratory conditions (a ten-day toxicity test using the amphipod *Ampelisca abdita*), and the occurrence of visible pathological problems such as tumors and lesions in fish. Results from the first year of sampling revealed that sediments from approximately 4% of the Delaware Bay and 8% of the Chesapeake Bay were toxic to amphipods. Pathological disorders were observed in seventeen of every 1,000 bottom-dwelling fish collected in all of the estuaries of the Virginian province.



Results for pathological disorders for the Delaware and Chesapeake Bays have not yet been reported (Weisberg, et al., 1992).

Delaware Bay

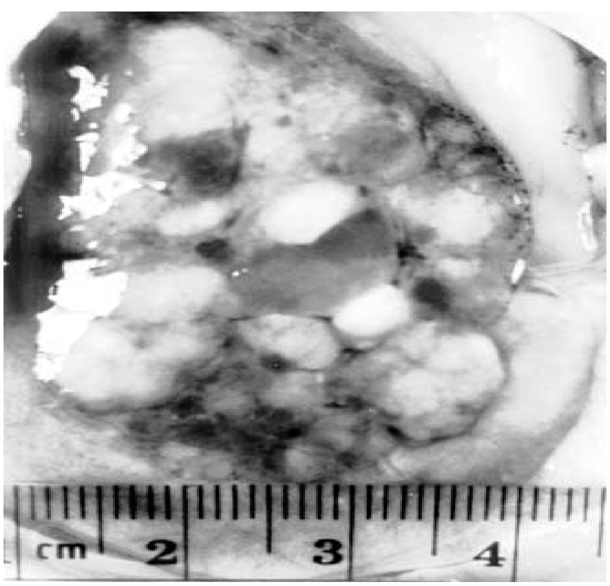
In June, 1993, a sediment bioassay was performed by contractors for the Delaware Estuary Program and the Delaware River Basin Commission using samples collected from 16 sites in the Delaware River and Delaware Bay. Two sites coincided with previously established NS&T Mussel Watch Program sites (site DBAP [10] at Arnolds Point Shoal and site DBBD [12] at False Egg Island Point). To test for sediment toxicity, juvenile amphipods *(Ampelisca abdita*) were exposed to sediment samples for ten days and the number of survivors were counted. After ten days exposure, mean survival ranged from 100% for one site in the Delaware Bay (south of Money Island) to 0% for two Delaware River sites (river mile 85, at the mouth of Dawby Creek, and river mile 110, inside the mouth of Dredge Harbor near Plum Point). Amphipods exposed to sediments collected from the two Mussel Watch sites showed a mean survival of 90% for both sites. The mean survival for amphipods exposed to the control sediment (collected from the same location as the amphipods) was 93% (Ward and Boeri, 1993).

In November, 1990, the Delaware River Basin Commission conducted an ambient toxicity study using water column samples from 12 Delaware River sites between Fieldsboro, NJ (south of Trenton) and the C & D Canal. For each sample, researchers analyzed the larval survival and growth of the fathead minnow, *Pimephales promelas*, and the survival and reproduction of the cladoceran (water flea), *Ceriodaphnia dubia*. Larval survival and growth of the sheepshead minnow, *Cyprinodon variegatus*, and survival and reproduction of the mysid shrimp, *Mysidopsis bahia*, were also tested using samples from three downstream sites which experience higher salinities. Survival of all four test species was unaffected by exposure to any of the water samples, however, growth of fathead minnows was significantly reduced in samples collected from 8 sites, with the highest reduction occuring in samples from the Philadelphia area. Reproduction of *C. dubia* also was significantly reduced in one sample from a downstream site located near Wilmington, DE (Delaware River Basin Commission, 1991a).

Chesapeake Bay

Between 1986 and 1987, Sunda et al. (1990) compared the survival of larvae of the copepod, *Acartia tonsa*, in water from the Elizabeth River estuary with survival in water from adjacent sites in Hampton Roads and the lower Chesapeake Bay. The three Elizabeth River stations had the lowest survival rates, with 53%, 52%, and 44% of the copepods surviving. These stations also had the highest concentrations of copper and zinc. The highest survival rates were from the two stations collected the farthest out in the Chesapeake Bay, with 86% and 90% of the copepods surviving. These stations also had the lowest concentrations of copper and zinc. Additionally, the survival of *A. tonsa* larvae in Elizabeth River samples increased following the addition of chelators EDTA and NTA, which complex and detoxify copper and zinc, and possibly nickel, cadmium, and lead. Sunda et al. concluded that copper, zinc, and possibly other toxic metals are present at high enough concentrations in the Elizabeth River to adversely affect *A. tonsa* and other sensitive estuarine organisms.

Weeks and Warinner (1984) and Weeks et al. (1986) compared measurements of indicators of immune system function in spot and hogchokers



(Trinectes maculatus) collected from the southern branch of the Elizabeth River with similar measurements on fish from control sites in the York River, VA. Macrophages (a large cell that engulfs and digests foreign bodies in an organism's tissues) isolated from the kidneys of Elizabeth River fish showed reduced chemotactic and phagocytic activity in comparison with control fish. The researchers concluded that high levels of PAHs in Elizabeth River sediments may have been responsible for this reduction. After Elizabeth River fish were held in clean water for three weeks, macrophage activity returned to control levels.

Huggett et al. (1987) observed a relationship between high levels of PAHs in sediments and reductions in biomass, total number of individuals, and abundances of selected fish species collected in the southern branch of the Elizabeth River. Fish collected there also showed an increasing frequency of gross abnormalities, such as cataracts, as the level of PAH contaminants in sediments increased. For individual fish species, the occurrence of cataracts also increased with size, possibly indicating a relationship between duration of exposure and biological effects.

In a study funded by the Maryland and Virginia Sea Grant College Programs, Chu and Hale (1992) analyzed the relationship between pollutant exposure and oyster susceptibility to the pathogen *Perkinsus marinus*. In a preliminary experiment, oysters inoculated with *P. marinus* infective particles were exposed to three concentration regimes of toxic mixtures (5 and 10%; 10 and 20%; and 10 and 25%) extracted from Elizabeth River sediments. Both the prevalence of infection and weighed incidence (sum of infection level/ number of oysters) were found to increase with exposure, however, no mortality occurred during the exposure period. Chu and Hale speculated that exposure of oysters to 25% or higher concentrations of toxic extracts would be required to weaken their defense system and increase their susceptibility to disease.

Conclusions

Results to date from the nationwide NS&T monitoring data have indicated that, in general, contaminant levels have been found to be holding steady or, in the case with several contaminants, decreasing in coastal areas over the past few years, reversing trends of contaminant increases that occurred in the first two-thirds of this century.

Chemical Contaminant Findings. For three of the seven heavy metals (Cr, Pb, and Zn), as well as two of the four organics (tCdane and tPCB) examined, at least one NS&T site in both the Chesapeake and Delaware Bays exceeds the ER-M concentration, above which sediments usually cause adverse biological responses. Concentrations at Ft. McHenry [31] exceed the ER-M for all five of these contaminants (Cr, Pb, Zn, tCdane, and tPCB). In addition, Mattox Creek [21] has levels that exceed the ER-M for Cr, Zn, and tCdane, while Elizabeth River [6] levels exceed the ER-M for Pb and Zn. A total of 12 sites have zinc levels that exceed the ER-M and 6 sites have levels that exceed it for chromium. For all seven of the metals and for two of the organics classes (tPCB and tPAH), the level at the Ft. McHenry [31] site is above the 89th percentile for the nation. In the case of zinc, Ft. McHenry has the highest concentration of all NS&T sites and is followed closely by the Elizabeth River [6] site. In addition, Elizabeth River [6] has levels above the 87th percentile for five of the seven heavy metals (Cu, Cd, Pb, Hg, and Zn) and two of the reported organic compounds (tPCB and tPAH).

In general, the Delaware Bay sites have higher concentrations of the contaminants in their oyster tissues than most of the sites from the Chesapeake Bay. In the case of Cu, Cd, Pb, Zn, tDDT, tCdane, and tPCB, the concentrations at all six of the Delaware Bay sites are above the 60th percentile. Of the 21 oysters sites in the Chesapeake Bay, only nine sites for tCdane [16, 15, 17, 28, 24, 29, 21, 19, and 25], six sites for Cu [29, 15, 16, 23, 21, and 17], Cd [15, 29, 16, 23, 21, and 17], and tPCB [15, 16, 17, 29, 21, and 28], two sites for Zn [15 and 29], and one site for Pb [28], have mean contaminant concentrations higher than the lowest concentration found in the Delaware Bay. All six of the Delaware Bay oyster sites have mean concentrations of tDDT that are higher than any of the Chesapeake Bay sites. Hope Creek [9] has a level at or above the 92nd percentile for five of the heavy metals (Cu, Cd, Cr, Pb, and Zn), and has the highest concentrations of cadmium and zinc in the nation. In addition, these two bays have two or more sites above the 80th percentile for six of the seven metals (Ag, Cd, Cr, Cu, Pb, and Zn), and one or more sites above the 85th percentile for all four of the organic contaminants (tDDT, tCdane, tPCB, and tPAH) quantified. In mussels from the two sites in Delaware Bay, five of the contaminants (Ag, Cd, Pb, tCdane, and tPAH) have concentrations below the national mean concentration. Cadmium concentrations are relatively low in the mussels and rank in the 19th percentile, whereas the remaining four contaminants (Ag, Pb, tCdane, and tPAH) have levels within the 37th to the 50th percentile. For two heavy metals (Hg and Cr) and for tDDT, both mussel sites have levels above the national mean, and the Hg and tDDT levels are at the 54th percentile. The Chromium level, however, is above the 80th percentile.

The fish liver data indicate that for five of the metals (Ag, Cr, Pb, Hg, and Zn), and for all three of the organics quantified (tCdane, tDDT, and tPCB), two or more sites have concentrations above the 60th percentile. All copper concentrations are below this mark and all cadmium concentrations are below the 42nd percentile. The concentration at the York River [5] Atlantic croaker site is in the 99th percentile for the nation.

The NS&T data show that a number of the sediment and oyster samples have high concentrations of multiple contaminants. This pattern is consistent with other estuaries around the nation that are highly impacted by humans.

Contaminant Effects Findings. Studies on the effects of contaminants on organisms in these two bays have detected symptoms in portions of each bay that are consistent with studies done in other heavily impacted estuaries. These symptoms include: (1) indicators of exposure to and uptake of toxic chemical contaminants; (2) impaired immune responses in marine and estuarine organisms; (3) decreasing shellfish and finfish populations and thus landings; (4) greatly reduced SAV coverage; (5) recurrent fish kills; and (6) public advisories on the consumption of fish and shellfish caught in these waters.

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Appendices

Appendix A - *NS&T 'High' and 'Very High' Chemical Contaminant Concentrations*

The appendix lists the NS&T sites sampled in the Chesapeake and Delaware Bays in the Benthic Surveillance Program from 1984-1988 and the Mussel Watch Program from 1986-1990. Benthic Surveillance sites are listed in bold italic. If all sediment samples from a site contained more than 80% sand-sized particles, that site is indicated to be sandy and chemical data from it have not been used when comparing among sites. The last columns indicate which chemical concentrations, if any, at a site exceeded concentrations that are 'high' [★] (more than the mean plus one standard deviation of the log-normal distribution for all sites) or 'very high' [★★] (more than the mean plus two standard deviations of the log-normal distribution for all sites).

NS&T Sediment Data

General Site Name	Specific Site Name	Type	Cd	Cr	Cu	Pb	Hg	Ag	Zn	tDDT	tCdane	tPCB	tPAH
New Jersey													
Delaware Bay	Cape May							★	★				
Delaware Bay	False Egg Island									★			
Delaware Bay	Ben Davis Point Shoal												
Delaware Bay	Arnolds Point Shoal												
Delaware Bay	Hope Creek								★★				
Delaware													
Delaware Bay	Woodland Beach								★				
Delaware Bay	Kelly Island												
Delaware Bay	Cape Henlopen												
Delaware Bay	***Brandywine Shoal***										★		
Delaware Bay	***The Shears***			★★									
Maryland													
Chesapeake Bay	Bodkin Point								★			★	★
Chesapeake Bay	Mountain Point Bar								★				★
Chesapeake Bay	Hackett Point Bar								★				
Chesapeake Bay	Choptank River												
Chesapeake Bay	Hog Point	Sandy											
Chesapeake Bay	Swan Point		★						★				
Baltimore Harbor	***Fort McHenry Channel***		★★	★★	★★	★	★	★	★★		★	★	★
Chesapeake Bay	***Gibson Island***								★				
Chesapeake Bay	***Kent Island***								★			★	
Chesapeake Bay	***Smith Island***												
Virginia													
Chesapeake Bay	Chincoteague Inlet	Sandy											
Quinby Inlet	Upshur Bay												
Chesapeake Bay	Cape Charles												
Potomac River	Mattox Creek		★					★	★		★		
Potomac River	Ragged Point												
Chesapeake Bay	Ingram Bay												
Rappahannock River	Ross Rock												
Chesapeake Bay	Dandy Point												
Chesapeake Bay	James River												
Chesapeake Bay	***York River***												
Chesapeake Bay	***Elizabeth River***		★		★	★	★		★★			★	★★

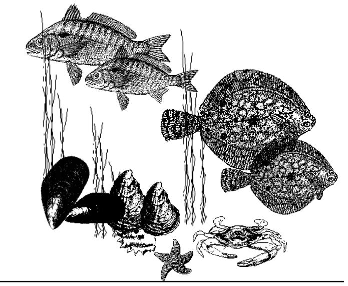
NS&T Bivalve Data

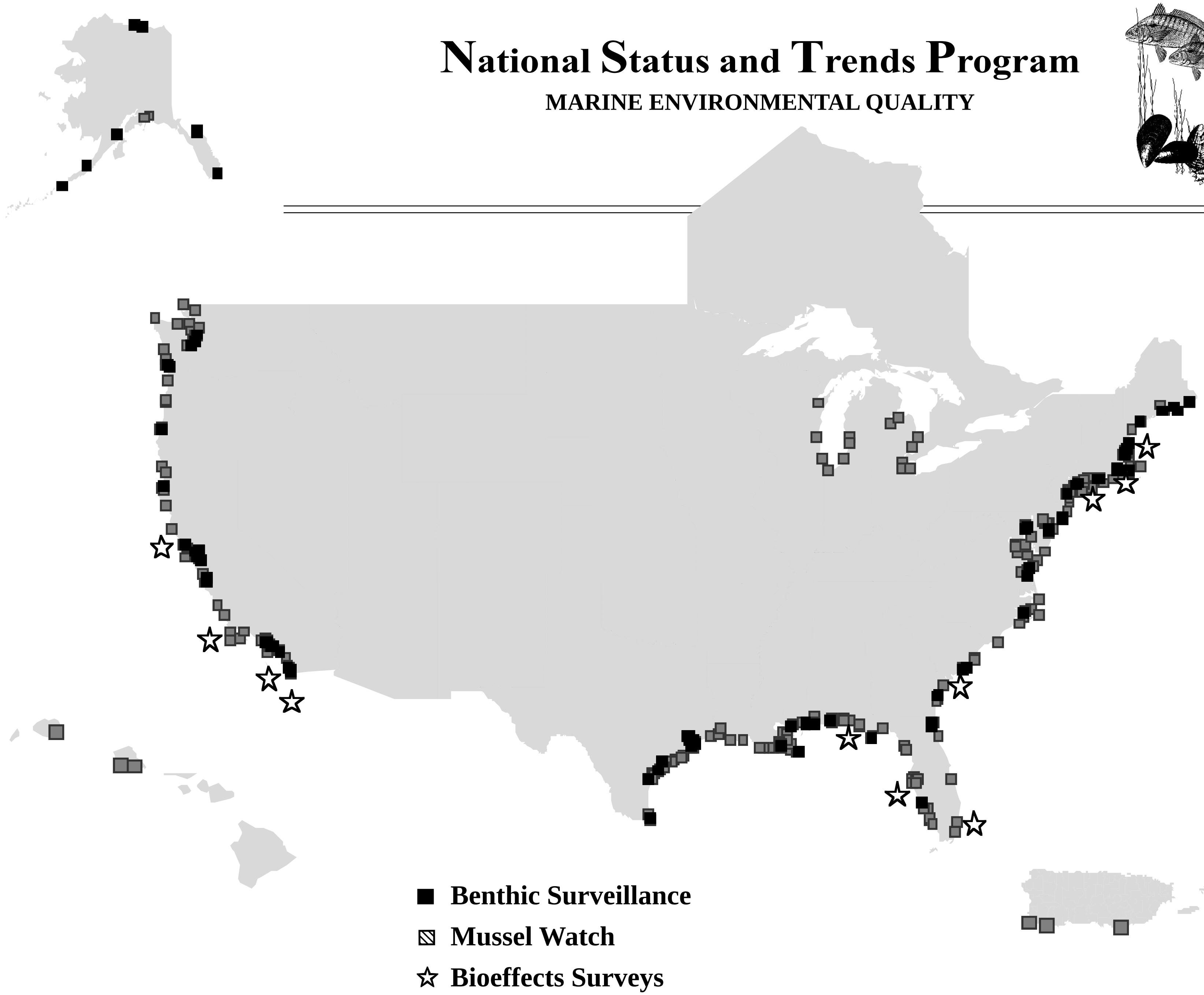
General Site Name	Specific Site Name	Cd	Cr	Cu	Pb	Hg	Ag	Zn	tDDT	tCdane	tPCB	tPAH
New Jersey												
Delaware Bay	*Cape May*											
Delaware Bay	*False Egg Island*							★	★			
Delaware Bay	*Ben Davis Point Shoal*							★	★		★	
Delaware Bay	*Arnolds Point Shoal*	★	★	★				★★	★		★	
Delaware Bay	*Hope Creek*	★★	★	★★	★			★★	★			
Delaware												
Delaware Bay	*Woodland Beach*	★		★				★★	★			
Delaware Bay	*Kelly Island*						★	★	★		★	
Delaware Bay	*Cape Henlopen*											
Maryland												
Chesapeake Bay	*Bodkin Point*	★	★	★				★		★	★	
Chesapeake Bay	*Mountain Point Bar*	★						★		★	★	
Chesapeake Bay	*Hackett Point Bar*											
Chesapeake Bay	*Choptank River*											
Chesapeake Bay	*Hog Point*											
Potomac River	*Swan Point*											
Virginia												
Chincoteague Bay	*Chincoteague Inlet*											★
Quinby Inlet	*Upshur Bay*											
Chesapeake Bay	*Cape Charles*											
Potomac River	*Mattox Creek*											
Potomac River	*Ragged Point*											
Chesapeake Bay	*Ingram Bay*											
Rappahannock River	*Ross Rock*	★										
Chesapeake Bay	*Dandy Point*											
Chesapeake Bay	*James River*	★	★	★				★				

General Site Name	Specific Site Name	Species	Tissue	Sediment
New Jersey				
Delaware Bay	Cape May	blue mussel	89 90	89
Delaware Bay	False Egg Island	American oyster	86 87 88 90	87
Delaware Bay	Ben Davis Point Shoal	American oyster	86 87 88 89 90	87
Delaware Bay	Arnolds Point Shoal	American oyster	86 87 88 90	86 87
Delaware Bay	Hope Creek	American oyster	89	89
Delaware				
Delaware Bay	Woodland Beach	American oyster	89	89
Delaware Bay	Kelly Island	American oyster	86 87 88 89 90	86 87
Delaware Bay	Cape Henlopen	blue mussel	89 90	89
Delaware Bay	***Brandywine Shoal***	windowpane flounder	84 85 86	84 85 86
Delaware Bay	***The Shears***	windowpane flounder	87	87
Maryland				
Chesapeake Bay	Bodkin Point	American oyster	89 90	89
Chesapeake Bay	Mountain Point Bar	American oyster	86 87 88 89 90	86 87
Chesapeake Bay	Hackett Point Bar	American oyster	86 87 88 89 90	86 87
Chesapeake Bay	Choptank River	American oyster	89 90	89
Chesapeake Bay	Hog Point	American oyster	86 87 88 89 90	86
Potomac River	Swan Point	American oyster	89 90	89
Baltimore Harbor	***Fort McHenry Channel***	no fish collected		86
Chesapeake Bay	***Gibson Island***	spot	85 86	85 86 87
Chesapeake Bay	***Kent Island***	spot	87	87
Chesapeake Bay	***Smith Island***	no fish collected		85 86
Virginia				
Chincoteague Bay	Chincoteague Inlet	American oyster	86 87 88 89 90	86
Quinby Inlet	Upshur Bay	American oyster	86 87 88 89 90	86 87
Chesapeake Bay	Cape Charles	American oyster	86 87 88 89 90	86 87
Potomac River	Mattox Creek	American oyster	90	90
Potomac River	Ragged Point	American oyster	89 90	89
Chesapeake Bay	Ingram Bay	American oyster	86 87	86 87
Rappahannock River	Ross Rock	American oyster	89 90	89
Chesapeake Bay	Dandy Point	American oyster	86 87 88 89 90	86 87
Chesapeake Bay	James River	American oyster	89 90	89
Chesapeake Bay	***York River***	Atlantic croaker	84 86	84 86 87
Chesapeake Bay	***York River***	spot	85	85
Chesapeake Bay	***Elizabeth River***	Atlantic croaker	86	86

National Status and Trends Program

MARINE ENVIRONMENTAL QUALITY





NOAA ship Ferrel

November 1994