NATIONAL STATUS AND TRENDS PROGRAM

MARINE ENVIRONMENTAL QUALITY

Assessment of Chemical Contaminants in the Hudson-Raritan Estuary and Coastal New Jersey Area

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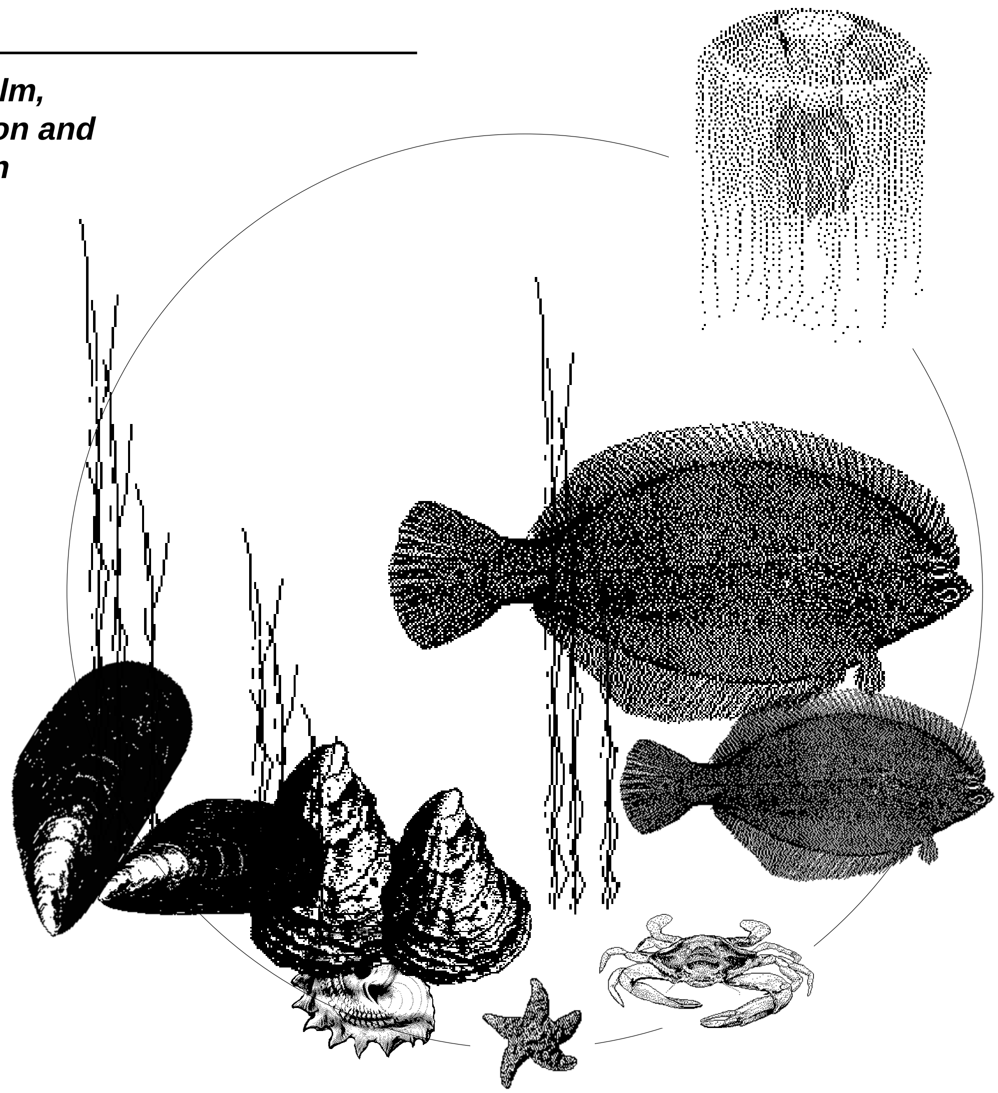

U. S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Ocean Resources Conservation and Assessment
Coastal Monitoring and Bioeffects Assessment Division
Silver Spring, Maryland 20910

ABOUT THIS REPORT

This coastal contamination assessment summarizes results of the National Status and Trends (NS&T) Program from sites in the Hudson- Raritan Estuary and coastal New Jersey. It characterizes the system, its drainage basin, and inputs that influence the concentration 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 in evaluating toxic contaminant conditions in their areas and placing those conditions in perspective to those throughout the nation.

NATIONAL STATUS AND TRENDS PROGRAM

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 National Oceanic and Atmospheric Administration (NOAA) initiated the National Status and Trends (NS&T) Program in 1984. 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 initially decided to focus the program 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; Quality Assurance Project;** and **Specimen Banking**.

As part of its nationwide effort, 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 potential 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 more than 100 sites (refer to the map on the 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 database. This information is analyzed and made available to coastal and marine resource managers and the public in a variety of reports and publications, which number 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 NS&T's **Quality Assurance Project**, established for all laboratories participating in the program. Selected samples collected as part of the NS&T's **Specimen Banking** component 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 performed in areas such as reproductive impairment, genetic damage, sediment toxicity, methodology refinement, 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.

The **Historical Trends** component synthesizes in reports 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 HUDSON-RARITAN ESTUARY AND COASTAL NEW JERSEY AREA

Copies of this report can be obtained by writing to:

Coastal Monitoring and Bioeffects Assessment Division
Office of Ocean Resources Conservation and Assessment
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Assessment of Chemical Contaminants in the Hudson-Raritan Estuary and Coastal New Jersey Area

GENERAL DESCRIPTION

This assessment report provides information on the status of chemical contaminant problems in the Hudson-Raritan Estuary and southward along the New Jersey coast to Cape May, NJ. To understand and interpret the NS&T contaminant data measurements, the following information on the characteristics of the region should be noted.

■ Within the region encompassed by this report, three estuaries have been described by NOAA's National Estuarine Inventory data base. These estuaries, the Hudson River/Raritan Bay, Barnegat Bay, and New Jersey Inland Bays, have a combined estuarine drainage area of 10,600 square miles and a water surface area of 510 square miles (Figure 1). These three estuaries together have an average depth of 12 feet, an average daily freshwater inflow of 30,100 cubic feet per second, and a volume of 211 billion cubic feet (Basta et al., 1990).

■ The Hudson-Raritan Estuary has a semidiurnal mean tidal range of 1.37m (4.5ft) in the northern portion of the estuary which increases at the mouth of the Estuary to 1.52m (5.0ft). The tidal range then decreases to 1.25m (4.1ft) in southern New Jersey coastal waters (Swanson, 1976).

■ The estuarine drainage areas of the Hudson-Raritan and Barnegat Bays have a combined total of approximately 418,000 acres of coastal wetlands. Of these, 58,400 acres (14%) are salt marsh, 18,200 acres (4%) are freshwater marsh, 295,300 acres (71%) are forested-scrub/shrub, and 46,100 acres (11%) are tidal flats. No data are available for the New Jersey Inland Bays Estuarine Drainage Area (Field et al., 1991).

■ According to Culliton et al. (1990), the coastal areas of New York and New Jersey are among the most populated in the Western Hemisphere, with New York having 6,738 persons per shoreline mile and New Jersey having 3,898 persons per shoreline mile. New York has a total land area of 47,377 square miles; of that, 7,570 (16%) square miles are coastal. New Jersey has a total land area of 7,468 square miles of which 5,686 (76%) square miles are coastal. New York's population in 1988 was 17,771,000, with 69% (12,330,000) living in coastal counties. New Jersey's total population in 1988 was 7,686,000, with 90% (6,934,000) living in coastal counties. Land-use distribution in this estuarine drainage area includes approximately 2,046 square miles of urban area, 2,035 square miles of agricultural land, and 4,467 square miles of forest (Strategic Assessments Branch, 1987).

■ In 1990, the total commercial fisheries catch for the Hudson-Raritan Estuary was 2,755,400 pounds (lbs). The top ten landings were: Atlantic menhaden (*Brevoortia tyrannus)* at 1,090,200 lbs; blue crab (*Callinectes sapidus*) at 800,100 lbs; American and hickory shad (*Alosa sapidissima* and *A. mediocris,* respectively) at 444,500 lbs; bluefish (*Pomatomus saltatrix*) at 320,100 lbs; Atlantic, green, and white sturgeon (*Acipenser oxyrhynchus, A. medirostris, and A. transmontanus*, respectively) at 49,800 lbs; butterfish (*Peprilus triacanthus*) at 13,200 lbs; seatrout (*Cynoscion nebulosus*) at 10,300 lbs; winter, fluke (fourspot), and yellowtail flounder (*Pleuronectes americanus, Paralichthys oblongus,* and *Pleuronectes ferrugineus)* at 6,900 lbs; Spanish mackerel (*Scomberomorus maculatus*) at 6,100 lbs; and Atlantic herring (*Clupea harengus*) at 4,800 lbs (Schween, pers. comm.).

■ The total number of fish caught for recreational purposes in the Mid-Atlantic region for 1990 was 81,986,000 fish with the top seven landings being (in thousands of fish): 25,672 various unclassified; 14,780 spot (*Leiostomus xanthurus*); 9,217 black sea bass (*Centropristis striata*); 9,011 bluefish; 7,138 summer flounder (*Paralichthys dentatus*); 6,078 Atlantic croaker (*Micropogonias undulatus*); and 5,273 scup (*Stenotomus chrysops*). Fifteen other species account for the balance of the landings (National Marine Fisheries Service, 1991).

■ The region covered in this report contains approximately 336,466 acres of waters classified with respect to shellfish harvesting status. In 1990, 86,283 acres (26%) were approved, 82,339 (24%) acres were conditional, 20,875 (6%) acres were restricted, and 146,969 (44%) acres were prohibited (Slaughter, pers. comm.). In the past, all of the conditional beds were in New Jersey, but since 1985, 67,864 acres of shellfish beds in the Hudson-Raritan Estuary have been upgraded to conditional (Leonard et al., 1991). The Hudson-Raritan Estuary still had no approved shellfish beds. Shellfish beds are closed during the summer when vacation homes along the coast are occupied.

■ Dredging for navigational purposes occurs periodically to ensure that the shipping channels remain open. The dredged material then may be used for other purposes if the sediments pass EPA sediment contamination standards (Tam, pers. comm.). Mining of sand and gravel for landfill, beach revampment, and construction, also occurs in this area. About 42 million cubic meters of sand were removed from the Lower Bay between 1950 and 1979 (Bokuniewicz and Coch, 1986). Many of the contaminants associated with fine-grained sediments that accumulate in these mining pits and navigational channels, are thereby released and transported elsewhere.

CONTAMINANT SOURCES

The rapid rate of population growth in this area has placed intense pressure on local ecosystems. In general, higher levels of contaminants are characteristic of urban estuaries due, in part, to an increase in inputs to the system, including commercial and industrial discharges. Other stresses include changing and conflicting land uses, and intensive use of the limited number of outdoor recreational areas (Basta et al., 1990).

Point Sources of Pollutant Discharge. After Chesapeake and Galveston Bays, the Hudson-Raritan Estuary contains the largest number of point sources of discharge in the nation (Basta et al., 1990). Most of the point sources of nutrient loading into the Hudson-Raritan Estuary are sewage treatment plants (See Figure 2). In 1988, it was estimated that 6.8 million gallons per day of raw sewage were discharged into the Estuary (NYS DEC, 1988), mainly from Manhattan, Staten Island, and Brooklyn (Leonard et al., 1989), contributing most of the 50,000 tons of total nitrogen and 32,000 tons of total phosphorus added to the region per year. Wastewater treatment plants contributed 43% of the total nitrogen and 90% of the total phosphorus to the New York Bight. Toxic metals were added at the rate of 35,700 tons per year. Contributing to

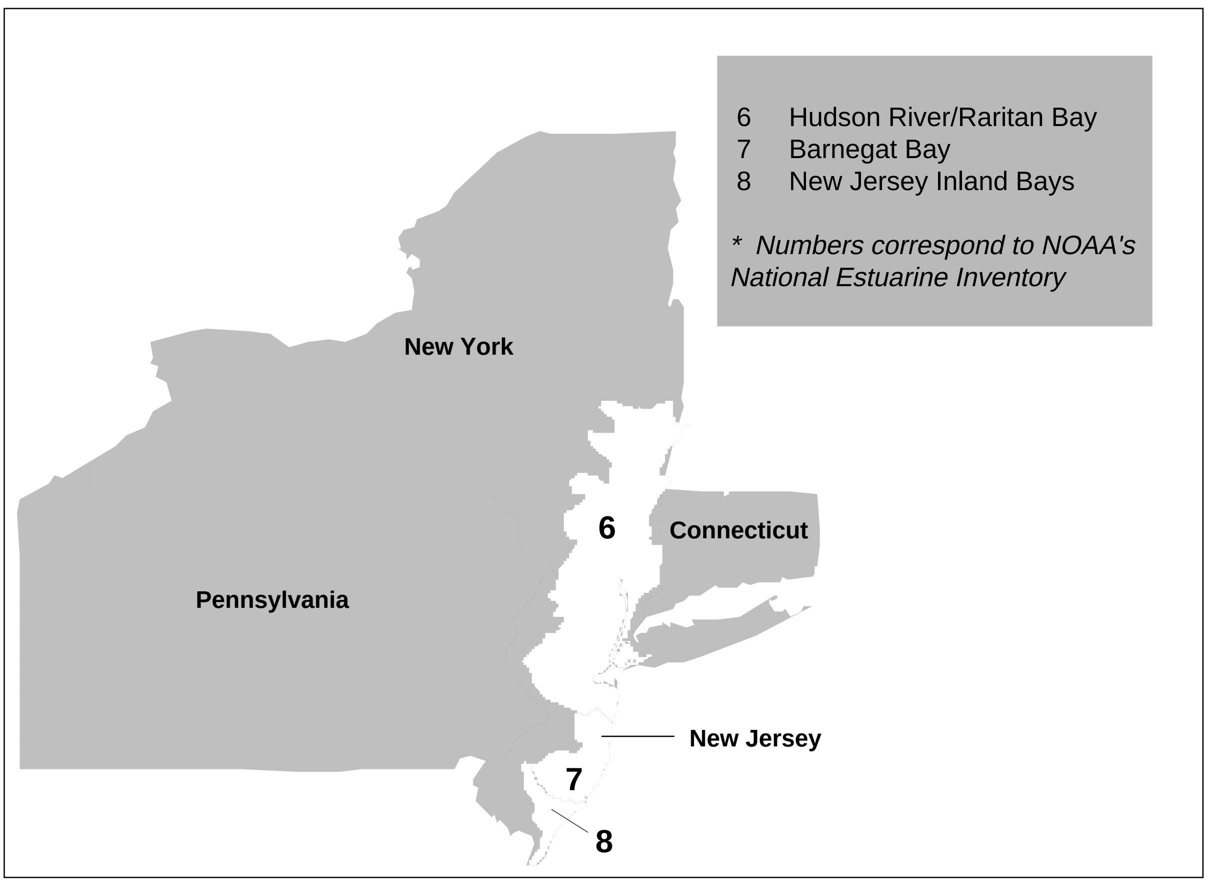

Figure 1. *Estuary drainage areas (Source: Basta et al., 1990).*

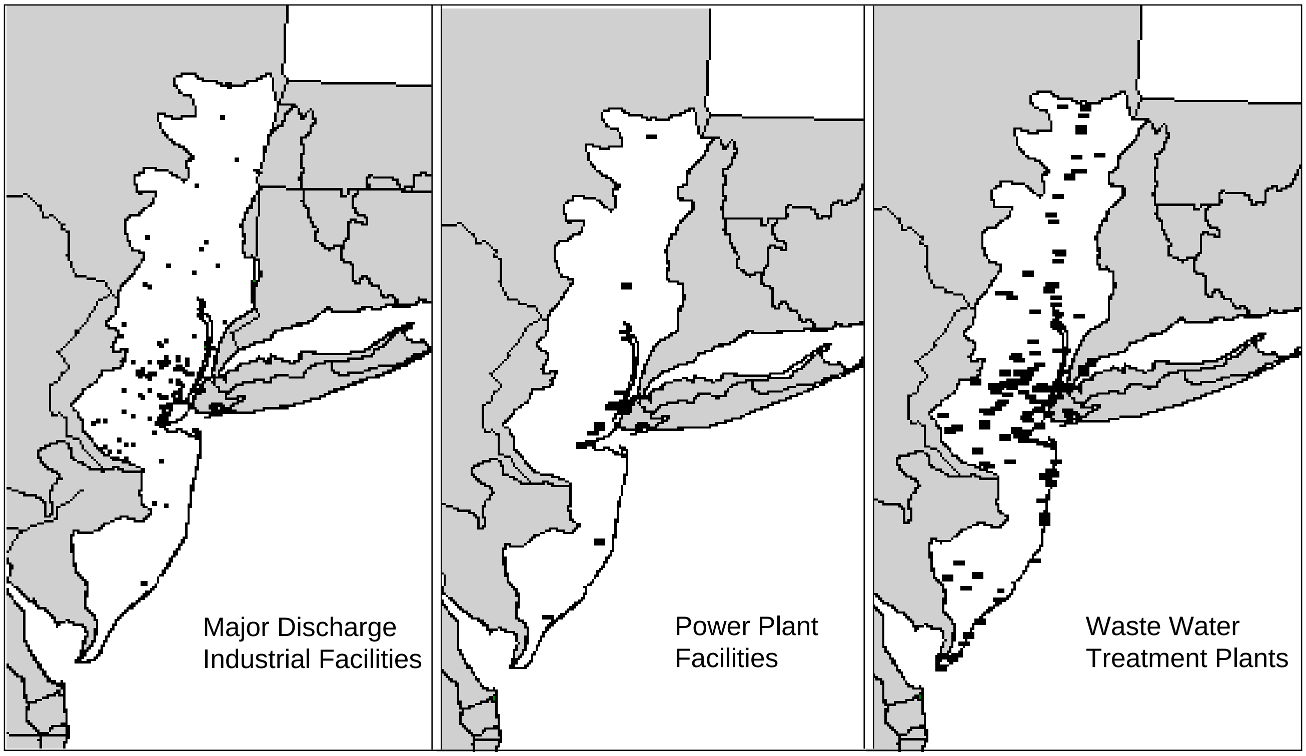

Figure 2. *Point sources of pollutant discharge (Source: National Coastal Pollutant Discharge Inventory, 1990).*

this loading was urban runoff (31%), wastewater treatment plants (19%), direct industrial discharge (14%), and various other sources (Strategic Assessment Branch, 1988). By 1991, the total nitrogen and total phosphorus had significantly decreased to 35,000 and 19,000 tons per year, respectively (Pacheco, pers. comm.). According to figures released by the City of New York Department of Environmental Protection (1993), the discharge of raw sewage into the Estuary had decreased by 1992, to less than 1.0 million gallons per day. This decline is due in part to the addition and/or the upgrade of wastewater treatment plants that discharge into the Estuary.

Non-Point Sources of Pollutant Discharge. Non-point pollution discharge occurs primarily during storm events in the Hudson-Raritan Estuary. This storm-water runoff can carry with it ground-based, as well as atmospheric-based contaminants. The ground-based contaminants include soil-bound pesticides and fertilizers, and various automobile-associated contaminants, mainly gasoline and oil which have been spilled on the roads and parking lots. In this area the fallout of atmospheric particles also may be a significant source of heavy metals. Contributing to this is the burning of fossil fuels for heating and transportation. Vanadium and nickel have been associated with the burning of coal with a high sulfur content; while lead and cadmium have been linked with automobile emissions. In the Hudson-Raritan area, decreasing atmospheric inputs of lead, vanadium, and nickel have been attributed to the phasing out of the use of leaded gasoline and coal with a high sulfur content (Mueller et al., 1982).

High loads of toxic contaminants to an estuary result in the accumulation of these materials in bottom sediments and estuarine organisms, such as fish and shellfish. An estuary's susceptibility to dissolved contaminants can be estimated by its ability to flush and/or dilute pollutants. 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 the smaller its volume for diluting pollutants, 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), which is an estimate of whether an estuary is likely to

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
Hudson River/Raritan Bay	85	165	298	21	267	172	582	287	M	M
Barnegat Bay	14	14	102	5	23	13	24	28	H	M
New Jersey Inland Bays	7	7	110	9	11	26	18	16	H	M
Total	**106**	**186**	**510**	**12**	**301**	**211**	**624**	**331**		

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

***** *DCP is designated Dissolved Concentration Potential; whereas, PRE is the Particle Retention Efficiency.*

retain dissolved pollutants. The DCP is high for both Barnegat Bay and the New Jersey Inland Bays.

Contaminant Spill Events. *As a consequence of heavy industrialization and ship traffic in this region, contaminant spills occur at a high frequency. All contaminant spills that occur in U.S. coastal waters are required to be reported to the U.S. Coast Guard (USCG). Hundreds of such spills are reported each year from the Hudson-Raritan Estuary. The USCG database indicated that from January 1976 to April 1992, 23 spills of 50,000 gallons or more had occurred. One of the largest spills occurred on January 5, 1991 when 3 million gallons of raw sewage were spilled into Jamaica Bay from a facility located on Coney Island (Helton, pers. comm.). Even with improvements in vessel operation, shoreside facilities, and vessel traffic control systems, spills still occur. Many small spills are never reported. The most common substances spilled are refined oils; such as diesel, gasoline, and bunker fuels, followed by crude oil and industrial chemicals. Impacts to birds and wildlife are frequently associated with larger oil or chemical spills. NOAA's Hazardous Materials Response and Assessment Division's (HAZMAT) data base shows that between 1987 and 1990 there were eight oil or chemical spills in excess of 100,000 gallons. The largest of these occurred at the Exxon Bayway Terminal in 1990, when 567,000 gallons of #23 fuel oil were spilled. The second largest spill occurred in 1987 at the Rollins Terminal, when 450,000 gallons of caustic soda were released into the Estuary.*

RESOURCE DEGRADATION

Fish Kills. *NOAA's Strategic Environmental Assessments Division's data base on fish kills contains information about this area from 1980 to 1989. In that period of time, 236 fish kill events were reported for the entire region, with the Hudson-Raritan Estuary accounting for 19. The number of fish killed per event ranged from fewer than 100 to 1,000,000. For most fish kill events the cause was not reported. Some of the causes that were reported included disease, wastewater releases, chemical spills or releases, and low dissolved oxygen levels. This area is particularly susceptible to low dissolved oxygen caused by: (1) algal blooms, (2) nutrient laden river discharge, and (3) poor mixing and aeration of the waterbody due to the estuarine basin structure coupled with relatively weak tides (Lowe et al., 1991).*

Marine Mammal Strandings. *Between July 1987 and September 1988, 834 Atlantic bottlenose dolphins (Tursiops truncatus) washed ashore along the middle Atlantic coast (Brody, 1989). The dolphins examined were of both sexes and all age classes. Skin afflictions including peeling, blistering, and ulcerations were observed. These dolphins also had congested lungs and lacerated blowholes. Although the cause of this massive die-off remains unknown, hypothesized causes include systemic infection, poisoning by a dinoflagellate neurotoxin* (which was discovered for the first time in mammals), and exposure to toxic contaminants (Brody, 1989).

Fish Advisories. Both New York State and New Jersey have devised and implemented fish consumption advisories for fish caught in their coastal waters. The New York State Health Department (1992) advises that individuals consume no more than one meal (one-half pound) per week of fish caught from the state's freshwaters, the Hudson River estuary, or the New York City harbor area. Additionally, from the Tappan Zee Bridge south to and including Lower New York Harbor, the department recommends that individuals eat no more than one meal per month of striped bass *(Morone saxatilis)*, bluefish *(Pomatomus saltatrix)*, Atlantic needlefish *(Strongylura marina)*, rainbow smelt *(Osmerus mordax)*, largemouth bass *(Micropterus salmoides)*, smallmouth bass *(Micropterus dolomieui)*, walleye *(Stizostedion vitreum)*, northern pike *(Esox lucius)*, or tiger muskellunge [a hybrid of muskellunge *(Esox masquinongy)* and northern pike], and entirely avoid consumption of American eels *(Anguilla rostrata)*, white perch *(Morone americana)*, carp *(Cyprinus carpio)*, goldfish *(Carassius auratus)*, and white catfish *(Ictalurus catus)*. For the same waters, individuals are advised to eat no more than six blue crabs *(Callinectes sapidus)* per week, and to avoid consuming the hepatopancreas (commonly called the mustard) of the crab completely. For Peconic/Gardiners Bays and Long Island South Shore waters, the department advises against eating more than one meal per week of bluefish, and one meal per month of striped bass. In addition, it is recommended that women of childbearing age and children under the age of 15 not eat fish from any region that has advisories posted (New York State Department of Health, 1992). Since May, 1991, New Jersey has had a commercial fishing and shellfishing ban in effect in the New York Bight because of high dioxin levels. New Jersey also has issued a "no consumption" advisory for American eel caught throughout state waters, and for striped bass caught in offshore waters and in Newark and Upper New York Bays. Bluefish caught in the Upper New York Bay and in offshore waters, white perch caught in Newark Bay, and white catfish caught in the tidal Passaic River also are under "no consumption" advisories (USEPA, 1991).

NS&T REGIONAL MONITORING

In the region this report covers, the NS&T Program's Benthic Surveillance Project began sampling specimens of winter flounder *(Pleuronectes americanus)* in 1984 for levels of liver contaminants, length, weight, age, and prevalence of tumors and disease. The NS&T Program now monitors fish from five sites in this region and performs the preceding analyses as well as measuring DNA damage and enzyme responses to contaminant exposures. In 1986, the NS&T Program's Mussel Watch Project began monitoring the blue mussel (*Mytilus edulis*) for the prevalence of disease as well as levels of chemical contaminants. Both monitoring projects collect sediments (1-3 cm depth) and analyze them for a variety of trace metals, petroleum hydrocarbons, and synthetic organic compounds (refer to Table 2). NS&T selection of monitoring sites is based on collecting samples from areas that are representative of general contaminant conditions, avoiding waste discharge points, local dump sites, and other "hot spots." Figure 3 indicates the location of NS&T monitoring sites in the Hudson-Raritan Estuary and New Jersey coastal area. Sites range in depth from intertidal (collection of mussels) to 17m (for fish trawls). The laboratories which have collected and analyzed the Benthic Surveillance samples are NOAA's National Marine Fisheries Service (NMFS) laboratories in Gloucester, MA, Sandy Hook, NJ, and Seattle, WA. The Mussel Watch samples are collected and the analyses performed by Battelle Ocean Sciences, Duxbury, MA and Sequim, WA.

NS&T CHEMICAL DATA

The graphs on pages 8 through 13 (Figures 4 and 5) show the mean concentrations of contaminants found at the Hudson-Raritan Estuary and New Jersey coastal area sites in relation to the concentrations found nationwide at all NS&T sites. The curves are formed by connecting the rank-ordered mean concentrations of chemical contaminants at all NS&T sites. Concentrations of contaminants in sediments, mussels, and fish at the Hudson-Raritan and coastal New Jersey sites are indicated by the vertical lines (concentrations are on a logarithmic scale). Numbers at the top of each vertical concentration line refer to the site locations indicated in Figure 3. The dashed horizontal lines on the sedi-

DDT and its metabolites	Polycyclic aromatic hydrocarbons	Major elements
2,4'-DDD	2-ring	Al*
4,4'-DDD	Biphenyl	Fe
2,4'-DDE	Naphthalene	Mn
4,4'-DDE	1-Methylnaphthalene	Si
2,4'-DDT	2-Methylnaphthalene	
4,4'-DDT	2, 6-Dimethylnaphthalene	
	1,6,7-Trimethylnaphthalene	
Tetra, tri-, di-, and monobutyltins	3-ring	**Trace elements**
	Fluorene	
	Phenanthrene	Sb
	1-Methylphenanthrene	As
Chlorinated pesticides other than DDT	Anthracene	Cd
	Acenapthene	Cr
	Acenaphthylene	Cu
Aldrin		Pb
Cis-Chlordane	4-ring	Hg
Trans-Nonachlor	Fluoranthene	Ni
Dieldrin	Pyrene	Se
Heptachlor	Benz(a)anthracene	Ag
Heptachlor epoxide	Chrysene	Sn
Hexachlorobenzene		Zn
Lindane (gamma-BHC)	5-ring	
Mirex	Benzo(a)pyrene	
	Benzo(e)pyre	
	Perylene	
Polychlorinated biphenyls	Dibenz(a, h)anthracene	
	Benzo(b)fluoranthene	
PCB congeners 8, 18, 28, 44, 52, 66, 77, 101, 105, 118, 126, 128, 138, 153, 179, 180, 187, 195, 206, 209	Benzo(k)fluoranthene	
	6-ring	
	Benzo(ghi)perylene	
	Indeno(1,2,3-cd)pyrene	
Toxaphene at some sites		**Related parameters**
		Grain Size
		Total Organic Carbon (TOC)
		Clostridium perfringens spores

*Symbols are Al (aluminum), Fe (iron), Mn (manganese), Si (silicon), Sb (antimony), As (arsenic), Cd (cadmium), Cr (chromium), Cu (copper), Pb (lead), Hg (mercury), Ni (nickel), Se (selenium), Ag (silver), Sn (tin), Zn (zinc)

Table 2. *List of NS&T chemicals.*

ment and mussel graphs indicate the national mean concentrations. Metal concentrations are in micrograms per gram (µg/g) dry weight, while organic compounds are expressed in nanograms per gram (ng/g) dry weight. The *"n"* at the bottom of each graph represents the number of sites used to create the curve.

Concentration values for sediment samples containing less than 80% sand have been adjusted by dividing the contaminant concentration by the fraction of the sediment sample that was fine-grained (i.e., dividing by a number between 0.20 and 1.00). Data from samples containing more than 80% sand-sized particles by weight [greater than 63 microns (µ)] were not used. The solid horizontal line on the sediment graphs represent the Effects Range-Median (ER-M) (Long and Morgan, 1990). These values denote toxicant concentrations (on a dry weight basis, not adjusted for fine sediments) above which sediments usually exhibit adverse biological effects in aquatic organisms. Values used for the sediment curves include 1984 through 1986 Benthic Surveillance and 1986 through 1989 Mussel Watch data. The curves for mussel tissue concentrations are based on the Mussel Watch results from 1986 through 1990. The fish curves are derived from results of 1984 through 1988 analyses of contaminant concentrations in the livers of various species of fish nationwide. The solid vertical lines, highlighted by shading, represent winter flounder data from the Lower Bay [4], East Reach [12], Wells Island [10], Seven Island [13], and Intracoastal Waterway [14] sites, while the dashed vertical lines represent all other NS&T winter flounder sites.

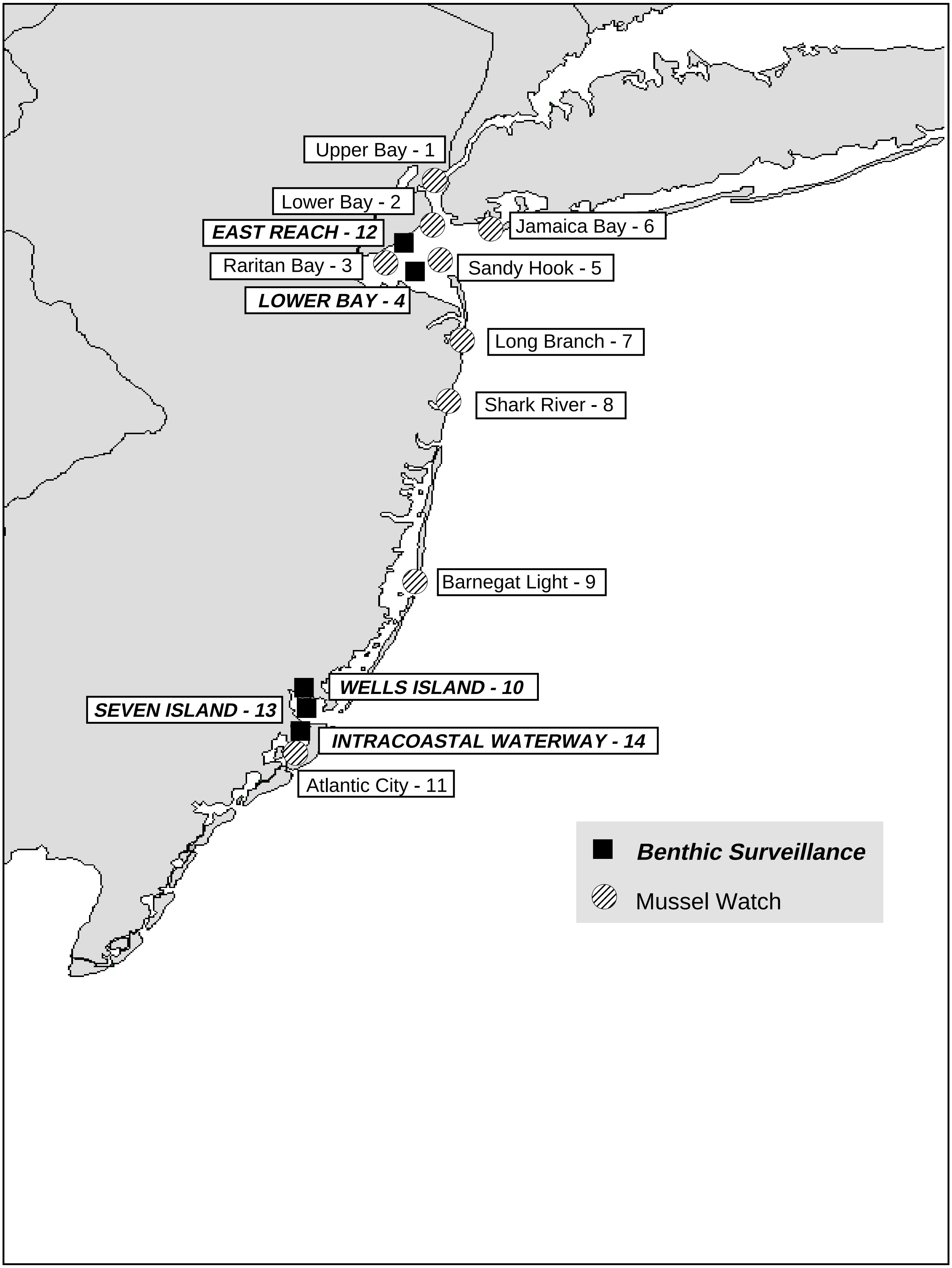

Figure 3. *NS&T Program monitoring sites (Hudson-Raritan Estuary and coastal New Jersey).*

RESULTS TO DATE: METALS

Silver. The sediment data indicate that the six Hudson-Raritan [1, 2, 3, 4, 5, and 6] sites have mean silver concentrations that are within the twelve highest nationally. All sites, including Wells Island [10], are in the top 25th percentile of NS&T sites sampled. The mussel tissue data indicate that two of the Hudson-Raritan [1 and 2] area sites, along with the Barnegat Light [9] site, have mean silver concentrations that rank within the twenty highest nationally. The remaining sites have mean concentrations at or above the national mean. The data for winter flounder livers range from a mean of 0.7 parts per million (ppm) at the East Reach [12] site, to 1.3 ppm at the Lower Bay [4] site. When compared to other NS&T winter flounder sites sampled, these sites have mean concentrations that are exceeded only by winter flounder sites in Casco Bay, the Merrimack River, Salem Harbor, and a Boston Harbor site. Among all fish sampled nationally, they are within the upper 25th percentile.

Copper. Mean copper concentrations in sediments of the Hudson-Raritan area sites are within the upper 10th percentile, with all six sites ranking within the twenty highest nationally. The concentration of copper in sediments at the Wells Island [10] site is near the national mean, while the levels in mussels range from a low of 10 ppm at Barnegat Light [9] to a high of 22 ppm at the Upper Bay [1] site.

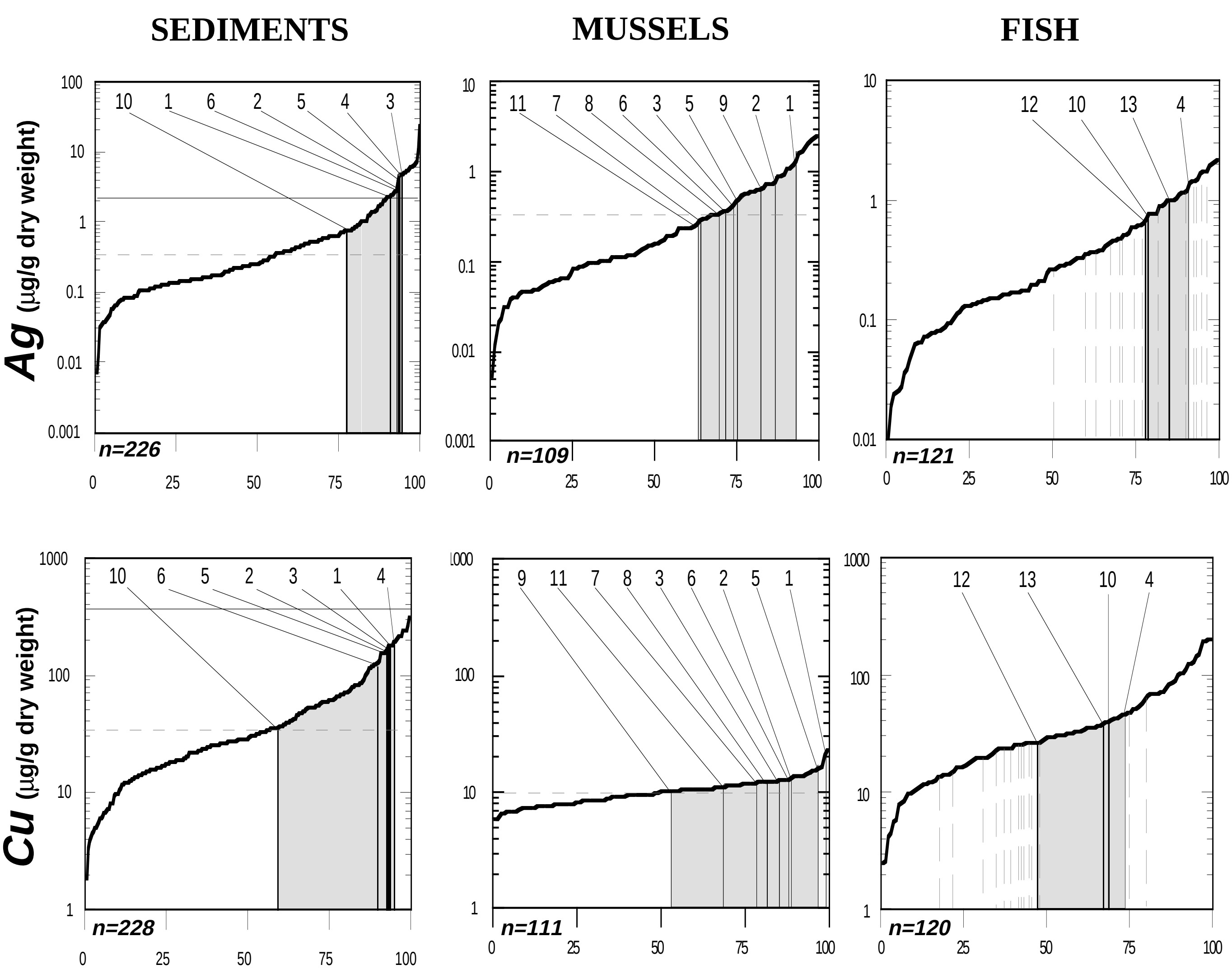

Figure 4. *Distributions of metals at Hudson-Raritan and coastal New Jersey sites in relation to nationwide (all NS&T sites) concentrations for sediments, mussel tissues, and fish livers. (Vertical scale chemical concentrations are logarithmic; the horizontal scale is cumulative percent of national sites.)*

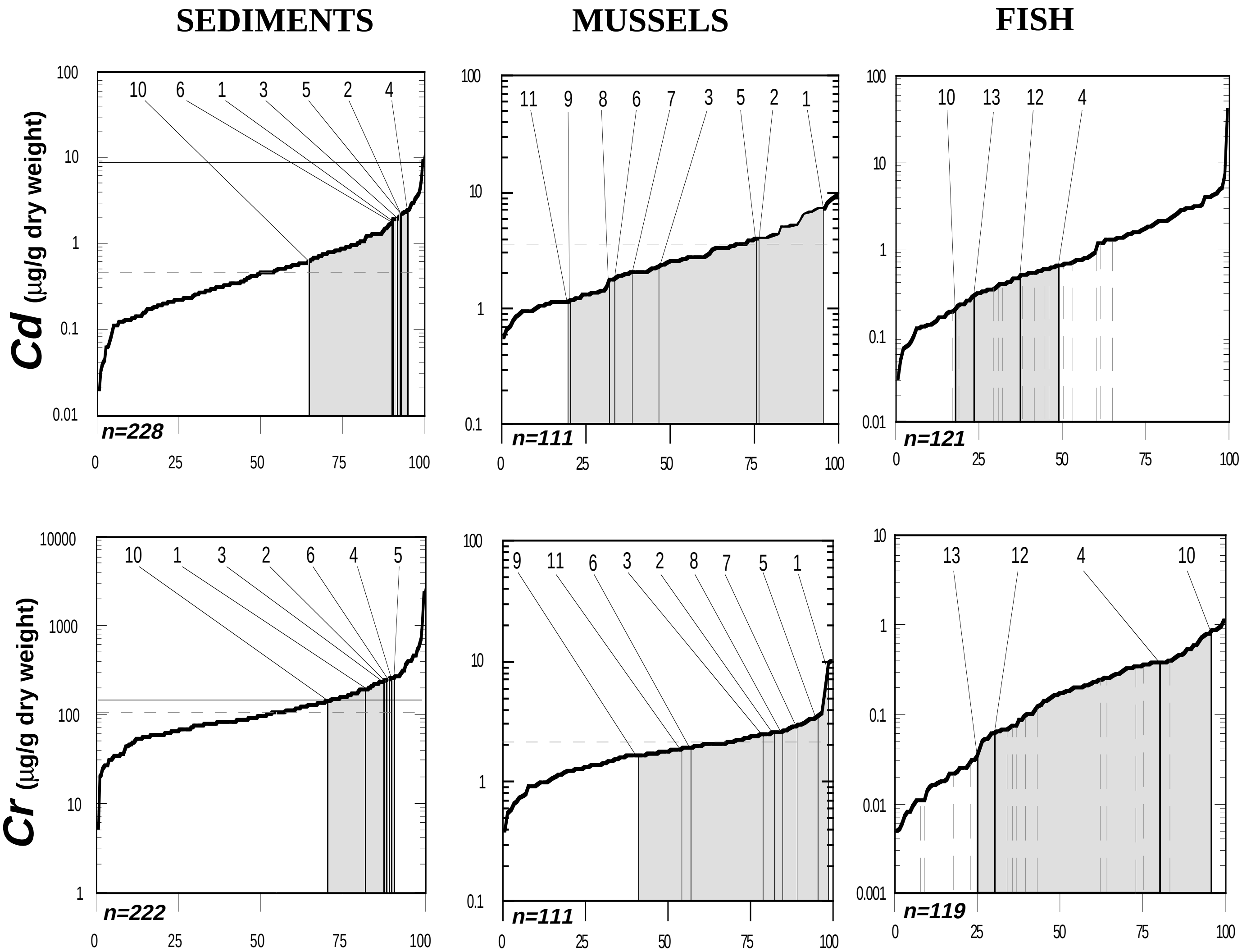

Figure 4. *Continued.*

All eight sites exhibit moderate to high levels of copper contamination in mussel tissues, with the Upper Bay [1] site having the highest mean concentration level of copper among NS&T Mussel Watch sites. Winter flounder liver concentrations of copper range from 24 ppm at East Reach [12] to 45 ppm at Lower Bay [4]. These concentrations are exceeded only by levels in winter flounder from Casco Bay and the Merrimack River.

Cadmium. Concentrations of cadmium in sediments exhibit the same trends as copper. The six Hudson-Raritan area sites are within the upper 10th percentile and rank within the twenty highest nationally. The mean concentration of cadmium at the Wells Island [10] site is slightly above the national mean in sediments. Mean concentrations of cadmium in mussel tissues vary considerably, from a low of 1 ppm at Atlantic City [11] to 9 ppm at the Upper Bay [1] site, the second highest of all NS&T mussel sites sampled. Concentrations of cadmium in winter flounder livers range from 0.2 ppm at Wells Island [10] to 0.6 ppm at Lower Bay [4]. Of all the NS&T winter flounder sites sampled, Wells Island [10] had the lowest concentration of cadmium.

Chromium. All seven sediment sites have mean concentrations of chromium above the national mean. The six Hudson-Raritan sites are within the upper 20th percentile nationally. Mean concentrations of chromium in mussel tissues range from a low of 1 ppm at Barnegat Light [9] to 10 ppm at the Upper Bay [1] site. As with copper, the Upper Bay has the highest mean level of chromium of all NS&T mussel sites sampled. The data for winter flounder livers range from a low of 0.04 ppm at the Seven Island [13] site to a high of 0.9 ppm at Wells Island [10]. The Wells Island [10] site has the third highest concentration of chromium nationally.

Lead. Mean concentration of lead in sediments for the six Hudson-Raritan area sites are among the highest nationally, with all six ranking within the upper 5th percentile of all NS&T sites. Mean concentrations of lead in mussel tissues at the Hudson-Raritan [1, 5, 2, 6] area sites indicate high levels of contamination, with the Upper Bay [1] site concentration greater than 20 ppm, highest of all mussel sites sampled nationwide. Both the Long Branch [7] and Shark River [8] sites rank within the upper 20th percentile. Concentration levels of lead in winter flounder livers range from 0.6 ppm at Wells Island [10] to 2.2 ppm at Lower Bay [4], which has the second highest mean lead concentration of all NS&T winter flounder sites sampled.

Mercury. Of all NS&T sites sampled, the Hudson-Raritan area sites are among the highest mean concentrations of mercury nationwide; even levels in Great Bay sediments are well above the national mean. Regional mean concentrations of mercury in mussel tissues are above the national mean for all sites. The Upper Bay [1], Lower Bay [2], Sandy Hook [5], and Shark River [8] sites in New Jersey, along with the Jamaica Bay [6] and Long Branch [7] sites in New York, are within the twenty highest concentrations nationally. The winter flounder liver data show mean mercury concentrations ranging from 0.2 ppm at Seven Island [13] to 0.7 ppm at Lower Bay [4], the second highest for all NS&T winter flounder data .

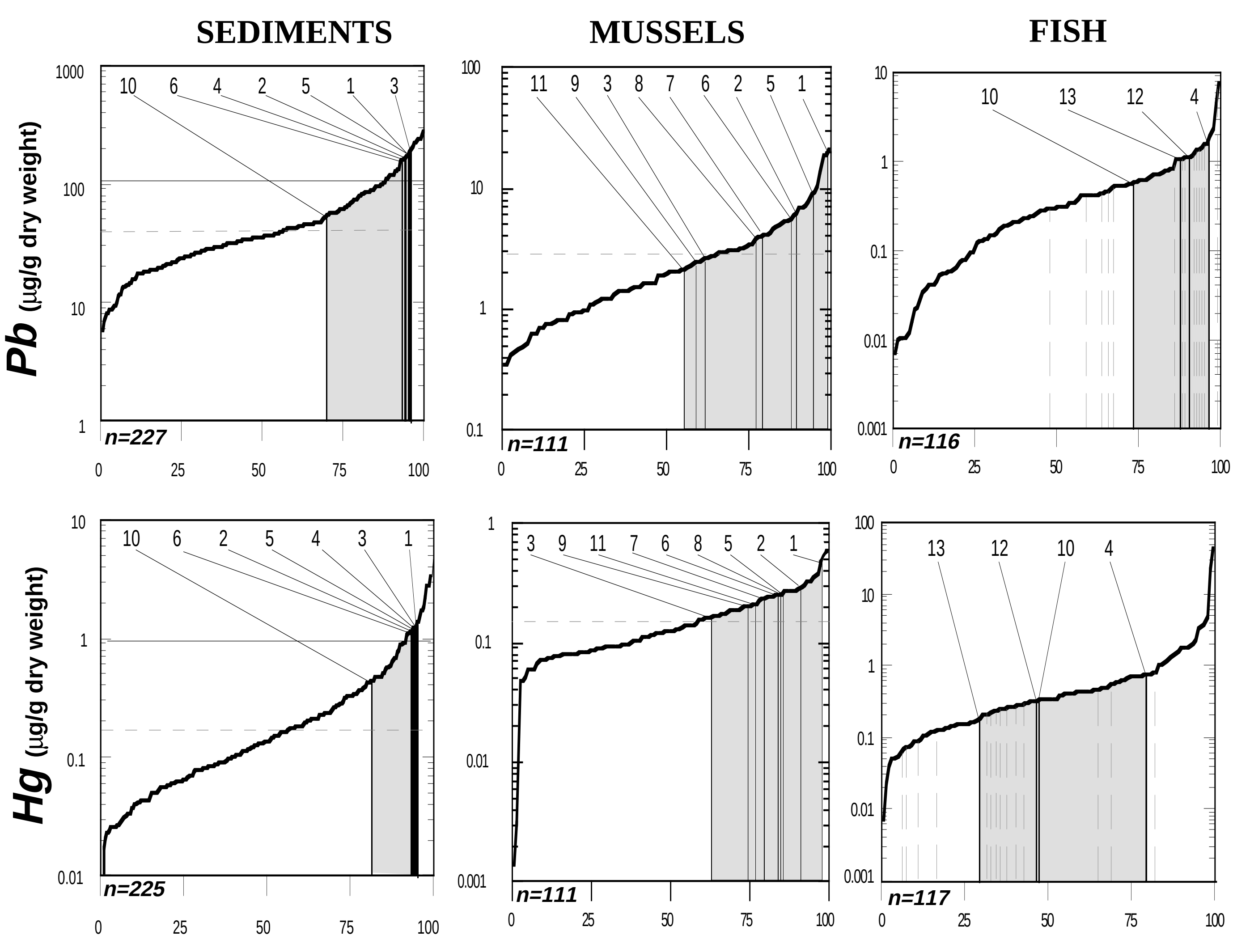

Figure 4. *Continued.*

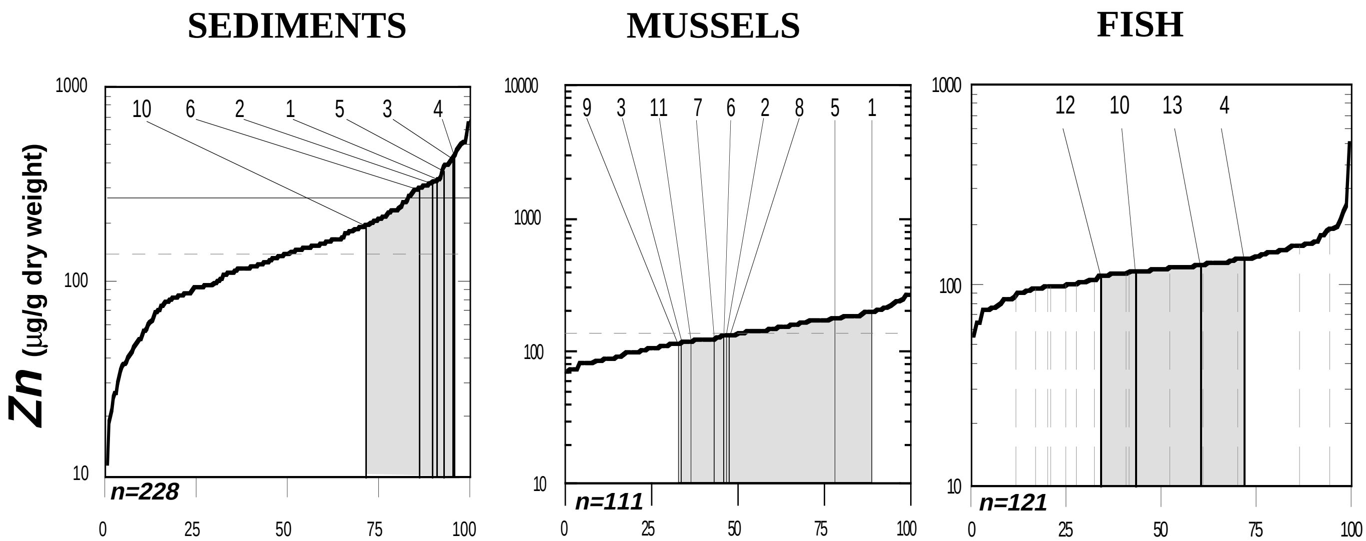

Figure 4. *Continued.*

Zinc. Mean concentration levels in sediments of zinc are above the national mean for all sites, with the Hudson-Raritan area sites ranking within the upper 10th percentile of all NS&T sites. Mean concentrations of zinc in mussel tissues vary about the national mean, from 112 ppm at Barnegat Light [9] to greater than 200 ppm at the Upper Bay [1] site. Concentrations of zinc in winter flounder livers range from 108 ppm at East Reach [12] to 131 ppm at the Lower Bay [4] site, which is exceeded only by winter flounder from Casco Bay and the Merrimack River.

RESULTS TO DATE: ORGANICS

DDT. Mean concentrations in sediments of total DDT (tDDT), an aggregated value of DDT and the metabolites DDD and DDE, were found to be within the upper 20th percentile nationwide for five of the Hudson-Raritan [6, 2, 5, 3, 4] area sites. Mean concentrations of tDDT in mussel tissues indicate values ranging from 33 parts per billion (ppb) at Atlantic City [11] to 600 ppb at the Lower Bay [2] site, with four area sites [2, 1, 5, 3] within the upper 15th percentile nationally. Winter flounder livers have mean concentrations ranging from 492 ppb at the Intracoastal Waterway [14] site to 1,177 ppb at the East Reach [12] site. The East Reach [12] and Lower Bay [4] sites have the two highest mean concentrations of DDT in winter flounder.

Chlordane. Mean concentrations in sediments of total chlordane (tCdane), the sum of concentrations of alpha-chlordane, trans-nonachlor, heptachlor, and heptachlor epoxide, exhibit a trend similar to that of tDDT. Five sediment sites [6, 2, 5, 4, 3], are within the upper 10th percentile nationally. Mean concentrations of tCdane in mussel tissues for six sites [2, 1, 6, 5, 8, 3] range in the upper 15th percentile nationwide, with the Lower Bay [2] site having the highest concentration level (> 120 ppb) of all NS&T mussel sites. Concentrations of total chlordane in winter flounder livers range from 158 ppb to 422 ppb which is almost half of the highest concentration (Boston Harbor) measured at any NS&T site (Gottholm and Turgeon, 1991).

PCB. Mean concentrations of total PCB (tPCB), an aggregate of twenty PCB congeners, exhibit trends similar to those of tDDT and tCdane in sediments. Five of the six Hudson-Raritan area sites [4, 6, 5, 2, 3, 1] rank within the twenty highest mean concentrations nationally. Mean concentrations in mussel tissues for seven of the sites [2, 1, 5, 8, 3, 6, 7] range in the upper 15th percentile nationally, while three of these sites [2, 1, 5] have concentrations within the upper five percent of all NS&T mussel sites sampled nationwide. Concentrations in winter flounder livers range from 2,563 ppb at Seven Island [13] to 9,085 ppb at the East Reach [12] site, the third highest concentration of all the NS&T winter flounder sites.

PAH. Total PAH (tPAH) is the summed concentration of 24 individual polycyclic aromatic hydrocarbons. The Upper Bay [1] site has the highest mean concentration (57,400 ppb) of all NS&T sites sampled nationwide. Five other sites [2, 5, 4, 3, 6] have concentrations within the twenty highest nationally. Mean concentrations of tPAH in mussel tissues exhibit trends similar to those of the other three organic compounds reported here. The Upper Bay [1], Jamaica Bay [6], and Lower Bay [2] sites are within the ten highest concentration levels nationwide. The National Status and Trends Program does not measure tPAHs in fish livers because fish rapidly metabolize PAHs and maintain relatively low and uniform levels in their tissue (Krahn et al., 1986).

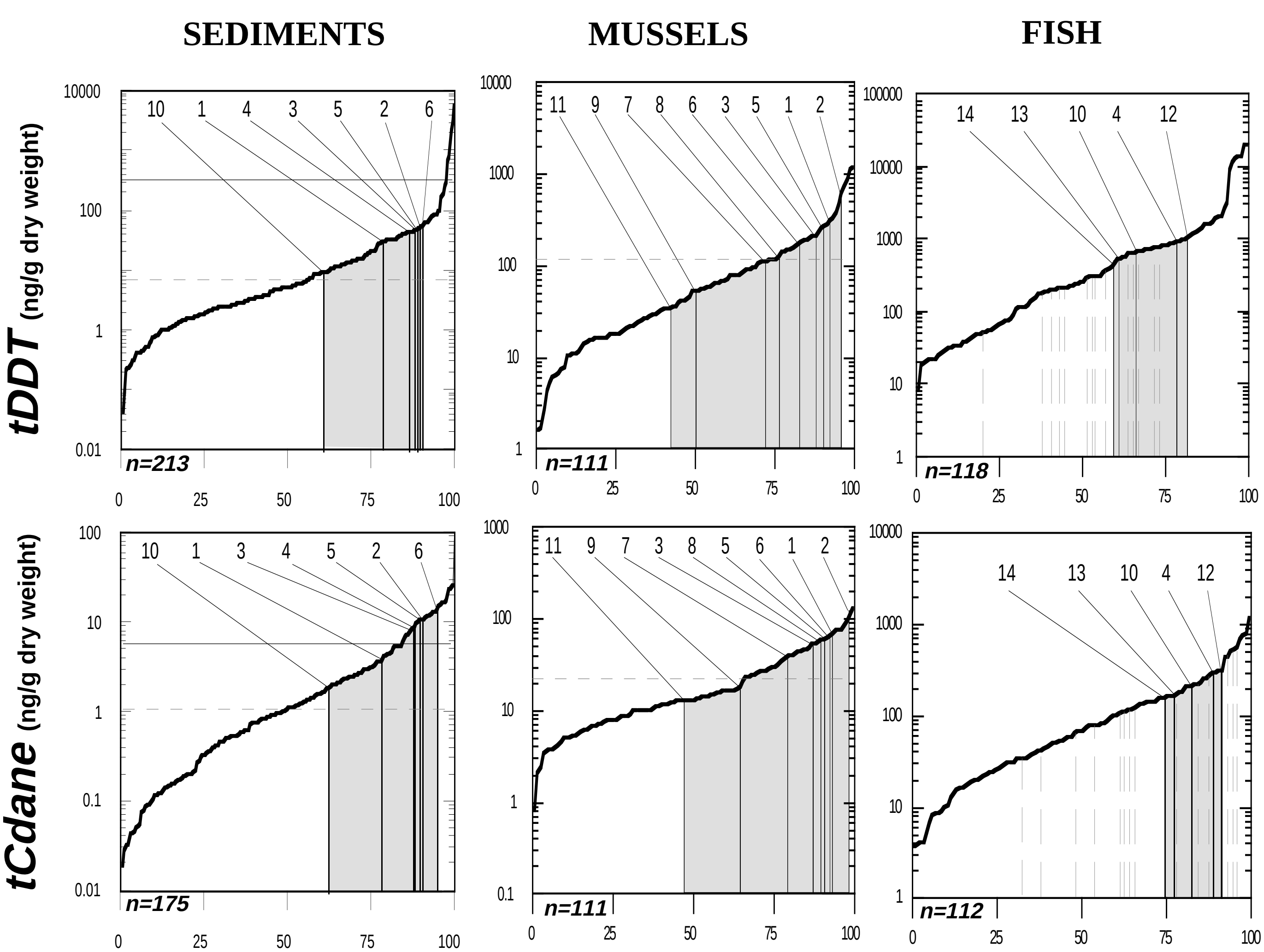

Figure 5. *Distributions of organics at Hudson-Raritan and coastal New Jersey sites in relation to nationwide (all NS&T sites) concentrations for sediments, mussel tissues, and fish livers. (Vertical scale chemical concentrations are logarithmic; the horizontal scale is cumulative percent of national sites.)*

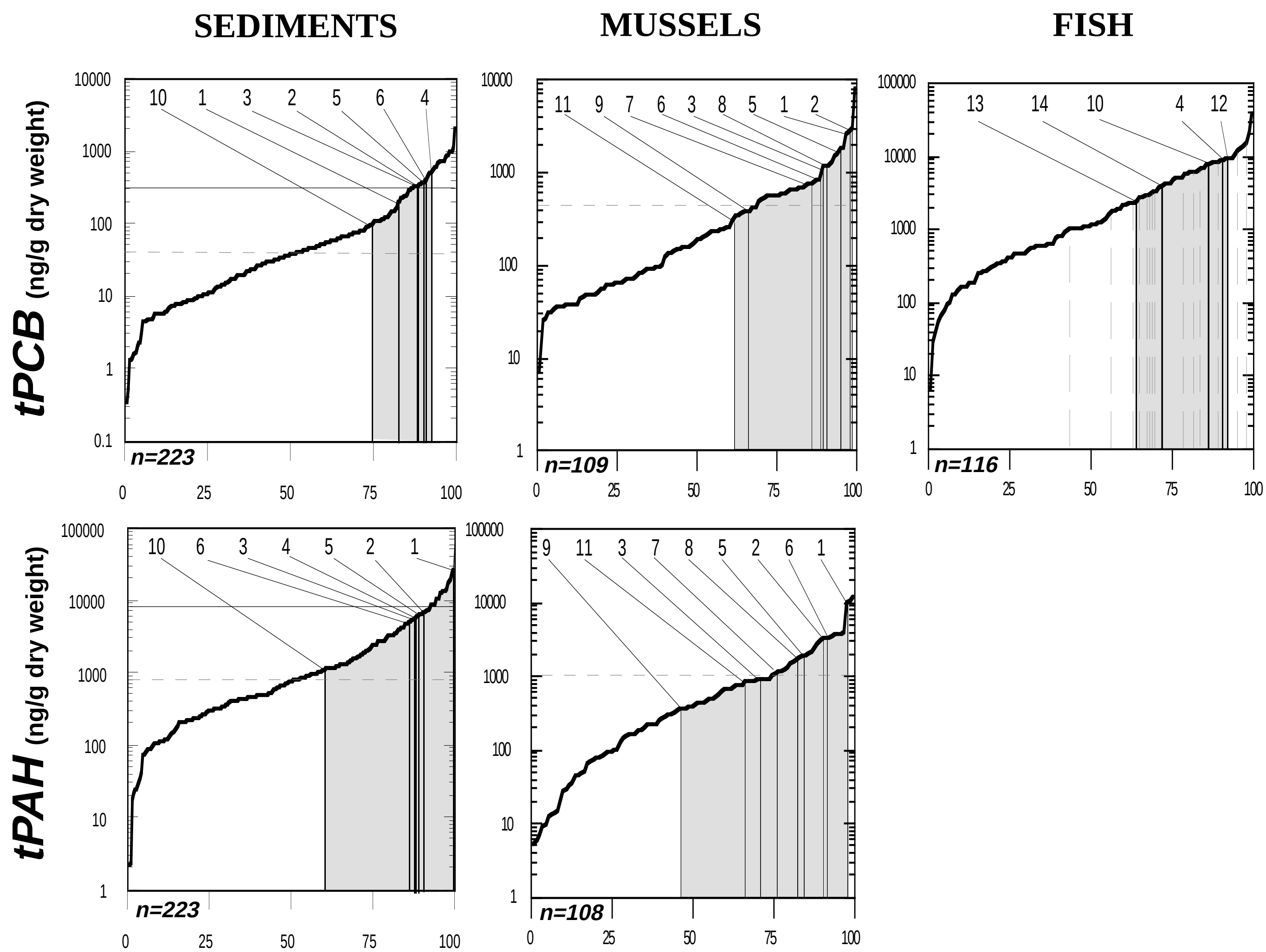

Figure 5. *Continued.*

CONTAMINANT EFFECTS STUDIES

NS&T's monitoring (from 1984 onward) noted sites in the Hudson-Raritan Estuary where sediment and biotic samples displayed mean concentrations of multiple toxic metals and organic compounds that were among the highest nationwide. During an evaluation of the potential for adverse biological effects attributable to toxicant-associated contaminants at NS&T Program sites, several sites within the Hudson-Raritan Estuary were determined to have a high potential for toxic effects (Long and Morgan, 1990). At these sites, the concentrations of many chemicals equaled or exceeded the ranges in concentrations commonly associated with adverse biological effects. The sites with the highest chemical concentrations in sediments included the upper and lower portions of New York Harbor, several locations in western Long Island Sound, Jamaica Bay, Sandy Hook Bay, and western Raritan Bay. Squibb et al. (1991) evaluated available sediment chemistry data from this area and determined that concentrations of many chemicals were generally highest in Newark Bay, the lower Passaic River, the Hackensack River, Kill van Kull, Arthur Kill, and Newtown Creek off the East River. Eastern portions of the Lower Bay leading out into the New York Bight were least contaminated.

NS&T monitoring for the prevalence of tumors and general disease in fish identified sites in Raritan Bay where neoplasms (cancerous tumors) in fish livers consistently occurred (Zdanowicz and Gadbois, 1990; Johnson et al., 1992a). In winter flounder caught in 1988 and 1989, liver neoplasms in fish from the Gravesend Bay (5.2%) and the West Reach (3.6%) sites in Raritan Bay were significantly elevated in comparison with the Rocky Point reference site in Long Island Sound (Johnson et al., 1992a). Other lesion types (including foci of cellular alteration, hydropic vacuolation, and necrotic lesions) were found in significantly higher prevalences in flounder sampled at all four Raritan Bay sites compared to the reference site.

In 1986, Cormier focused on the differences between the fine structures of livers in Atlantic tomcod (*Microgadus tomcod*) from the Pawcatuck River (located between Connecticut and Rhode Island), and those from the Hudson River. The Pawcatuck River served as a relatively non-impacted reference site, for the highly impacted Hudson River estuary. Dey et al. (as referenced in Cormier, 1986) found that 90% of two year old and 45% of the one year old tomcod in the Hudson River had evidence of hepatocellular carcinomas (liver cancer). The Hudson River fish were found to have a high accumulation of lipids, and little to no storage of glycogen in their livers which lacked smooth endoplasmic reticulum associated with lipid production and detoxification in mammals. She concluded that the pathology displayed in the Hudson River tomcod population was consistent with laboratory responses induced by exposure to various contaminants, including PCBs and petroleum products (Cormier, 1986).

On the basis of cumulative evidence regarding problems related to chemical contaminants, a series of intensive NS&T surveys were initiated in the Hudson-Raritan Estuary to study the magnitude and extent of biological effects that may be associated with chemical contaminants. Work carried out at various sites in 1989 through 1991 measured: several bioindicators of reproductive impairment in winter flounder, acute sediment toxicity in several indicator organisms, contaminant trends in sediment cores, and ambient water toxicity of copper and zinc. A complementary study was added in FY 91 to investigate the occurrence of sublethal indications of sediment toxicity. This study used sediment toxicity bioassays with growth of a polychaete *(Armandia brevis*) and a sand dollar *(Dendraster excentricus*) as endpoints.

During 1988 and 1989, a study was conducted on prespawning female winter flounder *(Pleuronectes americanus*) from 11 sites along the Northeast coast to test impairment of reproduction in winter flounder from exposure to xenobiotic compounds (Johnson et al., 1992b; Johnson et al., in press). Contaminant levels in winter flounder tissues were determined for all sites. Ovarian developmental stage, ovarian atresia, fecundity, gonadosomatic index, egg weight, and plasma estradiol (the hormone essential to fertilization and egg development), were examined in flounder from all sites including the four in Raritan Bay (Gravesend Bay, Shrewsbury River, Old Orchard Shoals, and Sandy Hook). The authors generally concluded that indicators of contaminant exposure were elevated and prevalences of suspected toxicopathic lesions were highest in fish from sites within Boston Harbor and Raritan Bay. Prevalences of two categories of lesions — hydropic vacuolation and biliary or hepatocellular proliferation — were positively correlated with concentrations of PCBs in tissues and fluorescent aromatic compounds (FACs) in bile. Chromosomal anomalies, indicated by the presence of xenobiotic-DNA adducts, were most prevalent in the livers of winter flounder from the Sandy Hook site. However, contaminant exposure had no clear negative impact on gonadal recrudescence, gonadosomatic index, plasma estradiol concentration, or fecundity in female winter flounder. The apparent lack of susceptibility of winter flounder to contaminant effects on early stages of reproductive development may be related to the migration pattern of this species, which includes movement to offshore areas away from urban bays for periods of up to several months each year.

A survey was initiated in March 1991 to document the severity, spatial pattern, and extent of sediment toxicity within this area. Surficial sediments [upper 1-3 centimeters (cm)] were sampled at 39 sites (3 stations per site, a total of 117 samples) strategically located throughout the Estuary. All samples were evaluated with a solid-phase test using the amphipod *Ampelisca abdita* (a shrimp-like animal), an elutriate test with the dwarf surfclam (*Mulinia lateralis*), and an organic extract Microtox test with a phosphorescent bacteria (*Photobacterium phosphoreum*). Portions of these samples were collected and set aside for possible chemical and other biotic analyses. Preliminary data indicate that toxicity is pervasive throughout the estuary and that some of the samples are extremely toxic, especially those collected in Arthur Kill, Raritan Bay, Upper East River west of the Throg's Neck Bridge, Sandy Hook Bay, and the lower East River. Sediments were less toxic at stations in western Long Island Sound east of the Throg's Neck Bridge, lower Hudson River off Manhattan, the central portion of upper New York Harbor, and in the central and southern portions of Raritan Bay.

Huntsman and Sunda (1992) surveyed dissolved copper concentrations at 14 sites from the northern end of Manhattan island to the mouth of Raritan Bay in both 1988 and 1990. They found values that were consistent spatially between years and varied over quite a small range, from 15 to 45 nanomoles per liter (nM) in 1988 and from 16 to 41 nM in 1990. The low values occurred in the open waters of Raritan Bay, while the highest levels were at the head of the Bay and in the Arthur Kill. Cupric ion concentration (an indicator of copper bioavailability) reached potentially toxic levels (greater than 10^{-2} nM) at all sites except those near the mouth of Raritan Bay.

CONTAMINANT TREND ANALYSIS

Recently, the NS&T Program added a component to survey historical trends in contaminant levels in highly contaminated estuarine areas from around the U.S. This is done by measuring contaminant concentrations in undisturbed sediment cores at selected depths. Such sediment core studies are near completion for Long Island Sound and the Hudson-Raritan Estuary. Chronologies from 1950 through 1990 were established for gravity cores taken in New York Harbor (2 cores), Raritan Bay (1 core), and Jamaica Bay (2 cores) (Bopp et al., in press), and from the marshes (4 cores) and subtidal waters (3 cores) of Long Island Sound (Cochran, et al., 1993; Brownawell, et al. 1993). Each core was dated using radionuclides ^{137}Cs, ^{210}Pb, ^{238}Pu, and/or ^{7}Be, and analyzed for the NS&T suite of elements and organic compounds. Results were presented at an NS&T-moderated symposium held at the Estuarine Research Federation's Annual Meeting in November, 1991, and are part of a special issue of *Estuaries* (Valette-Silver, 1993).

CONCLUSIONS

Chemical Contaminants Findings. For all seven heavy metals (Ag, Cu, Cd, Cr, Pb, Hg, Zn) described in this report, one or more sites in the Hudson-Raritan area rank within the upper 17% of all NS&T sediment sites sampled. The Raritan Bay [3&4] sites rank in the upper 3% of all NS&T sites sampled for Cu, Pb, Hg, and Ag. One of the Raritan Bay [3] sites and the Upper Bay [1] site had the highest mean concentrations for Pb and Hg of all NS&T sites. In general, because of the various sources of particle-associated contaminants in the Hudson-Raritan Estuary, elevated levels of contaminants are likely to be found wherever fine-grained sediments accumulate (Bokuniewicz and Coch, 1986; Olsen et al., 1984). Concentrations in mussel tissues show that the Upper Bay [1] site ranks in the upper 1% nationally for five metals (Cu, Cd, Cr, Pb, and Hg) and in the upper 10% nationally for all four organic compounds. The data show that mean concentrations of lead in mussels at the Upper Bay [1] site were 10 times the NS&T national median, and mean concentrations of tPAH were over 20 times the NS&T median for mussels. At the Lower Bay [2] site, tDDT mean concentrations were 12 times the U.S. median. Concentrations for three of the organic contaminants (tDDT, tCdane, tPCB) and four of the heavy metals (Ag, Cr, Pb, Hg) measured in winter flounder livers at the Lower Bay [4] site ranked in the top 25th percentile of all NS&T sites sampled for fish. The concentrations of lead at this site ranked in the top two percent nationally. The Wells Island [10] site had the highest mean concentration for chromium of all of the winter flounder sites. For all of the contaminants reported, most of the sites within this region rank above the 50th percentile except cadmium, for which all of the sites fall below this mark. The NS&T data indicate that high concentrations of multiple contaminants are found in sediments, mussel tissues, and fish liver tissues in the Hudson-Raritan Estuary, which is consistent with general NS&T findings of elevated contaminant levels in highly urbanized areas.

Biological Effects Findings. Studies of the Hudson-Raritan Estuary by the NS&T Program and others have found symptoms of a troubled coastal ecosystem. In certain areas biological indicators point to problems from human contaminant inputs, such as: (1) exposure to and uptake by selected estuarine species of many of the most toxic chemical contaminants studied by the NS&T Program; (2) incidences of liver tumors and other histopathological disease conditions in fish at levels among the highest found nationwide; (3) extensive, recurring fish kills, some linked to chemical contaminants; (4) fish consumption advisories for more than a dozen fish species issued by New York and New Jersey resource administrators; (5) pervasive sediment toxicity in laboratory tests with several species; and (6) much of the area's recreational waters and beaches closed to swimming and the taking of shellfish. Preliminary findings from the NS&T Program's recent bioeffects survey of the Hudson-Raritan Estuary indicate that sediment and water from some sites are toxic and may impair growth, reproduction, and development of adult and larval stages of organisms.

Estuarine Susceptibility. In U.S. coastal waters, areas can be found which are relatively restricted, have little circulation, and where contaminant levels are higher than those in surrounding areas. The Hudson-Raritan Estuary exhibits some of these features. For the Raritan Bay, Jefferies (1962) estimated a flushing time of 32 to 42 tidal cycles (16 to 21 days), which retards the dilution of pollutants entering the estuary.

Characteristically, an estuary's circulation pattern carries saline bottom water landward while fresher, less saline water flows seaward. This feature, combined with the estuary's protected nature enhances its 'trapping' ability for fine-grained sediments and associated contaminants. Many estuaries, including the Hudson-Raritan, are almost 100% efficient in trapping sediments supplied by rivers as well as importing additional material from their adjacent coastal waters (Bokuniewicz, 1988). Coch (1986) described the area of mud accumulation as extending from Raritan Bay into Sandy Hook Bay, with the sediment generally becoming finer westward, towards the mouth of the Raritan River estuary. Southward, sand is found along the New Jersey coast.

Natural variation in environmental parameters can have a marked influence on the fate or transport of contaminants. This region's semidiurnal tides, tidal currents, and freshwater discharge from seasonal precipitation and periodic storm events are primary causes of predictable environmental impact on contaminant levels (Duedall et al., 1979). Large amounts of precipitation can decrease contaminant concentrations near mussel beds by diluting the inputs from point sources. Periodic strong tides and storms also have a marked effect on contaminant levels in coastal waters by exposing and resuspending sediments, causing the resuspension of sediment-associated contaminants within the water column.

Coastal Assessment. Given the physical characteristics of the estuaries in this region, the coastal population density, and the number of known point and non-point sources of contaminant inputs in the estuarine drainage area, the levels of chemical contaminants and biological effects found in this assessment are consistent with those found in other highly urbanized areas. Use and consumption of fish and shellfish resources from a considerable amount of the upper and mid-portion of the Hudson-Raritan Estuary remains prohibited or restricted.

Much is being invested to study problems associated with urban land use and to improve estuarine habitats. A comprehensive coastal contaminant assessment with more in-depth discussion of the results from recent NS&T bioeffects studies in the Hudson-Raritan Estuary is expected to be available from the NS&T Program in 1994. In 1990, EPA initiated coastal monitoring through its Environmental Monitoring and Assessment Program - Near Coastal Component (EMAP - NC) in the Virginian Province (Cape Cod, MA, to Cape Henry, VA). Currently, the NS&T Program and EMAP - NC are preparing a joint assessment of the Virginian Province. This assessment, scheduled to be available in 1993, should offer additional insight on the status of contaminants in the Hudson-Raritan Estuary and New Jersey coastal area.

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APPENDIX

The appendix lists the NS&T sites sampled in the Hudson-Raritan Estuary and New Jersey coastal area in the Benthic Surveillance Program from 1984-1988 and the Mussel Watch Program from 1986-1990. Benthic Surveillance sites are listed in bold italic with only a general site name. Mussel Watch sites are given both a general and specific site designation. 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	State	Type	Cd	Cr	Cu	Pb	Hg	Ag	Zn	tDDT	tCdane	tPCB	tPAH
Hudson/Raritan Estuary	Jamaica Bay	NY			★		★★	★★	★★	★	★	★	★	★
Hudson/Raritan Estuary	Upper Bay	NY		★		★★	★★	★★	★★	★			★	★★
Hudson/Raritan Estuary	Lower Bay	NY		★	★	★★	★★	★★	★★	★	★	★	★	★
Hudson/Raritan Estuary	Raritan Bay	NJ		★	★	★★	★★	★★	★★	★★	★	★	★	★
Raritan Bay		NJ		★★	★	★★	★★	★★	★★	★★	★	★	★	★
New York Bight	Sandy Hook	NJ		★	★	★	★★	★★	★★	★	★	★	★	★
New York Bight	Long Branch	NJ	Sandy											
New York Bight	Shark River	NJ	Sandy											
Barnegat Inlet	Barnegat Light	NJ	Sandy											
Great Bay		NJ						★						
Absecon Inlet	Atlantic City	NJ	Sandy											

NS&T Mussel Tissue Data

General Site Name	Specific Site Name	State		Cd	Cr	Cu	Pb	Hg	Ag	Zn	tDDT	tCdane	tPCB	tPAH
Hudson/Raritan Estuary	Jamaica Bay	NY				★	★					★	★	★
Hudson/Raritan Estuary	Upper Bay	NY		★★	★★	★★	★★	★	★	★	★	★	★	★
Hudson/Raritan Estuary	Lower Bay	NY				★	★	★	★		★	★★	★★	
Hudson/Raritan Estuary	Raritan Bay	NJ									★	★	★	
New York Bight	Sandy Hook	NJ			★	★	★				★	★	★	
New York Bight	Long Branch	NJ			★							★	★	★
New York Bight	Shark River	NJ										★	★	
Barnegat Inlet	Barnegat Light	NJ							★					
Absecon Inlet	Atlantic City	NJ												

National Status and Trends Program

National Oceanic and Atmospheric Administration
National Ocean Service
Office of Ocean Resources Conservation and Assessment
Coastal Monitoring and Bioeffects Assessment Division

NOAA ship Ferrel

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